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Modular Structure Construction Progress Scenario: A Case Study of an Emergency Hospital to Address the COVID-19 Pandemic

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Abstract: Recently, emergency structures have been in the spotlight because of the coronavirus disease (COVID-19) pandemic. This research examines the use of modular integrated construction (MiC) in developing an emergency hospital for individuals with novel coronavirus-infected pneumonia (NCIP). The whole process of building is based on the modular design and assembly idea. The primary structure was constructed using the modular steel buildings (MSBs) concept to suit emergency structures' functional qualities and quick construction needs. An intelligent operation and maintenance management platform was built utilizing 5G, AI, IoT (IoT), cloud, big data, an d other technologies. A BIM model was created to evaluate and compare the construction plan, develop the combined section and connection node plan, and complete the detailed design of assembled steel structures. On-site modularization of fundamental structural components and accessories is utilized in a flowing operating mode, where the housing and supporting installation are closely coordinated. The research results show that information and data interaction is the key to speedy building design and construction, with digital simulation in one stage and on-site assembly in a crammed way. The study findings may be used to build comparable structures faster, utilizing modular building techniques.

Keywords: accelerated construction and design; building information modeling (BIM) technology; emergency hospital; modular steel buildings (MSBs); modular integrated construction (MiC); intelligent systems; COVID-19 pandemic

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1. Introduction

Modular steel construction is a novel kind of building structure. The modular building structure system uses a single room as a "module" that is built in the factory. The interior of the module can be arranged and decorated in the factory, and then the module is lifted to the building site and connected to the other modules to make the building body. This system has a high prefabrication ratio, saves labor and materials, shortens construction time, and is green. Modular building has an advantage over traditional architecture in that it can simplify the complex building structure and break up the complex functional system into subsystems, making it easier to manage and implement [1,2]. Today, the development of assembled buildings is relatively fast in the United States, Japan, Canada, Singapore, and other countries.

In general, keywords are used to describe the knowledge areas found in a particular subject of study. It may show the borders of the study domain and certain connections and trends between the research fields. Figure 1 shows the keywords network of modular construction based on the literature visualization tool VOSviewer. As shown in Figure 1, the keywords related to the modular structure, including Building Information Modeling (BIM) technology, off-site construction, efficient management, and prefabricated components, can be seen.

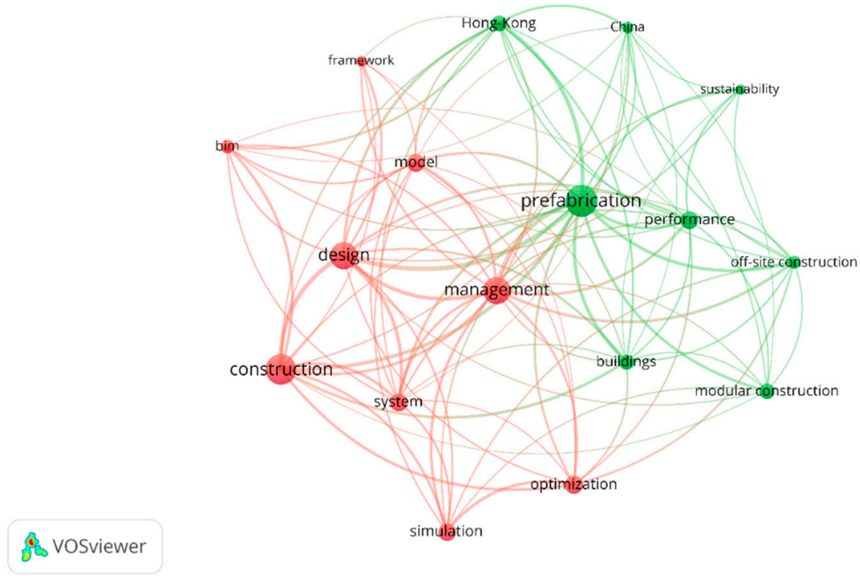


Figure 1. Keywords network of modular construction.

The spread of the novel coronavirus disease (COVID-19) pandemic created considerable excitement about emergency preparations. Emergency buildings would have rapid construction methods such as modular buildings, integrated buildings with fast construction methods, 3D-printed buildings, and temporary structures such as inflatable membranes [3–5]. All of these emergency building forms must fulfill the following specifications to respond to the needs in disaster time: streamlined designs, industrialized machining and processing, simple assembly phase, installed interiors, parts, and incorporated equipment and facilities points to functional satisfaction, quick construction, and intense productivity [6–9].

Modular integrated construction (MiC) is a game-changing technology due to its inherent topological modular structure and increased number of repeatable modules. It enables faster construction, safer fabrication, improved quality control, and lower environmental impact than traditional on-site construction [10]. Modular construction is a viable alternative to on-site construction in the case of repetitive modules. Prefabricated volumetric modules are manufactured in a controlled environment such as a factory, then transported and assembled on-site to construct bigger, more permanent structures, such as modular steel buildings (MSB) [11]. On the other hand, BIM opens up new ways to use computers to design and build modular buildings, which increases productivity and saves money. Sanchez et al. [12] made a BIM tool that automatically picks the right parameters so that modular building parameters can be automatically extracted. Using BIM, Gan [13] came up with a way to make it easier and more efficient to make modular buildings. The graphical data model he created is based on the modular theoretical representation of the building's most important features. He and others [14] looked into how BIM could be used to design and build connected modular shells on a computer. The BIM-based automated lifecycle assessment (LCA) of prefabricated buildings was developed by Ansah et al. [15]. It has different assessment levels, unique system boundaries, and functional units, making it unique.

Today's modular structures have sophisticated architectural, structural, and mechanical systems that span their entire lifespan, necessitating more study into interconnected building systems to improve lifecycle performance through the digital twin. In order to make the transition to data-driven decisionmaking, the Internet of Things

(IoT) and artificial intelligence (AI) research fields must be expanded to gather massive data from preconfigured processes and conduct predictive analytics to improve control choices for manufacturing facility operations. In architecture, digital twins (BDTs) may be thought of as a manifestation of BIM+ derived from digital descriptions. The BIM design encompasses the potential of selecting building shapes, comparing and analyzing the performance of various materials, and using digital twins (BDTs) and BIM for architectural design [16].

After decades of growth and progress, artificial intelligence is establishing a foothold in our everyday lives and starting to influence the disciplines of design and sustainability significantly. AI applications in sustainable buildings include energy-efficient building design, energy forecasting, and consumption minimization; devising methods to alleviate environmental and climatic consequences; and enhancing the safety and comfort of living spaces. Due to the dramatic rise in Internet speed and accessibility over the last several years and the decline in computer and data storage costs, big data (BD) now plays a critical complementary function to AI. The algorithms and computer programs have been created for data mining and analysis. The BD has reintroduced artificial intelligence technologies and applications in various disciplines, including sustainable architecture [17].

The IoT is a self-contained intelligent service system capable of holistic status awareness, efficient data processing, and flexible information application. It is comprehensive in scope and extensively uses sophisticated information and communication technologies such as mobile Internet and artificial intelligence to enable human interaction with all power system components. Numerous IoT-enabled BIM (BIM) solutions have been created to improve production management by increasing information visibility, traceability, and collaboration [18].

The present study tackles this gap by evaluating modular building research utilizing a three-tiered research strategy (data collation, scientific mapping, and systems analysis). The findings indicate that digital tools and technologies (DTT) are underutilized in the prefabricated transportation phase of modular integrated construction (MiC) and that blockchain and other integrated DTT have significant potential for usage in MiC projects [19]. These findings underline the critical nature of the planning and design phases in effectively executing circular modular building projects [20]. These examples demonstrate the critical nature of the planning and design phases in effectively executing circular modular building projects. Zabin et al. [21] used machine learning approaches to go through the study field of BIM data production. The stages of modular building design and construction were identified as potential research objectives.

The hospital for dealing with emergencies uses modular construction to provide different areas. This article describes the establishment of a temporary emergency hospital—Vulcan Mountain Hospital/Huoshen Mountain Hospital—for patients with novel coronavirus-infected pneumonia (NCIP). Figure 2 shows a panoramic view of the construction of Vulcan Mountain Hospital/Huoshen Mountain Hospital. This research framework in the present study blends the ideas of both the building and the layout. This article describes the in-depth integration of BIM technology in the design and construction process of the Vulcan Mountain Project, which may be seen as a rapid and time-saving solution given that BIM technology was employed throughout the building of the Vulcan Mountain Hospital project. The construction of emergency hospitals can be seen as an example of timely crisis management and response to potential risks [1,22].

Figure 2. Panoramic view of emergency hospital construction.

This study is based on the Vulcan Mountain Hospital/Huoshen Mountain Hospital engineering background and uses the organic integration of modular design and assembly construction for project building. Structure and electromechanical equipment are constructed using a modular container assembly approach; BIM technology based on big data is employed to handle information exchange and collaboration. Using the quick construction idea of modular design and assembly construction, Vulcan Mountain Hospital/Huoshen Mountain Hospital was completed promptly with excellent quality. This study examines its technical capabilities and application features better to understand the benefits of modular construction for emergency buildings. The research shows how BIM design and modular construction may be used to enhance the quality of manufactured structures.

2. Background and Project Overview

Figure 2 shows the panoramic view of emergency hospital construction. The hospital occupies 220,000 m^2 of constructed space and 79,000 m^2 of unconstructed space. The hospital's primary mission is to diagnose and treat patients with new coronavirus pneumonia. The east and west areas are planned and designed as isolation medical areas and medical and nursing living areas, respectively, with a total bed count of 1500 in the isolation medical area and approximately 2300 medical and nursing staff in the medical and nursing living area, which is equipped with the related operation and maintenance rooms. The isolated medical area and the medical and nursing living areas are primarily self-contained, and tight flow lines for medical and nursing, patients, logistics, and dirt are designed, with physicians and patients moving in separate directions; the sewage, rainwater, and medical waste are all collected and treated separately and are not discharged into the lake [1,23,24].

3. Standardized, Modular, and Low-Carbon Design of Emergency Hospital

3.1. Incorporating BIM and Modular Construction

The cloud platform is configured automatically throughout the project's design phase, and the design is carried out concurrently by people from different departments to maximize consistent standards and information interoperability. Using Revit software a28s as an example, the benefits of combining the two technologies in the design process are summarized to optimize and correct conflicting issues that arise during the design process, such as colliding pipes and incompatible structural elements within the building, as well as issues such as design considerations that were overlooked during construction and installation [25,26].

Furthermore, BIM technology enables the pre-calculation of engineering quantities during the design stage and the more scientific calculation of engineering quantities during the design stage. Additionally, the building model created using BIM technology has increased visibility, facilitating the depth and detail design phases of architectural design. The 3D visualization model saves half the work required for plan screening [27].

To fulfill the construction deadline, the structural design of emergency hospitals must provide safety while also achieving the target in the shortest amount of time feasible.

The modular light system may be free of the conventional building methods required at the building site and, at the same time, fulfill the demands of the emergency hospital's functional area, which are crucial for responding to public health crises.

The hospital assembly structure follows standardization, modularity, and integration principles and uses established industrialized product systems extensively. The greater the degree of integration of completed modules, the less installation work is required on-site, the quicker the building process, and the simpler it is to guarantee the final product's quality. The structural design process must consider site construction circumstances. The early design phase must communicate with the builder about the construction time, processing and transportation, personnel and equipment, material supply, and site-building techniques.

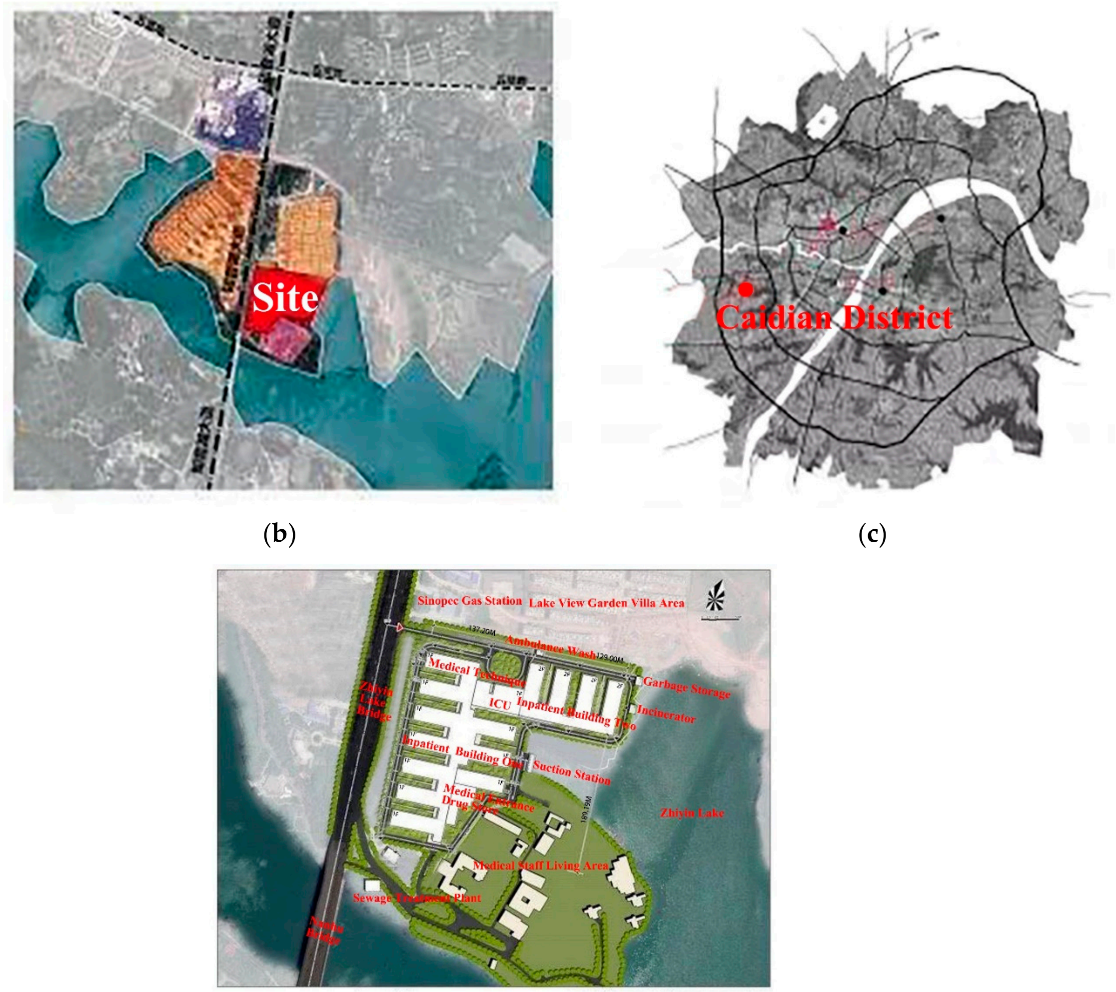
The structural plan is presented based on a complete demonstration to guarantee that on-site execution is feasible. The isolated medical area is a new one-story temporary structure that houses the health care unit, the ward nursing unit, the medical technology unit, and the reception area, but not the emergency clinic. The ward nursing unit is a light modular and steel frame construction mix. At the same time, the medical technology section is a steel frame + lightweight wall panel construction with a "fishbone" arrangement. The isolation medical sector comprises 30 isolation wards and 2 critical care units. The living space for medical and nursing staff includes a dormitory, an office, a dining area, and a storage room for cleaning materials. The dormitory area will see the addition of ten new dormitory buildings, all of which will be light steel movable panel structures, the majority of which will be two stories.

Perhaps it should be mentioned that the "Vulcan Mountain" and "Thunder Mountain" emergency hospitals were constructed in reaction to the COVID-19 pandemic. On a piece of waste ground, the Vulcan Hill Hospital was constructed. The Thunder God Hill Hospital was constructed on the parking lot of the 2019 7th World Military Games' athletes' village, and the original athletes' restaurant of the military games may be used directly. Figure 3 shows the planning diagram of the Vulcan Mountain Hospital/Huoshen Mountain Hospital.

The emergency hospital building comprises surgical isolation beds, patient and nursing living quarters, complete logistics environment, where the isolated medical area is separated into hospitals, reception rooms, intensive care units, medical technology rooms, positive and negative pressure stations, liquid oxygen stations, sewage treatment stations, sanitation services, and other functional areas [28]. These critical sections may be modularly decomposed into regular units and then assembled and mixed according to the same modules. The architectural concepts of an emergency hospital are composed of the following.

3.1.1. Scalable, Symmetrical, Central-Axis Herringbone Configuration

In the shape of a fishbone with a central-axis symmetry, the architectural structure of the hospital consists of three zones and two channels. The working zoning module of the emergency hospital is seen in Figure 4. The sterile location of the polluted site, the semi-polluted, and the contaminated sites are the three areas. The medical personnel channel and the patient channel are the two networks. The different groups of patients should be isolated from the networks utilized by patients and medical personnel, meaning that the medical staff's role can be safe and more covered. While the clean region between ward units is the semi-contaminated field, the ward in the ward unit is the contaminated area [29].



(**b**) (**c**)

(**a**)

Figure 3. Planning diagram of the emergency hospital. (**a**) General layout; (**b**,**c**) area map 2.2. Architectural design.

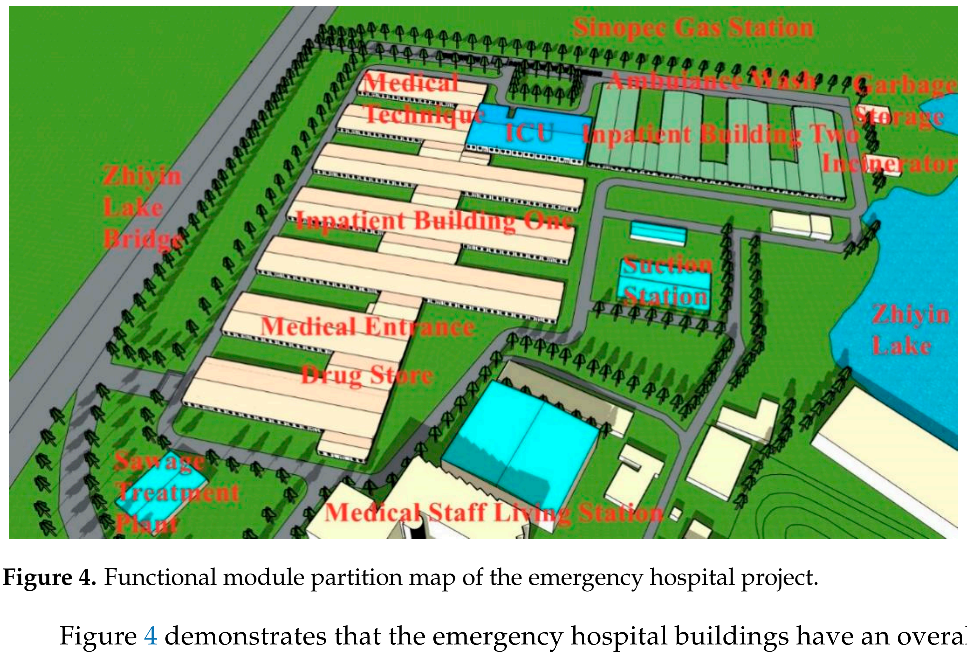


Figure 4. Functional module partition map of the emergency hospital project.

Figure 4 demonstrates that the emergency hospital buildings have an overall "fishbone" layout in the center and the wards on both sides. The "main fishbone" is the long hallway in the center, which acts as a corridor for medical, nursing, and office workers. The "secondary fishbone" linked to the aisle is the nine wards, which can be reached from one of the wardrobes in the gallery. The long arms of the floor plan consist of 12 simple units situated opposite each other, all of which form the whole medical unit of the emergency hospital.

Every "fishbone" is an individual treatment facility, and entry to the hospital is entirely segregated for patients and medical staff, with patients accessing the ward from the "fishbone" perimeter of the ward and medical staff entering the ward through the core "fishbone" path, eliminating cross-contamination.

One of the critical benefits of this "fishbone" style, inherited from an emergency Hospital during the SARS period, is that it is highly scalable—if desired, it can be extended easily to the appropriate "long-arm" without disrupting the original construction purpose, which is a unique architectural feature that addresses the present outbreak's needs and requires a capacity to be developed for additional wards as the epidemic progresses.

3.1.2. Assembled Design and Space Modularization Realization

As shown in Figures 5 and 6, Vulcan Hill Hospital will consist of multiple H modules arranged as shown in Figure 5b, with office areas and medical staff access along the central axis. Each H-module is responsible for four nursing units. Two rows of wards are placed in the nursing units, each with 49 beds. Forty-nine beds are arranged as shown in Figures 5c and 6. Four nursing units are one H-module, i.e., one treatment area.

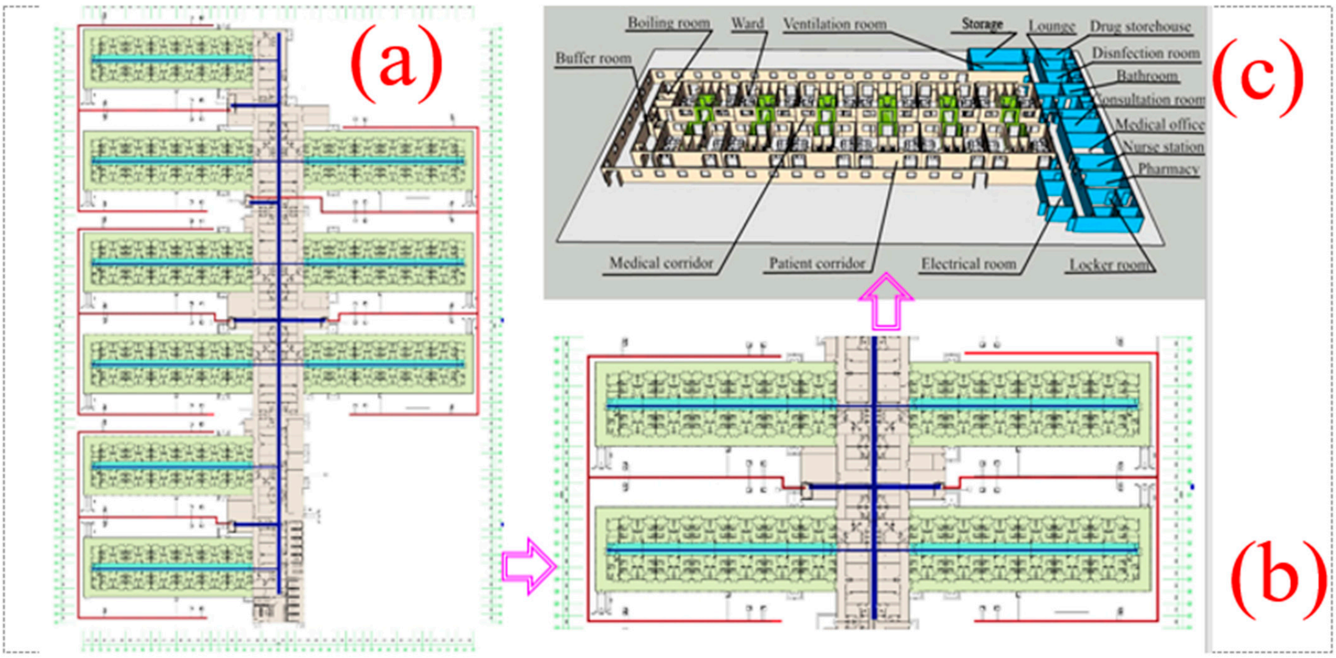


Figure 5. Isolation medical area plan. (**a**) Schematic diagram of isolation medical area H-module, (**b**) detailed drawing of H-module, (**c**) three-dimensional drawing of nursing unit.

Patients are admitted to and discharged from the unit through the outer ward. Medical and nursing personnel enter the center through several layers of clothes and hygienic passages to conduct examinations, administer medicine, and provide care. Such a strong structure enables strict control of the air purity scale, ensuring the health and welfare of medical and nursing personnel and providing for their optimum treatment.

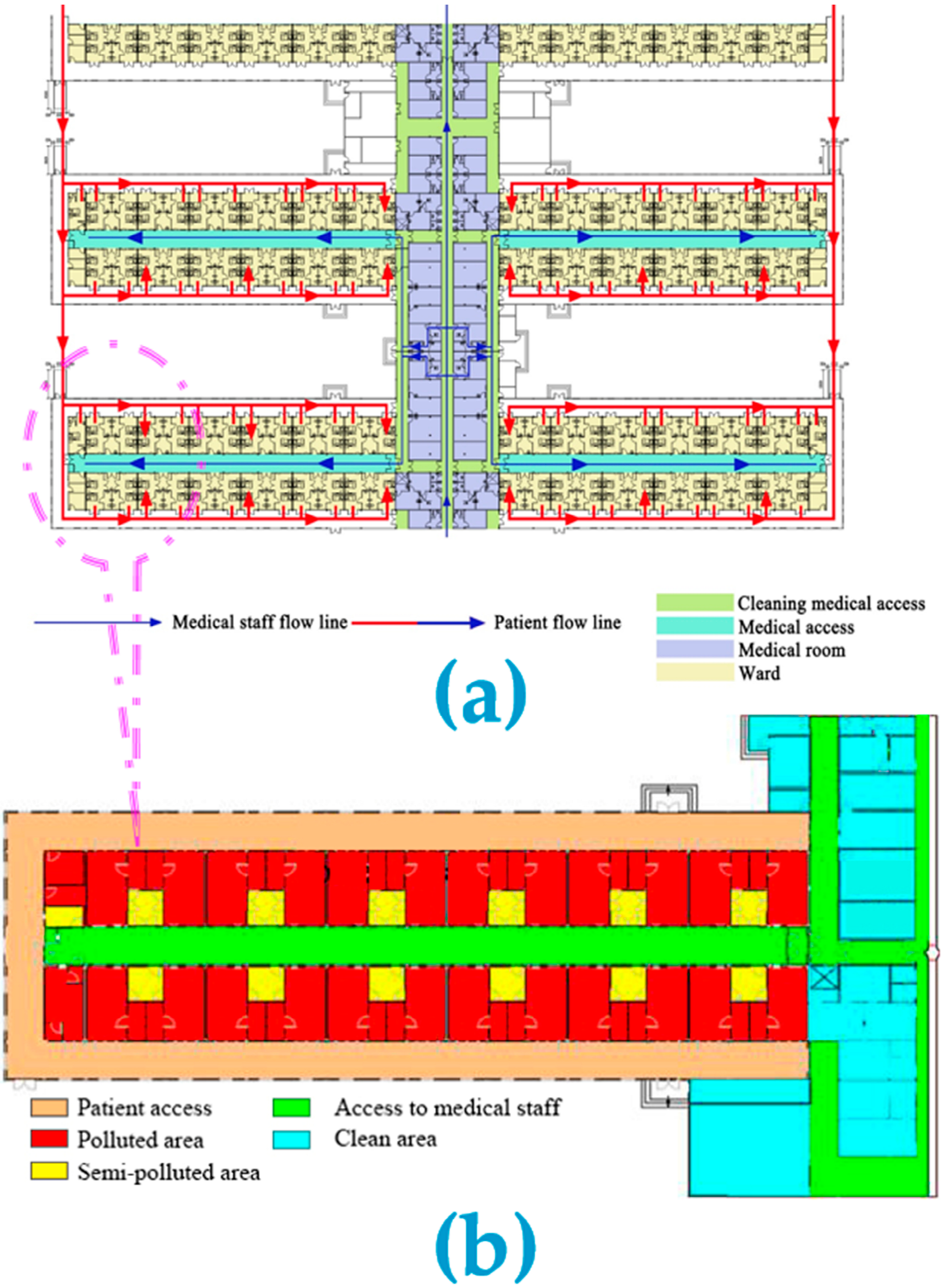


Figure 6. Plan view of a structured nursing unit with a three-zone, two-aisle. (**a**) Diagram of flow analysis; (**b**) diagram of floor layout analysis.

3.1.3. Assembled Design Together with BIM

BIM technology combines and categorizes construction and structural materials electromechanical devices and specifically directs factory production [8]. At the same time, BIM technology simulability is used to mimic on-site construction and determine the right assembly construction strategy that will significantly increase on-site assembly performance and speed development.

For BIM's complete model forward design, the design and building period of the emergency hospital was too short. The design deals together with the stainless steel unit and the specialized design tools while developing the critical structure of the assembled stainless steel structure inside the medical/technical sector. The design model is specifically connected with the data for factory output, and the design phase information is directly imported into workshop production, saving much time.

3.2. Structural Design

The architecture of the building at the emergency hospital uses the concepts of standardization, modularity, and incorporation by allowing the use of mature, standardized building materials as much as possible. The more precisely the module systems are aligned, the less on-site assembly personnel is required, the faster the construction pace, and the easier it is to maintain uniformity. The engineering concept of the emergency hospital integrated two types of structural steel frameworks to fulfill different construction purposes in the separated patient field and medical and nursing living areas.

3.2.1. Nursing Unit Model

The nursing unit layout has a three-zone, two-aisle configuration, as seen in Figure 6. There are 50 beds in a nursing unit, and one field is four nursing units. The essential criteria for hospitalization with infectious diseases are "three zones and two channels": three regions are sterile areas, half-polluted areas, and polluted areas. The patient channel and the medical channel are linked to two outlets.

Partitioning considers that the medical workers should provide a safe work environment and continuous entry, as shown in Figure 6. An axis in the center of the plan is the washing location, access, and function area, and both sides of the central axis are ward units. The semi-contaminated region is between the cleaning area and the ward unit, and the ward in the ward unit is the contaminated area, i.e., the transfer section where the medical staff and the ward come into touch, and a lot of medical staff's work is performed in the semi-contaminated area.

Access for patients is beyond a nursing facility such that the access for patients is independent of access for health employees, meaning that the health workers are not infected. As seen in Figure 7, the workers enter from clean areas into the emergency hospital, change into protective clothes in the wards; enter the work area for medical and nursing preparations, change into insulation garments and entering into the medical and nursing hall into the semi-contaminated area; and enter the contaminated wavelength.

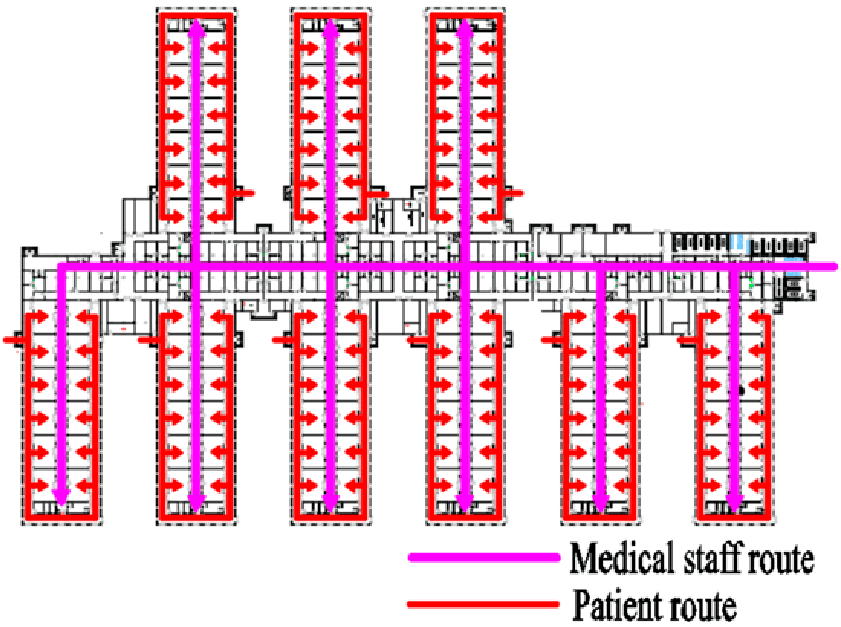


Figure 7. Nursing unit staff flow chart.

3.2.2. Designing of a Modular Steel Frame

The isolated medical zone is a single-story building that includes a health access facility, a ward unit, a medical technology unit, and an intake space. Different assembly building types are used due to the other specifications of functional areas with varying net heights. The nursing unit is a standardized assembly-style, integrated architecture unit.

Figure 8 demonstrates the ward unit plan (module). The hospital has a rigid "three zones and two channels" design for medical and nursing workers to organize their work areas according to the "clean zone-semi-polluted zone-polluted zone" workflow. Each time people reach the first-floor region, the medical and nursing channels are segregated from the patient channels. There is a transition room in the isolation ward composed of two layers of glass and an ultraviolet light device under which the meals and drugs of the patient are passed and disinfected to prevent contamination by the ultraviolet light system in the cell. In each ward, two beds are located, and a separate toilet in the room provides medical and nursing staff with several safeguards in a secure and efficient working setting.

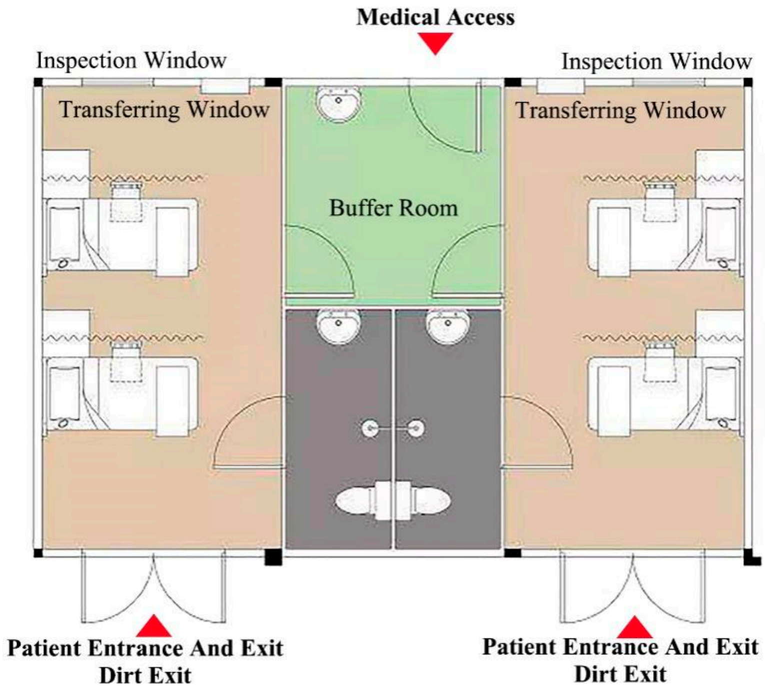


Figure 8. Ward unit (module) plan.

According to market inventory, the main sizes that can be procured are two types of 6.0 m × 3.0 m × 2.9 m and 2.0 m × 6.0 m × 3.0 m box-type modules (Figure 9), and the building plane adopts a standardized design according to this condition. All units can be divided into two basic units, arranged and combined. The module unit height is 2900 mm, and the module is united by the main structure, floor, wall, ceiling, equipment pipeline, and interior parts. Furthermore, the module is a functionally integrated three-dimensional space body to meet the requirements of various building functions and lifting and transport requirements. The single container module consists of prefabricated plates and prefabricated steel columns, the size of prefabricated plates is 3 m × 6 m, the steel columns are "L"-shaped angles with a height of 3m, and bolts connect the hooks and prefabricated plates [26,27].

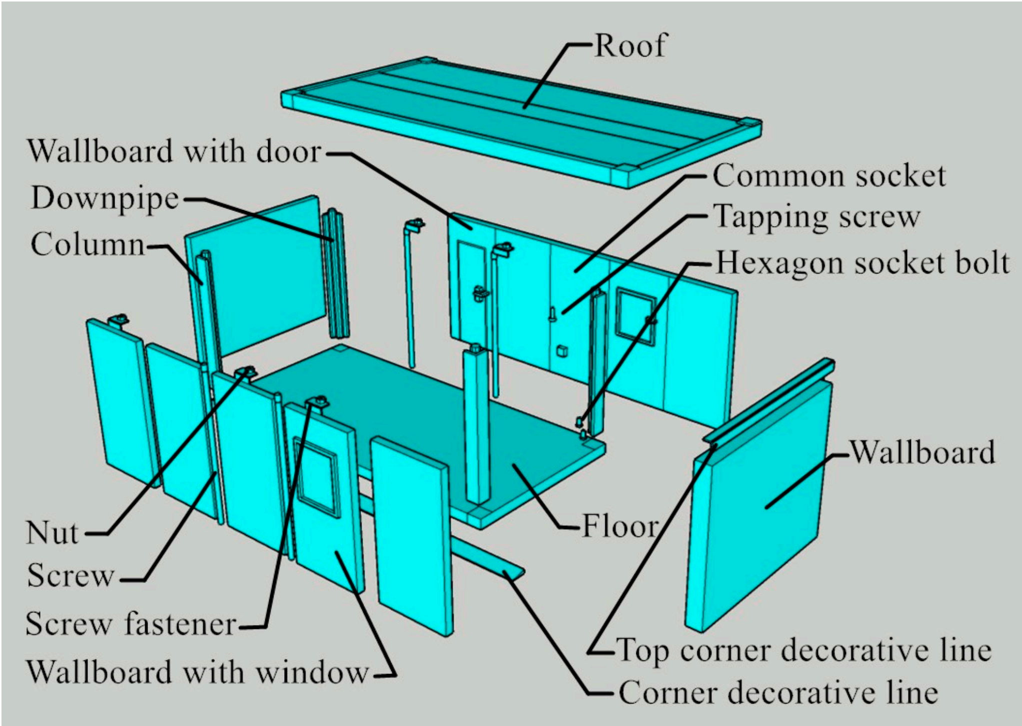


Figure 9. Box space cell module (medical staff and patient ward) configuration decomposition diagram.

In the emergency hospital's engineering design, modular and standard steel structures are adopted for the various building functions and spatial characteristics of isolated medical areas and medical and nursing homes. Since the modular assembly style steel framework insulating the ward care unit patient area has standard model modular characteristics, the modular assembly style steel structure construction technique is used. This modular box-type unit adopts a steel frame and color steel composite panel walls, which has strong structural integrity, high bearing capacity, wind and earthquake resistance, and safety and applicability.

The modular box units can be used individually and combined in different combinations as required and freely spliced to form a spacious usage space through different combinations in horizontal and vertical directions. They can be stacked vertically to form a multi-layer modular assembly building system. This project utilizes only one-layer modular assemblies, and the total amount of modules used exceeds 3190. The modular box is a steel frame structure, and the mainframe beams and columns are all cold-formed steel welded together, with a cold-formed steel spacing of 500~1200 mm welded on all six sides to ensure wall, top, and bottom plate strength and stability.

Figure 9 displays the box room unit's module configuration decomposition schematic diagram. The prefabricated manufacturing plant prefabricates and extracts the products according to the processing diagram. After building requirements are available, the components are transported to the assembly site. Many on-site production procedures are transferred to the plant for industrial standardization, specialization, and mechanization, transforming the building and installation industry's conventional construction mode, increasing performance, minimizing material waste, and reducing site emissions.

The medical–technical building and ICU's s internal roles are diverse, and all are non-standardized units, so a light steel frame is used close to the shape of a temporary panel house.

The emergency hospital project reserved the rooting points of the brackets and holes through the walls needed for the electromechanical pipelines to ensure strong and durable powers during the container processing level. The pipeline equipment is mounted on-site owing to design and installation coordination. It requires the interspersed articulation of several technical jobs, creating shared constraints to combat a volatile circumstance and eventually disrupting the development time. For this purpose, mechanical and electrical engineers consider matching the modularization of building ward units. Each practical electromechanical pipeline equipment often adopts a modular device rapid-replication architecture, which can modularize and standardize pipeline production and equipment acquisition and processing, significantly accelerating development.

All wards are manufactured with the fire performance of container-type environmentally safe products; factory manufacturing and on-site prefabricating can significantly accelerate construction development. In order to ensure that the waterproof nodes are tight and eliminate water leakage, all components of the modular buildings are made in one go in the factory, which can control the installation error to the millimeter level. The hospital ward windows are locked, and the wards are fitted with a transition chamber comprising two layers of glass and an ultraviolet disinfection device. Each ward is uniquely fitted with a non-circulating fresh air system and an exhaust air system, creating a negative pressure system. Each ward care unit has 700 sets of fan supply and exhaust appliances, and the ventilation system plays the function of "guiding and navigating" indoor air. A pressure gradient of 5–10 Pa is established between contaminated, semi-polluted, and clean areas by monitoring air adjustments, air supply, and exhaust volume in polluted, semi-polluted, and clean rooms to "guide" it from a safe zone to a dirty zone. Simultaneously, it is set in the poisoning device's exhaust duct to destroy the first poisoning treatment indoor air before discharge to remove air pollution.

3.2.3. Foundation and Seepage Control Design

In general, the pouring and hardening of concrete were achieved in less than eight days (with low temperatures), ending on the eighth day. The concrete design of the emergency hospital project belongs to the winter construction, which has steps to speed up the structure, while maintaining the building quality is a cautious problem.

Due to the bigger foundation area, heavier backfill at the site, and short construction duration, the design uses a reinforced concrete raft slab foundation to minimize uneven settling. In order to make equipment pipeline laying quick and easy, the raft foundation surface was lowered 150~300 mm, and steel beams were installed on top to support container units. Figure 10 shows the two foundation types for Vulcan Hill Hospital. This method allows impermeable membrane protection and equipment majors' pipeline laying requirements to be met simultaneously, shortening construction time.

The emergency hospital is built and developed for wastewater management in line with long-term construction and is completely enclosed for service. It is similar to a whole patient wearing a protective clothing layer. The medical wastewater is pumped to the municipal network after tertiary liquid chlorine disinfection. The whole hospital foundation is paved with an impermeable membrane according to landfill requirements, and all rainfall is collected and treated to ensure no sewage enters the environment. Specific procedures are listed here.

The anti-seepage construction method is as follows: sand of 20 cm thickness is laid on the leveled ground and interspersed with the pre-burial pipeline construction. Then, two cloths and one membrane (two layers of 600 g/m^2 polypropylene filament geotextile and one layer of 2.0 mm double rough surface impermeable membrane HDPE) are laid on top, and then 20 cm of sand is applied, which has an anti-seepage solid effect (Figure 11).

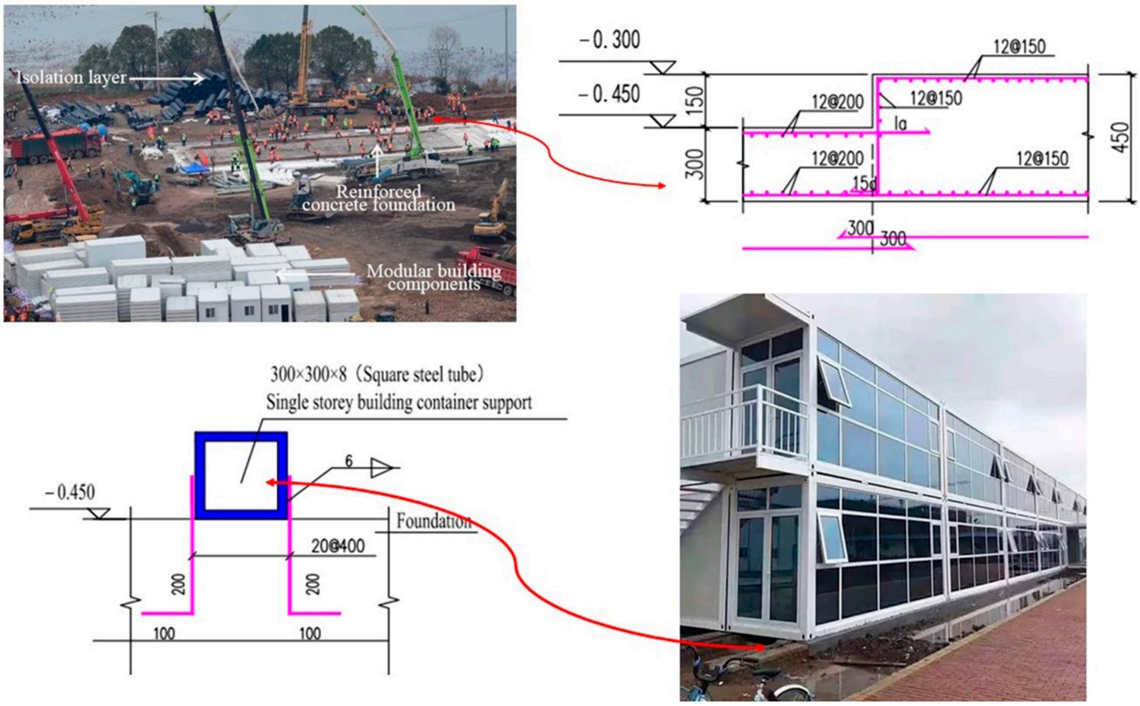


Figure 10. Foundation schematic.

Figure 11. Foundation construction drawings.

4. Accelerated Construction of the Emergency Hospital

The emergency hospital's building phase focuses on the general contractor model, incorporating the project's planning procurement and construction to accelerate building development. The project was introduced based on requirements such as the Code for the Development and Approval of Hospital Buildings for Infectious Diseases (GB 50686-2011), Building Architecture Code for General Hospitals (GB 51039-2014), and Building guidelines of the emergency medical facility (IWA38).

4.1. Difficulties of Accelerated Construction and Countermeasures

The emergency hospital project encountered several difficulties, from a patch of wasteland to a standard infectious disease facility: firstly, the extreme environments in preparation, the gap in height between the east and west of the site up to 10 m, the high workload of the site leveling, and the massive volume of planning for the relocation of the initial gas and high-voltage pipelines; secondly were the challenge of personnel mobilization, the complexity of organization and coordination, and the hundreds of subcontracting groups. Part of the construction photos are shown in Figure 12.

Figure 12. Construction photos. (**a**) Land grading on 25 January; (**b**) box-type skeleton house panel installation on 29 January; (**c**) installation of medical devices on 1 February.

Moreover, the supply demand is enormous; the need for site materials is considerable: the demand for box-type cubicles amounts to 1650, different doors amount to 1500, the demand for concrete amounts to 14,000 m^3, and the need for HDPE film amounts to 100,000 square meters. Because the construction was during the Chinese New Year, ordering was difficult, and there were differences in the specifications of the required modular panels. The protection and disease will be inconsistent; epidemic preventive protection was also evaluated. Table 1 demonstrates the project's challenges, countermeasures, and measures studied.

Table 1. Project challenges, interventions, and countermeasures.

No.	Construction Difficulty	Countermeasures	Specific Measures
1	Hospital construction tasks have been highly complicated.	Standardization and modular decomposition of complicated functional fields and chopping up each part for improved interaction.	Using identical structures widely found in the same functional areas promotes building.
2	Complex, multi-disciplinary cooperation.	Interdisciplinary and innovative, and integrated architecture.	BIM network data exchange.
3	Very short construction duration for design and construction ornamentation.	Standardize the architecture of several building ventures on a single level, synchronize variances between design and construction activities and fight for time.	Standard single-story decomposition of modular construction assemblies, considering construction ease and without lift installation completely.
4	A significant number of modular buildings are generated and then mass purchased.	Functions, grouping, and synchronization of processing output are often used.	A general contractor identifies appropriate manufacturing factories from all over the world and coordinates the production and procurement.
5	Many building workers are on site.	Single-layer construction, modular decomposition into sections of the whole project	Simultaneous development of the entire site in blocks of one sheet to maximize the housing area.
6	Multi-process cross-construction.	The basic construction, equipment installation, and decorating are all separated.	Using modular building design, all the building roles are formed together in the warehouse—in-house general configuration and servicing.

4.2. Control of Information and Development Installation

Because of the standard container material supply size error, the assembly error is far greater than the typical module space because of the horizontal configuration of two standard modules plus one standard vertical module arrangement (corridor) of the assembly type. If the seam width is not treated correctly, the roof leakage issue may occur, but it affects home décor and medical equipment installation afterward. In order to solve the above problems, BIM technology was implemented comprehensively to evaluate and compare construction solutions and decide on the structural system, combined segment, and attachment node solutions for rapid construction of ICU buildings, and medical–technical buildings. In order to realize the rapid construction of assembled steel framework, the line model in AutoCAD format was refined, completed, and imported into the Tekla program to create a BIM model online and render the comprehensive design of steel structure construction to solve the problems of irregular building shape, complicated structural layout, and collision of bars.

The BIM model is used to encourage construction technology performance, as anticipated. Electromechanical installation includes water supply and drainage, illumination, ventilation, air conditioning, connectivity, electricity service, and medical gas. The project adopts BIM technology to develop a clean area and separation area pipeline arrangement model to simulate pipeline collisions and other problems in advance, not just to achieve the necessary pipeline interspersed phase but also to optimize space and time to ensure the aesthetics of the pipeline arrangement.

The construction technology is incorporated into the engineering design by understanding both the building and structure functions and the processing quality and construction performance at the design level, which essentially solves the problem of information fault and information island among the rapid construction elements such as project design, manufacturing, and construction.

BIM technology facilitates the exchange and control of engineering knowledge via a standardized framework. In the medical care field building, the project technical team used BIM modeling to refine six designs, including utilizing a steel framework instead of the standard concrete base, backfilling instead of partial site hardening, adapting indoor stairs to outdoor, and so on. A total of 18 days were saved during the building of the Vulcan Mountain Hospital scheme, and its inhabitants could experience the new dormitory.

BIM technology is used to overcome the contradiction created by thousands of cross-operational events in the project. The planning, layout, manufacturing, and installation were meticulously planned and coordinated to speed up the construction process. Since the Vulcan Mountain Hospital project was developed during the winter, urgent hardening measures were necessary for the site: the flexible use of site conditions according to local requirements, the use of quick hardening of the ground, and the use of a variety of foundation forms, including steel support piers and raft slabs, to address the foundation construction issues that impede the rapid construction of assembly buildings. Another example is using beryllium beams to supplement the overhead beams and fix issues such as column footing installation.

4.3. Phase for Building

The design phases of the emergency hospital project involve the following: Site leveling → seepage resistance → tying of reinforcement → pouring of foundation → assembly of the main structure of modular building → power on, and commissioning. The development schedule of the project is shown in Table 2.

Table 2. Construction schedule.

Time	General Project	Progress and Contents of the Emergency Hospital Building
23 January	It takes a long time for feasibility study, project planning, development, and acceptance.	The municipality agreed to create the emergency hospital
24 January	Popular project planning does not use BIM technologies and does not effectively model the design and building schedule in advance in structured construction is vulnerable to design issues and structure. The building line and scheme cannot be simulated in advance, and construction according to the design model will likely contribute to construction difficulties or disputes with the subsequent construction and the pre-buried pipelines. The building time is about 20 days.	Hundreds of excavators arrived to begin ground leveling. Companies issued instructions to supply reinforcement bars, pipes, box-board house components, and other supplies to the site during the construction phase.
25 January		Officially unveiled initiative. Develop the environmental safety pipe network. At the same time, the building partner specifically enforces sanitation standards, gathers sewage, rainwater, and medicinal waste separately, which will not be dumped into Zhiyin Bay.
26 January		The building of the impermeable layer is in full flow, the underground pipe network trench is excavated, and the container slab materials come in one after another. Construction of the sewage treatment portion began. Thirty thousand square meters of HDPE impermeable membrane were built, and the building was in full force, bringing on a "protective coat" for the emergency hospital site to keep sewage from the field. Meanwhile, the first-panel room was finished. A negative pressure ward is the converted model space.
27 January		The stock of the first round of box-type cubicles was being shipped. Perimeter re-grading, demolition, and irrigation have all been completed. On the morning of the 22nd, the first batch of box-type cubicles started to be lifted at the hospital. The site was at one point located in single-chamber frame houses.
28 January		One double-story ward area's steel framework is taking form. A significant amount of containerized house panel products was elevated and placed on location. For accelerated building, semi-finished materials are used, and assembly-style construction is introduced.

Table 2. *Cont.*

Time	General Project	Progress and Contents of the Emergency Hospital Building
29 January	The houses are designed with the usual reinforced concrete foundation, and the building duration is up to 3–5 years.	More than 300 box-type house skeleton assemblies are finished, and the panel house erection's simultaneous electromechanical pipeline process starts in full swing. The steel structure of the medical and nursing housing area is all finished. The site leveling and backfilling of the wards' frame construction is performed, and the concrete pouring of the cubicle base is around 90% full. Simultaneously, piping, electrical, HVAC, electromechanical devices, and other components are in order and completed simultaneous activities.
30 January		HIPE membrane lying was finished, and equipment was mounted concurrently in the treatment area.
31 January		90% of the containers were installed. Moreover, the mobile board house skeleton is mounted at 3000 square meters—all electrified emergency hospitals.
1 February	Ordinary programs do not have many specialized medical devices for a limited time because installation takes much longer than one day.	One thousand six hundred fifty pieces of surgical devices were mounted together.
2 February		Emergency hospital finished and supplied.

5. Intelligent Emergency Hospital Project Scenario

There has been a huge rise in the use and development of technologies such as ICT, AI, cloud computing, and big data, which has led to changes in the medical and health fields. During the COVID-19 pandemic, 5G, IoT, AI, and service-oriented robots worked very well together to fight the pandemic, which was very bad.

(1) The creation of BIM, 5G, robots, and other technology such as Drone Technology: BIM aids in the integrated design of each specialty within the emergency hospital, the design and optimization of assembly modules, cost analysis, processing and production simulation, on-site visualization and delivery, 5D monitoring, and other applications, and the use of BIM, IoT (IoT), cloud platform, GIS, and 2D Code to enable on-site verification and tracking of the assembly process.

(2) For teleconsultation, remote diagnosis and treatment, remote monitoring, enormous data transfer, and supporting frontline medical professionals, 5G can provide high-speed Internet access.

(3) Medical AI that can precisely locate tumors on CT scans. The top of Vulcan Mountain Hospital/Huoshen mountain hospital has 1597 patients. Inpatients stay an average of 20 days in the hospital, and CT imaging is required every 3–4 days to identify patients. Reviewing and comparing patients' prior imaging data would be laborious for clinicians. Medical AI solves this. The developers created a novel AI model to capture changes in patients' situations throughout therapy that uses rich CT image samples to detect lesions and quantify their percentage change. Normal CT reading time is now 20 s, and AI now writes most imaging reports.

(4) Hospitals employ one set of network to connect various IoT devices. Many IoT devices are employed in hospitals, such as pharmacy temperature and humidity sensors, patient monitoring in isolation rooms, mobile care bracelets, and infectious waste tracking. Verified terminal and application identification achieve bandwidth assurance for specified terminals and applications. Realize modern medical care approaches such as telemedicine and AI to identify ailments and arrange treatments. Improve hospital service quality and operational efficiency. Simultaneously, it can perform real-time patient data analysis and clinical decision support.

6. Conclusions

Vulcan Mountain Hospital/Huoshen Mountain Hospital is built on a modular design and construction philosophy that combines modular design with assembly-based construction. The primary structure is constructed utilizing the MSBs assembly technique, which uses MiC to manufacture all components of the modular buildings in the factory and then install and prefabricate them on the construction site.

From four aspects, including assembly design, rapid construction, anti-pollution diffusion, and BIM technology and information technology, the paper studied the fast construction process of the emergency hospital project, drawing the following conclusions based on the above study.

Construction assembled. This is the first concept of emergency hospital design utilizing assembly technologies, using container-type package operation room for integrated assembly, up to 6.0 m × 3.0 m × 2.9 m panel splicing to form a standard unit, the full realization of the modular, automated, installed project to increase engineering progress design.

Preventing and designing waste. The emergency hospital project adopts the design of "three zones and two channels," and the medical and nursing workers organize the work areas according to the "clean zone-semi-polluted zone-polluted zone" workflow. The project adopts a modular sealing device, air pressure management ward anti-proliferation technology, and comprehensive anti-seepage technology, "two cloths and one film," to achieve successful infection prevention and control.

Speedy building technology. BIM technology is utilized throughout the building process to facilitate information exchange, integrated management of all professions, and coordination across all professions. It refers to the integrated design, assembly module design, and optimization of each specialization of the construction project with the assistance of BIM. Artificial intelligence, 5G, and the IoT are all being combined to construct a smart activity and maintenance management network for the emergency hospital.

Practical advice and instruction. Emergency buildings are still imperfect regarding relevant standards, and there are not many standardized series of standards that can be used as a reference for enterprises. China IPPR International Engineering Co., Ltd. prepared the Building guideline for the emergency medical facility (IWA38), authorized by the ISO Technical Committee for the Construction of the Scheme, to summarize the expertise acquired in the construction of emergency medical facilities and to provide the international community with a reference software.

Limitations. Vulcan Mountain Hospital/Huoshen Mountain Hospital is an EMT project. In an emergency, when only modular structures can be created fast, assembled buildings "may represent the future of swiftly deployable healthcare." Unlike long-term hospital structures, the Vulcan Mountain Hospital/Huoshen Mountain Hospital must answer current concerns. They are not created for eternity, but their remarkable timing and global testimony on the air may make their architectural history. However, this so-called experience may only be somewhat important.

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