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Application of Digital Twin in Handling and Transportation of Hazardous Chemicals

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Abstract: In China, the Ministry of Transport stressed the need to "Strengthen the application of active safety technology". The transportation of hazardous chemicals represented by LNG, LPG, and liquefied hydrocarbons is the weak link in traffic safety. The aim of this study is to apply digital twin (hereinafter referred to as DT) technology to the whole process of handling (including loading and unloading) and transportation of hazardous chemicals to help improve the anti-risk ability of road networks at all levels. The method is intended to design a monitoring system covering operation visualization, information fusion, cargo tracking, and hazard source monitoring that is based on DT technology and multi-source data acquisition technology. First, DT technology in the areas of hazardous chemicals handling and transportation is discussed. Then, the DT system is designed, including the system construction, functions, and the means of achieving these functions. Finally, taking the procedure in LNG road transportation as an example, we illustrate the application of DT in its four stages. This system is used to present the evolutionary path of accidents that occur in different links and assist in testing the rationality of the comprehensive disposal plan.

Keywords: digital twin; hazardous chemicals; handling; transportation; active safety

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Citation: Li, X.; Zhang, Y.; Li, C.; Wang, T.; Xi, C. Application of Digital Twin in Handling and Transportation of Hazardous Chemicals. *Appl. Sci.* **2022**, *12*, 12746. https://doi.org/10.3390/app122412746

Academic Editor: Dimitris Mourtzis

Received: 18 October 2022
Accepted: 1 December 2022
Published: 12 December 2022

1. Introduction

The management of hazardous chemicals requires not only meticulosity but also new technology. Accidents occur mainly in links between road transportation, loading, and unloading in the terminal. Transport companies have applied many new technologies to monitor these links, mainly through sensors and the Internet of Things (IoT) to collect information on road conditions, driver behavior, terminal working environment, and so on. All this information helps significantly in fully understanding the production situation. This helps to solve certain specific problems in production, and information is used locally.

We can also extend the uses of this information, integrate more information to establish a corresponding DT system in the links prone to accidents, and use this system to perform many tasks. DT technology has been widely used in industry; it integrates various pieces of information from all kinds of dimensions collected by sensors. More importantly, it could simulate the operation in the real world to a certain extent through running a DT engine, which is meaningful in helping safety managers simulate various accident scenarios. The objectives of this study are to:

(1) Determine the functions of the DT system used for hazardous chemical handling and transportation.

(2) Analyze the method of building the infrastructure model in the system, handle data, and allow the system to play a role in production.

(3) Show how DT plays a role in the specific operation of LNG loading, unloading, and transportation.

The significance of this study is to define a general framework aimed at the construction of a DT system for hazardous chemicals that is complete and includes the aspects required as much as possible, hoping to provide reference for future developers.

2. Literature Review

During the past decades, new technologies applied in hazardous chemical safety management have mainly concentrated on the problems at one certain point. The literature review summarizes the current situation of hazardous chemicals and the characteristics of DT technology, and finally, we illustrate the applicability of DT in the safety of hazardous chemicals.

2.1. Current Situation of Hazardous Chemicals

Most countries all over the world are strengthening the monitoring of “carbon emissions” and environmental protection during development. China is also scientifically eliminating backward industries and shutting down highly polluting factories according to the monitoring results of the environmental protection department. In this context, clean energy, represented by liquefied natural gas (LNG) and liquefied petroleum gas (LPG), has become the most important industrial and civil energy, and the demand for them will continue to expand in the future. Their filling locations are mainly divided into two categories: the ports close to the market and the inland Chemical Industry Park [1], and their unloading locations are energy consumer terminals distributed throughout the country, which can be roughly divided into four categories: chemical enterprises, power plants, manufacturing, and urban gas enterprises. However, the chemicals used are all dangerous with low-temperature, flammable, and explosive properties. The majority of them need to be transported by road to consumer terminals, which become mobile hazard sources. Accidents in the process of loading and unloading pose a threat to the entire industrial zone where the station is located, and accidents in the process of road transportation seriously affect the function of the road network. Jie Zhou et al. analyzed 5207 hazardous chemical leakage accidents in the period of 2009–2018 in China and found that most accidents occurred in the road or the pipeline transportation process. This kind of accident is more likely to occur between 6:00 AM–10:00 AM and 3:00 PM, and the high mortality rate occurs between 0:00 AM–5:00 AM in road transportation [2]. Additionally, Isaac Animaha et al. studied the current LNG infrastructure risk analysis model and sorted it comprehensively; it will help managers to choose the proper model according to the different conditions [3].

Active safety is based on the comprehensive control of all links in the production or transportation process [4]. China has released a series of important government documents to promote hazardous chemical safety [5], but Laijun Zhao analyzed 3974 hazardous chemical casualty accidents that occurred between 2006 and 2017 in China and found that there is a probability of 59.10% that 200–600 casualty accidents will occur per year. Fourteen provinces need better safety management with regard to hazardous chemicals [6]. As explained by Bing Wang, the breakthrough progress in some key and common technologies limiting the improvement of hazardous chemical safety has not been achieved yet. Meanwhile, some advanced safety management approaches and safety technology means have not been widely used in hazardous chemical enterprises [5]. In the specific loading and unloading operation process, the working scope of personnel at each post is difficult to communicate with others and the degree of information sharing is insufficient; therefore, enterprises cannot effectively monitor the standardization of on-site operation. In road transportation, tankers transporting hazardous chemicals are driving in different positions, and the transportation enterprises cannot grasp the driving behavior of drivers and the complex traffic conditions they are facing. All of the above show that all departments still lack effective monitoring and intervention, and it is difficult to achieve “active safety”.

2.2. Digital Twin Technology

DT helps to open the ‘God perspective’ to systematically observe the operation of real objects, it is an important force to help achieve ‘active safety’. Grieves defined three basic elements of DT: real objects, the connection between dynamic models and the objects, and the dynamic feedback of models to the objects [7]. Giulio Paolo Agnusdei et al. found that DT is still less popular in the industry, especially in the field of safety management, there are seven areas where DT and safety are combined: decision making and offshore applications, IoT and life-cycle approaches, manufacture and virtual reality, machine learning support for DT and safety, safety engineering, hazardous and risk assessment, DT in battery management system [8].

In recent years, the development of computing power, high-speed communication technology, Internet of Things (IoT) and sensor technology, provides a new impetus for the wider application of DT. Qinglin Qi et al. explained that the realization of DT mainly depends on real world information capture, DT modeling, big data management, the realization of specific applications, and the connection between DT and the physical world, and summarized the required technologies and existing tools in the market in detail [9]. The research of Zongming Jiang et al. shows that the combination of IoT technology and DT technology is the basis for the integration of the virtual world and real world, the implementation of DT requires data, models and services, and his DT framework is committed to using IoT as the basis, by means of using partial DT with different functions to make up the DT of the target equipment [10]. DT combines machine learning (ML) to accelerate the efficiency of data processing, the cost of collecting and marking training data for ML is very high in reality. To help speed up the efficiency of data acquisition in ML, the data generated in DT avoids these two tasks. The datasets generated by DT could be combined with real world information, in this way, the training phase would be accelerated in ML, and Kosmas Alexopoulos and other scholars have proposed a DT-driven ML framework [11]. Yueyue Dai et al. aimed to improve network efficiency in IoT under the system of DT. In this computing process, deep reinforcement learning is applied to the offloading of computing resources [12]. Additionally, to enable the allocation of computing resources in different layers of IoT architecture, Andre Luckow et al. developed a simulation approach for the optimization of task placements across the edge-to-cloud continuum [13]. Data and information are the main components of DT, and big-data-driven DT systems are used in various fields. Fei Tao proposed a new technique for the design, manufacturing and service of a product, which is driven by DT, it solved the data problem in the lifecycle of different product phases: information island, duplicate data, the lack of interaction and iteration between data analysis and various activities, and the limit of application in virtual models [14]. The implementation of DT is based on three foundations: data process technology, high-fidelity modeling, and model-based simulation. Mengnan Liu and others summarized the foundation of needs in three areas in detail [15].

2.3. Applicability of DT in the Safety of Hazardous Chemicals

In terms of technical application, Zhiheng Zhao et al. have developed a framework to accurately identify the abnormal static situation of personnel in indoor scenes. It is based on IoT and DT. They developed relevant algorithms to improve monitoring accuracy and eliminate false alarms in this framework [16]. As for present applications in handling and transportation, E.B. Priyanka built a framework of DT which comprises ML and a prognostics algorithms model used to predict the risks of pipeline system emergency [17]. DT has been applied in the field of petrochemical industry [18], just as in the field of hazardous goods. Oliveria et al. designed a DT platform for 3D and real-time georeferenced visualization of container parks and the location of hazardous containerized freight [19]. Additionally, Cherniaev displayed digital technologies and their benefits that have been incorporated into the exploration, production, and transportation of oil and gas products in Russia [20]. Extending to hazardous waste process, Yonghui Wu aimed to solve the multiunit linkage optimization problem under the framework of DT technology [21]. Yan Gao summarized the DT application in transportation infrastructure: railway, highway system, bridge and tunnel, pointing out the drawbacks at the same time [22]. Kan Wang illustrated how to construct a port management system based on DT and its implementation steps, furthermore, the function of this system is discussed, mainly focused on risk prediction, environment protection, data sharing and information communication, cargo handling and transportation, container terminal operation [23].

DT has application prospects in the handling and transportation control of hazardous chemicals. Firstly, as of the first half of 2021, there are more than 13,000 hazardous chemicals logistics enterprises in China, with a total of more than 575,000 transportation vehicles. The establishment of this system based on DT technology will fully integrate all kinds of information and provide a visual interface to show the operation links. It is necessary to further study various virtual risk scenarios. Secondly, a realistic problem has been raised in that there are so many risk scenarios in the hazardous chemical handling and transportation process, it involves a lot of different infrastructures, such as LNG terminals and chemical plants, etc. Although the number of them is huge, the construction and layout of their internal structures follow the national unified standards, and the transportation vehicles are governed by the same authorities as roads at all levels [5]. If the structures are modularized in the system, and then connected by 'assembly', this will reduce the burden of modeling. Thirdly, sensors are widely distributed in all positions of hazardous chemical production units. During transportation, the tanks of these vehicles are equipped with traditional sensors, such as temperature and pressure sensors and liquid-level manometers and GPS, and improved sensors offering more detailed monitoring of vehicle status are installed on it [24]. Figure 1 displays the diversity of sensors in the hazardous chemicals monitoring system. Concerning driver fatigue detection, many scholars are deepening the research on this issue. Deshmukh discussed all the techniques concerning driver fatigue detection, introducing all kinds of sensors, and how machine learning and big data techniques are used in this process was shown as well [25]. Heterogeneous sensors installed on the tank were used to evaluate the status of the vehicle synthetically. The environment in the station is more complex, and chemical leakage detection sensors are often equipped and interlocked with the actuator to control the emergency shutdown of the valve [26,27]. Based on the sensor data, the gas diffusion is further rehearsed and the risk assessment is carried out [28]. Moreover, FGS monitors the fire in real time, the electrostatic grounding interlocking setting on the filling equipment, and the filling metering system also display the filling status at all times. The cameras distributed in the station provide richer supplementary information for the system to help build the DT system.

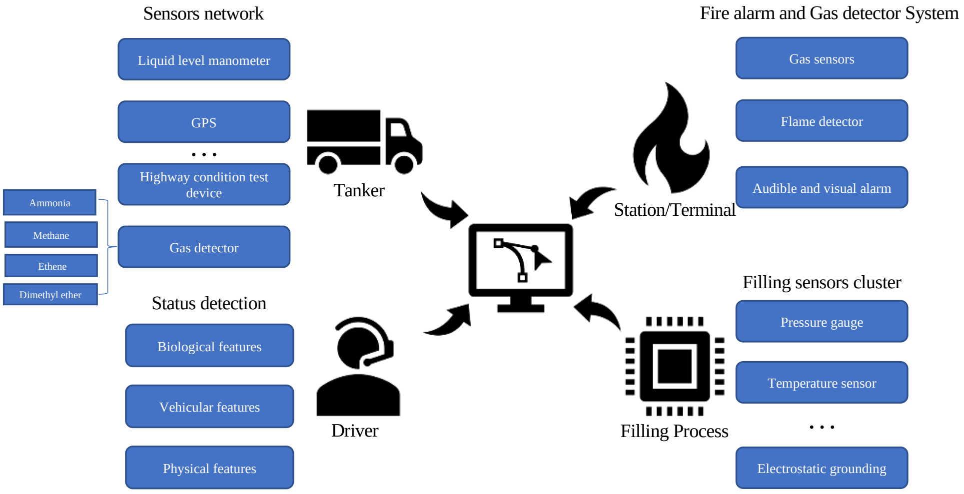

Figure 1. Overview of the hazardous chemical storage and transportation sensor system.

IoT has also been gradually applied in the field of transportation of dangerous goods and safety detection [29]. The lack of standardization for all kinds of data has led to a low degree of information integration. The use of sensors has long been characterized by 'islanding' in enterprises, but multi-source sensors can already collect vehicle and human behavior in real time and help establish the dynamic mapping of things in the system through data fusion. Additionally, the optimization scheme output by this system is fed back to the participants in real time through the communication device to realize the interaction between the two sets of subjects. Finally, with the help of the real-time performance of the DT system, the effectiveness of emergency plans for various accidents are tested. Gradually, the rescue plan library is formed by collecting the results of tests.

After the system is put into operation, it attracts more enterprises to join the system and constantly enriches the application scenarios. The richer the scenarios, the more functions the system can provide. In addition, the system can provide more market-oriented derivative functions, such as market energy consumption, distribution of new consumers, regional economic development, road traffic policy information, real-time road conditions, etc., to meet the needs of users at different levels and achieve economies of scale.

3. Methodology

Integrate existing roads, buildings, and other infrastructure into the system as the basic framework. Integrate the details of different types of stations and the characteristics of different levels of roads to depict the outline of the system. In terms of system dynamic performance, with the help of high-speed communication technology, use the dynamic GIS data as the base map, and fuse the dynamic data collected by existing sensors at key positions to build the dynamic information layer of hazardous chemicals vehicles and personnel. In addition, considering the characteristics of driving behavior, form three types of system databases: accident rescue plan database, driving route evaluation database, and transportation policy database. Figure 2 further illustrates the framework of the system.

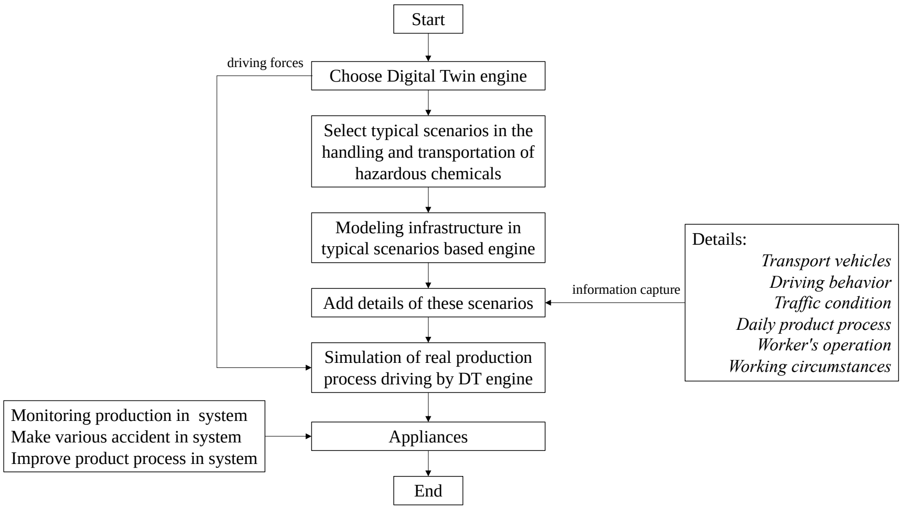

Figure 2. The framework of the constructure of DT system for hazardous chemicals.

3.1. Basic Functions of the DT System

Considering the needs of different types of users from different perspectives, the system functions should meet the following aspects, and the specific details are shown in Figure 3.

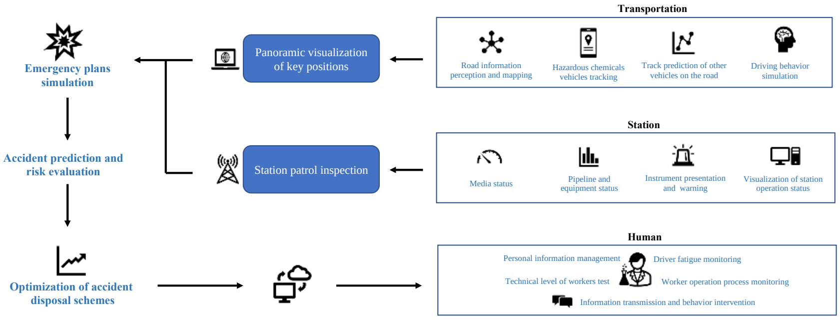

Figure 3. Basic functions of the system.

(1) Terminal and station patrol inspection.

The purpose of the DT system is to effectively present the 3D appearance of the whole process of hazardous chemical loading, unloading and transportation. The high-precision, detailed and dynamic expression of the participants in each link enables managers to conduct aerial inspection of any link at any time and find security risks and technical loopholes from a broader perspective.

(2) Risk discrimination.

Use the visual interface to identify the risk points in the operation. According to the route of tankers in the station, judge whether the operation is reasonable, and whether the existing loading and unloading process is reasonable. Further, for the new pipelines in the station, observe the rationality of profile setting from all angles with the help of the system.

(3) Simulation of rescue plan.

Many scholars have conducted expensive research on hazardous chemical traffic accidents, and have an understanding of the evolution mechanism and propagation path of fire, explosion and other accidents [30,31]. Once some changes happen in the real world, the corresponding reaction is presented in DT, so by setting the location and scale of various accidents in DT, the system simulates accident impacts on surrounding traffic networks and residents. The next step is retrieving the rescue plan or traffic control strategy from the accident rescue resource pool, applying these specific operations regarding rescue, and verifying the effectiveness of rescue plans relying on the system simulation platform. By evaluating the simulation results, experts can moderate and improve accident disposal schemes.

(4) Transportation tracking.

The main purpose of the system is to understand the current driving state of each tanker loaded with hazardous chemicals, and display the position, speed, loading capacity and other information of the vehicles in the system. Every vehicle must install GPS and other sensors to provide location according to Chinese law, chemical companies and terminals usually have their own monitoring system, companies will ask drivers to feedback their information. We need is to collect this data and integrate it into DT.

(5) Driving behavior simulation.

Invite drivers to participate in simulated driving in different scenarios at the initial stage of system establishment, collect drivers' reactions in sections with complex traffic conditions, mixed traffic and lane changing of different types of vehicles, and collect vehicle acceleration, turning speed, the turning radius of key sections, and other information into the vehicle driving simulation module of the system, to enhance the effectiveness of the driving behavior simulation.

(6) Accident prediction.

Many sensors have been set in the cab to monitor the driver's unsafe behavior [32,33]. The DT system combines algorithms for special usage, such as lane-changing behavior [34], this kind of algorithm is integrated into the system, and the environmental parameters detected by the vehicle are substituted into the calculation, when the tanker drives onto an accident-prone road section, it monitors the road conditions and traffic flow status, predicts the lane-changing behavior of other vehicles, and reminds the driver through sensors, screens, and mobile phones. At the same time, the inspection results of the facilities in the station and the daily inspection results of tankers are entered into the system to automatically assess the risk.

(7) Market information presentation.

Enterprises pay attention to market revenue, and the state pays attention to mastering information such as economic and social development and industrial structure. With the help of system data collection and information integration functions, collect the following information: consumer terminal location, industry type, product sales price and demand, and build a visual and convenient data query market-oriented energy consumption map.

3.2. Implementation Steps

The realization of DT mainly relies on computer and big data technology. To achieve the functions mentioned above, we need not only the concept of DT, but also the key points in the process of implementing the DT system for hazardous chemicals. Figure 4 shows the control logic of the system in detail, with the relationships between the functions of each part and the whole system.

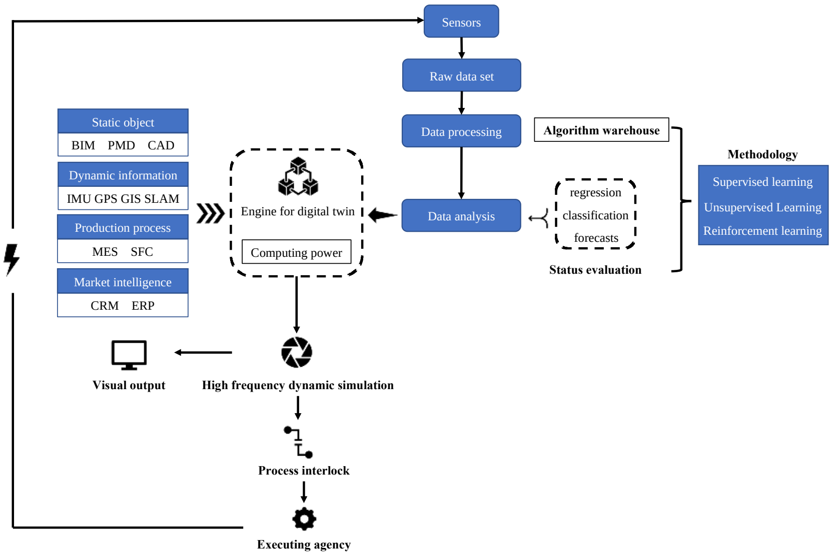

Figure 4. System operation logic.

3.2.1. Choose Engine for DT

The engine provides the library needed by the DT and drives the system to conduct dynamic simulation. Many manufacturers have transformed from game engines to industrial engines for DT development. Take the engine as the core, connect the physical digital model into the engine and develop new components as needed. Table 1 includes the leading DT engines on the market today.

Table 1. Mainstream engine.

Web3d Engine	Game Engine
Egret, Three.js, Pixi.js, Layabox, Cocos2d	Unreal, Unity 3D, Godot, Xenko, Ogre3d

3.2.2. Infrastructure Modeling in System

The construction of infrastructure in the system is the basis of follow-up work. The design of the station and terminal must comply with national standards, and the basic modules that meet the unified standards shall be established by CAD, PMD or BIM for assembly. Where the above material is lacking, SLAM or photographing modeling may be used.

In terms of the construction of road transportation modules, because each transportation management department has requirements for the driving routes of these vehicles, only select the corresponding road network import system. As such, this job just needs to focus on modeling the interchange system of each route, the accident-prone areas counted over the years, and the places with dense surrounding buildings. All the circumstances contain static information and dynamic data, the acquisition processes of the two parts are as follows:

(1) Static information.

Integrate the technical details of each station into the above, and carve the static details of key positions of the road, including road traffic signs, road fence depiction, tanker size, roads in the terminal, etc. In addition, the safety management of hazardous chemicals is inseparable from the industry standards, operating procedures, traffic database, emergency plan database and other laws, which are included in the system to facilitate the call of corresponding scenarios.

(2) Dynamic data.

Relevant dynamic data are widely accessed. GPS and speed are mainly used, and video data are used as supplements. Road condition information and station patrol information are collectively committed to the cloud, and market information is presented at the same time. Leakage management of station and road infrastructure can be fed back to users in the system in real time in case of station equipment maintenance, road section construction and culvert collapse. To include market information, ERP can also be accessed. This part aims to add system details within the feasible range, mainly to meet the system design functions and potential application development.

3.2.3. Data Processing

As an attachment of infrastructure, multi-source sensor data dynamically reflects the station status. On the road, through multi-source data, we can master the monitoring of vehicle distribution, vehicle speed distribution, vehicle following status, headway distribution and so on. The sensor is the dynamic foundation of DT, but the data obtained by the sensor needs to be processed and used before entering the system. “Multi-dimensional data fusion” has a wide range of applications, the purpose is to use a variety of existing data to outline the missing information. Select appropriate methods to establish a model warehouse and fuse the original data while reducing the dimension as little as possible. Zilin Huang et al. proposed the data fusion algorithm used to integrate bus smart card data and GPS data is an example, which aimed to supplement absent bus boarding information in the smart card [35], the data fusion algorithm could be transferred into the DT system to modify data collected by sensors in the same way, then fusion data are input into the next calculation pattern. There have been many methods to predict the parameters or behaviors reflected by the data in a variety of ways; LSTM and RNN et al. are popular tools used to predict traffic paraments or road changing behavior during driving [36], similarly, predicted results will be presented in DT.

3.2.4. Building Interlocking and Scalability

The value of DT lies in showing the results of production units in various situations and intervening in the production process for managers while visualizing [15]. The management process of hazardous chemicals is highly automated. Adjust some key production process or parameter according to the monitoring and prediction results of the system. In this procedure, there are not any new techniques such as ML or reinforcement learning because this pattern mainly applies to the established control scheme which depends on knowledge in the petrochemical industry. The interlocking of control units is realized with the help of DCS and SIS. Moreover, according to the needs of production, develop new functions at any time and enrich and improve them in the system by API.

4. Application of DT in LNG Road Transportation

LNG is a widely used fuel, which is loaded at the terminal or natural gas liquefaction station and transported by road to any gas terminal that cannot be reached by the pipeline, such as liquefied hydrocarbons and LPG, etc. The application of DT technology in LNG transportation is mainly reflected in loading, transportation and unloading. The application scenarios of other hazardous chemicals are similar to LNG.

4.1. Filling Stage

(1) Rationality analysis of unit layout.

Relying on the original design drawings and models of the charging area of the station, pipeline distribution, GIS data, distribution of hazard sources and firefighting equipment in the station, combined with the dynamic driving characteristics of LNG tankers and the distribution characteristics of personnel activity areas, the 3D models of pipelines and equipment in the charging area and the BIM models of ancillary buildings are constructed to realize dynamic supervision of charging vehicles and personnel in the station. It converts the previous non-intuitive methods, such as interpretation by intercom and instrument data, into a dynamic model that can be monitored intuitively, which facilitates station managers to consider the rationality of pipeline design and facility arrangement in the station from a more macro perspective and optimize the operation process.

(2) Filling process optimization.

Nowadays, most stations adopt the same conservative management model, for example, some stations set up buffer parking lots at the far side of the charging area, and many other stations follow suit, taking up more land. The location of each station and the nearby traffic conditions are different, and the distribution of vehicle arrival times is also significantly different. The same process will reduce the turnover rate and cause a burden on the surrounding road network. Through spatial-temporal analysis process optimization, improving the efficiency of filling can create benefits for enterprises.

(3) Security Monitoring.

The DT model is connected to the sensor signals in the on-site charging facilities and environment, making it possible to transfer the monitoring of the site to the visualization system, avoiding the previous situation of repeated communication through intercoms or video monitoring to monitor the production operation status of the site, and introducing the common instrumentation and DCS data into the system to monitor the abnormalities of the process in a timely manner.

4.2. Road Transportation Phase

(1) Analysis of tanker characteristics.

Collecting driving behavior parameters such as reaction time, lane-change and avoidance behavior of drivers of hazardous chemical tankers, as well as integrating the driving characteristics of trolleys at high speed or on typical road sections, the driving behavior of tankers is simulated in the system.

(2) Accident-prone roadway DT construction.

Depict vehicle distribution characteristics on accident-prone road sections and monitor parameters that reflect traffic operation conditions such as vehicle ratio, travel speed, and headway spacing. Incorporate the prediction of lane changing behavior of small vehicles and unsafe driving category discrimination to synthesize a DT system with three-dimensional features.

(3) Emergency hedging strategy development

Develop emergency avoidance strategies for different types of rollovers, explosions, and other types of accidents during road transportation.

(4) Rescue program selection.

Simulate the specific implementation process of multiple accident rescue programs and corresponding traffic control measures in the system and compare the implementation effect of the programs.

4.3. Liquid Unloading Stage

(1) Consumers information management.

The distribution of gas-using terminals is more extensive than that of filling sites, and statistics on the distribution, business type, gas consumption scale and price affordability of these sites are presented on a map. Additionally, the previous site qualification and information filing can also be transferred online.

(2) Operations Visualization.

The three-dimensional structure of buildings and internal facilities and equipment around the gas-using terminal site is constructed. Then, a visual view of the site is established by integrating on-site video surveillance, sensors, and personnel positioning data. Then, the station management scheme and operation procedures are integrated to monitor abnormal values during operation and provide early warning. It provides a comprehensive display of 2D maps, equipment, and corridor 3D models, and provides functions such as roaming tour, partition display, spatial measurement, station integrated intelligent monitoring and linkage control, inspection personnel positioning and inspection track query.

(3) Unloading monitoring.

There are several types of LNG terminals in general: industrial point supply, power plants, city domestic gas, and chemical companies, and each type of terminal has its own accident-prone locations. These key locations are monitored, and the interface incorporates document management, procedure management, and rescue measures to "treat" their safety management points.

(4) Emergency scenario simulation.

Based on the simulation environment and the characteristic parameters of each object, the emergency plan to be activated is determined according to the type and extent of the accident, and the characteristic parameters of each object involved in the accident simulation, such as the escape of personnel, the spread of fire, the change in the residual liquid in the tank, and the structural deformation of the auxiliary facilities in the station, are dynamically loaded into the environment model for simulation. The simulation is carried out by repeated simulations and calculations to analyze the accident state comprehensively [37].

4.4. Integrated Management

The daily management of LNG is a meticulous work, and many of the tasks are now performed by each department within its own system. For example, in technical management, tanker transportation qualification audit, vehicle filing in the field station, personnel training and certification each have a set of systems, and it is difficult to share information in real time; in sales management, each sales company and consumer terminal has its own transaction price and market protection policy. Therefore, the integration of existing non-technical information in the system, based on information on the protection of the rights and interests of the operating units, and the coordination of information on public services, such as accident disposal programs, and territorial management departments. During daily operations, the government monitors regional gas demand to facilitate the coordinated deployment of resources during the heating season.

Figure 5 shows the different patterns of LNG DT system, the different functions, and the hierarchical relationships between them.

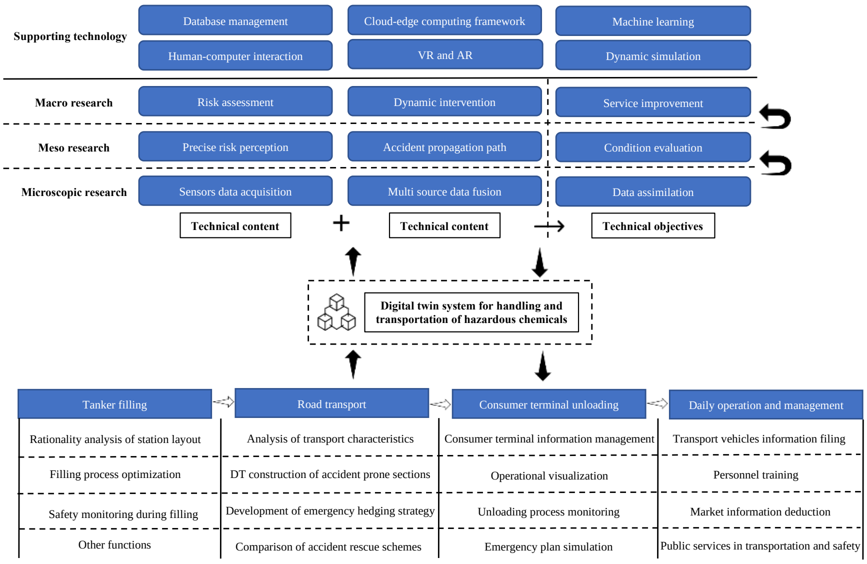

Figure 5. LNG digital twin system features.

5. Discussion and Conclusions

5.1. Theoretical Implications

The focus of DT technology is to create virtual entities in the virtual world corresponding to the real world and to enhance the real world through the analysis of virtual digital entities [38]. The continuous maturation of new technologies has contributed to the maturation of the DT in different dimensions, which has exploded in various scenarios, including aerospace [39], product design [40], and smart cities [41], meaning that this technology still has a large amount of application gaps to fill in station operations and road transportation of hazardous materials. Based on the actual situation of on-site operation and transportation of hazardous chemicals in China, we propose a design framework for the loading, unloading and transportation management system of hazardous chemicals based on DT, and introduce the functions and implementation methods of the system, which provides a new perspective for the realization of active safety in the road transportation of hazardous chemicals.

5.2. Practical Implications

The research and development of the DT system is applied to this industry. First of all, it is most conducive for the state department to monitor the hazardous chemicals market in China, but now they are partly unordered. Secondly, major enterprises (mainly state-owned enterprises and large private enterprises) can reduce operational risks. Finally, the integration of technology enables the technology in theory to be used and tested in practice.

5.3. Conclusions

The system is ideally built by linking all parties in the industry to form a dynamic network, containing producers, consumers, and intermediate members. As for the various types of data needed, different sectors are involved: traffic management, hazardous chemical producers, vehicle operators, and industrial operators, etc. Therefore, the project must rely on coordination at the national level. In the future development of this industry, the following factors should also be considered: from the technical point of view, it is necessary to establish a unified data standard to realize the call between multiple sources of data and the switch between engines in the development process; through the knowledge online, it will be necessary to build a public “resource pool” of various models to improve the efficiency of system development and operation. From the market perspective, we focus on the excavation of the commercial value of the system, attract multiple market players to participate in the construction, and enrich the industry ecology while ensuring the data security of all parties and strengthening the asset attributes of the data.

Author Contributions: Conceptualization, X.L. and Y.Z.; methodology, Y.Z.; validation, X.L.; investigation, T.W.; data curation, C.X.; project administration and funding acquisition, C.L. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by Science and Technology Commission of Shanghai Municipality, (20DZ1202900, 21DZ1200800, 22DZ1203200), and Social Science Fund of Shanghai (2022BSH005).

Data Availability Statement: Not applicable.

Acknowledgments: The authors especially appreciate the help and patience of editors and reviewers.

Conflicts of Interest: The authors declare no conflict of interest.

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