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Prefabrication challenges in community healthcare center renovations

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ABSTRACT

After the global public health crisis, outbreaks are seen as a cyclical phenomenon rather than a one-time event, hence the need to prepare for potential future pandemics. This study investigates the use of prefabricated technology in Chinese community healthcare centers to address spatial design challenges. This technology effectively resolves issues in general wards and enhances emergency response capabilities through isolation units, optimized layouts, and improved ventilation. Phased renovations ensure service continuity, making prefabrication a viable solution for rapid upgrades and strengthening pandemic response capabilities.

KEYWORDS

prefabricated building technology, community healthcare centers, general wards, emergency response capacity

1. INTRODUCTION

The outbreak of the COVID-19 pandemic has exposed numerous problems in the global public health system, particularly in its inability to cope effectively with emergency situations. In China, community health service centers played a significant role during the pandemic, not only providing routine medical services but also taking on responsibilities for prevention, isolation, and treatment. However, many community health service centers performed poorly in the face of public health emergencies due to factors including small building size, unreasonable layout, and outdated facilities [1]. The general wards in community health service centers can only provide basic medical treatment and are not equipped to admit patients with infectious diseases. But when the pandemic struck, they had to suspend regular medical treatments. This led to an even greater strain on medical resources during the special period, resulting in considerable waste of medical resources.

To address these issues, Prefabricated Building Technology (PBT) has been gradually applied to the renovation of medical facilities [2]. PBT has gradually become integrated into daily life with the passage of time and development (Table 1). PBT involves the prefabrication of modular components in factories, followed by transportation and assembly on-site. This technology not only greatly improves construction efficiency but also effectively increases the medical functional areas in confined spaces, meeting the spatial demands during emergencies. The introduction of PBT makes traditional building structures more flexible and adaptable, enabling them to quickly respond to sudden demands for medical facilities during the pandemic.

This study focuses on the spatial design challenges and solutions faced by Chinese Community Healthcare Centers when using PBT to renovate general wards. Specifically,

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Table 1. History of prefabricated technology development in China

Pioneering phase (1950s)	Borrowing from the technologies of the former Soviet Union and the countries of Eastern Europe, the material basis for factorization and mechanization was initially established
Development phase (1960s–1980s)	A variety of assembled building systems have been rapidly developed, gradually realizing the shift from manual production to mechanized production
Low phase (1980s-early 2000s)	The development of the industry has entered low ebb due to the emergence of poor seismic performance, waterproofing, soundproofing, and other problems. In addition, many cheap laborers entering the city for employment, coupled with the emergence of cast-in-place concrete mechanization and other factors led to the large-scale development of cast-in-place construction mode
Upgrading phase (2008–2013)	With the aging of China's population, the number of migrant workers in the construction industry to reduce the number of labor costs continue to rise advances in construction technology for the development of assembled buildings Mo Ding foundation; in addition to environmental protection policies tend to be more stringent, assembled buildings ushered in a new opportunity
Rapid development phase (2013-present)	Central and local governments continue to introduce relevant policies to vigorously promote the assembly of buildings; coupled with the increasingly mature development of assembly technology, the formation of including assembled frame structure, assembled shear wall structure, and other forms of building technology, China's assembly of buildings into a period of rapid development

Source: Authors.

this paper will analyze the spatial layout, functional zoning, and adaptability requirements of general wards in the renovation process, exploring how PBT can facilitate efficient space transformation and functional optimization to enhance the emergency response capacity of Community Healthcare Centers during public health emergencies. The goal of the research is to give practical strategies that provide both theoretical support and guidance for renovating general wards in Community Healthcare Centers in the future.

2. RELATED CONCEPTS

2.1. Prefabricated building technology

PBT refers to the transfer of a large amount of on-site construction work in traditional building methods to the factory. In the factory, architectural components, and accessories (including floor slabs, wall panels, stairs, balconies, etc.) are processed and manufactured, then transported to the construction site, where they are assembled and installed using reliable connection methods. Its main features are standardization, modularization, and high efficiency [3]. Prefabricated construction has attracted interest since the early 20th century and was finally realized in the 1960s. Countries like the United Kingdom, France, and the Soviet Union were among the first to attempt this method. Due to the fast construction speed and lower production costs of prefabricated buildings, they quickly spread and were promoted worldwide. On September 27, 2016, the State Council issued the guiding opinions on vigorously developing prefabricated buildings by the General Office of the State Council [4], which clearly defined the key areas for the development of prefabricated buildings and steel structures, the target proportion of new buildings to be prefabricated in the future, and the key cities for development. PBT enables the rapid assembly of modular structures, as illustrated by the image (Fig. 1), where prefabricated components are systematically positioned by cranes and workers to form a multi-story healthcare facility.

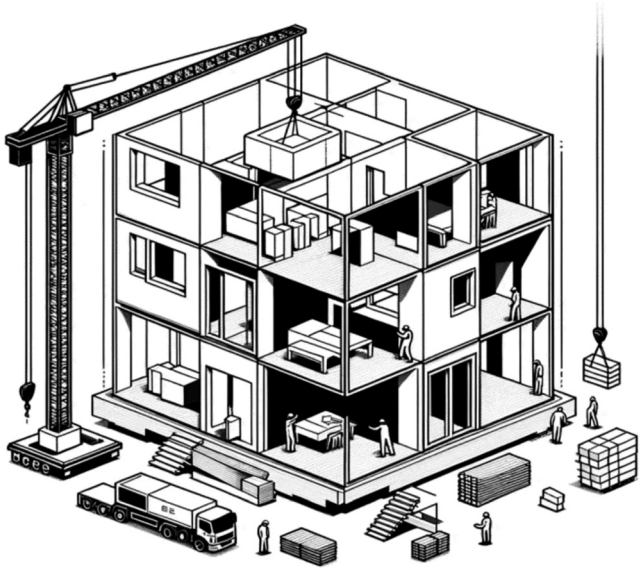

Fig. 1. Prefabricated building technology (*Source*: Authors)

2.2. Community healthcare centers

Community Health service Centers (CHCs) are grassroots health institutions in China that provide basic public health services and basic medical services at the community level. They are an important part of China's primary healthcare system. Most of these centers are public non-profit organizations. They mainly offer preventive health care, treatment, health education, and basic medical services. CHCs are set up based on the jurisdiction of sub-district offices, primarily established by the government. In communities

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with a larger population, a greater service radius, and where the CHCs are unable to cover the area, additional centers can be established, or lower-level Community Health Service Stations can be appropriately set up. For sub-district offices with a population exceeding 100,000, additional CHCs should be established. For sub-district offices with a population less than 30,000, the establishment of community health service institutions is determined by the health administrative departments of the district (city, county) government. The development of community healthcare centers in China has evolved through distinct phases, from initial small clinics in the 1980s to modernized, multifunctional facilities in the 2020s (Fig. 2).

2.3. General wards and emergency response capability

In recent years, with the continuous updating and advancement of medical technology, the traditional design and construction methods of medical buildings have been unable to meet the current medical needs of people. Medical buildings should evolve with the rapid development of modern technology, constantly changing medical layouts, and should have flexible design and high adaptability. Among them, PBT feature modular design, dry interior design, innovation in building materials, and efficient energy-saving construction characteristics, achieving a "flexible" design pattern of plasticity in architectural form and spatial layout, optimization of structural arrangement, and rapid installation and renovation of mechanical and electrical pipelines [5]. PBT is increasingly being applied to medical buildings. The use of PBT in healthcare buildings primarily helps to quickly change space and modular functionality. When a building requires temporary changes or expansion, prefabricated components can be disassembled, recombined, or rearranged, and spaces including wards, consultation rooms, and isolation units can be added as needed. This flexibility helps medical institutions quickly adapt to changing needs, improving the building's adaptability and response capabilities in emergency situations.

3. SPATIAL CHALLENGES OF GENERAL WARDS IN COMMUNITY HEALTHCARE CENTERS

3.1. Space limitations and inefficient functional layouts

Many CHCs have problems with limited space and poor layouts in their general wards. These issues become worse during public health emergencies. In some wards, the spaces are small, and the layout is unclear, making it hard to meet urgent medical needs. For example, many wards fail to effectively separate infectious disease patients from non-infectious ones, making it impossible to quickly adapt the space into isolation rooms that meet infectious disease control standards during an outbreak. Infectious disease patients and non-infectious patients should be housed in separate rooms to prevent cross-contamination. Furthermore, patients with the same infectious disease, particularly those infected by the same pathogen, should be grouped together for easier management and treatment [6] (Fig. 3).

In addition, the design of the wards lacks sufficient flexibility. The width of bed units and hallways does not

Fig. 3. Space limitations and inefficient functional layouts (*Source*: Authors)

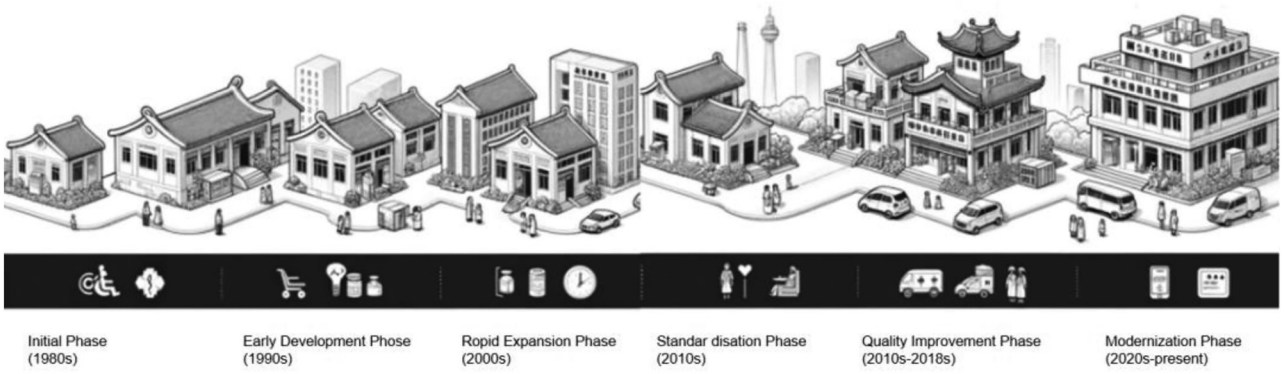

Fig. 2. History of the development of CHCs in China (*Source*: Authors)

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meet emergency requirements. The partitions between beds should be designed for easy cleaning and disinfection to ensure the sanitary safety of the ward during use. The hallway width between single-bed units should be at least 1.1 m to meet mobility and safety needs. The hallway width between double-bed units should be at least 1.4 m. The distance between beds should be more than 0.8 m to keep patients separated and reduce the risk of cross-infection [7]. Many existing wards do not follow these design standards, which caused delays in renovations at the start of an epidemic. During this time, CHCs had trouble handling the sudden increase in patients and the complex infection control needs.

Optimizing the layout of wards during renovations and improving their adaptability has become an important issue that needs to be solved.

3.2. Insufficient facilities and uneven resource distribution

China faces a shortage of high-quality medical resources, which are also unevenly distributed, and there are shortcomings in the service capabilities of grassroots healthcare institutions. Many CHCs have not planned for facilities and equipment to control infectious diseases. CHCs mainly provide routine medical services; when a public health emergency occurs, most CHCs are unable to quickly change their existing space and resources to treat patients with infectious diseases.

Basically, CHCs do not have negative pressure rooms and air purification equipment, which greatly limits their ability to handle infectious diseases. Without negative pressure systems and air purification equipment, these wards cannot control airborne viruses, thus failing to meet the basic requirements for infectious disease control. Many CHCs also lack doctors specialized in treating infectious diseases, making it even more difficult for them to cope during an outbreak. Inadequate lighting is another issue. In emergency situations, poor lighting may affect the efficiency of medical staff and the safety of the wards [8].

3.3. Ensuring uninterrupted healthcare services during renovation

Ward renovation and upgrading is a crucial breakthrough in filling the gaps in public health infrastructure, improving the quality of medical services, and enhancing the healthcare experience for the public. The use of PBT to renovate CHCs is a significant challenge, as it cannot interfere with regular medical services. During the renovation, there may be a shortage of ward beds and other issues, which affects the space for regular patients and may reduce the quality of care, making it difficult to meet the demands of regular services.

Therefore, finding a balance between reducing the number of beds and reserving space for regular medical services is the key to solving the problem. Given that most medical and CHCs have limited space, and the spatial design did not consider emergency medical needs, especially during public health emergencies, the limited area further increases the difficulty of renovation. Ensuring that ward renovations do not halt regular medical services has become a critical issue.

3.4. Core requirements and implementation pathways for compliance with national legal regulations in renovation processes

The renovation of community healthcare centers must strictly adhere to national laws, regulations, and industry technical standards to ensure building safety, medical functional compliance, and public health emergency preparedness. According to the Building Law of the People's Republic of China [9] and the Regulations on the Quality Management of Construction Projects [10], a structural safety assessment of the original building must be conducted by professional institutions prior to renovation. This ensures that the installation of prefabricated modules does not compromise the load-bearing system, and that construction is carried out by qualified entities, with unauthorized modifications to the main structure strictly prohibited. Additionally, mandatory standards as the code for design of general hospitals, like GB 51039:2014 [11] impose explicit requirements for ward ventilation and functional zoning, this imposes certain limitations on future spatial renovations, presenting considerable challenges.

4. STRATEGIES FOR ADDRESSING SPATIAL CHALLENGES IN COMMUNITY HEALTHCARE CENTERS' GENERAL WARDS

4.1. Spatial optimization and modular renovation

Modular renovation is a good solution to the space problems in general wards of CHCs. Using prefabricated building technology, isolation wards can be added quickly. The functional areas of existing wards can also be changed without changing the original building. This approach helps use the space better and allows for quick adjustments during an epidemic.

Community health service centers usually have smaller-scale wards, primarily providing basic medical care and rehabilitation services. They typically include single-bed rooms, double-bed rooms, and four-bed rooms. To fix the problem of bad space layouts in wards, movable isolation walls and barriers can be used. These can help divide the ward into different areas, including contaminated, semi-contaminated, and clean areas (Fig. 4). This helps prevent cross-contamination. This method is especially useful for quickly changing spaces to meet infection control needs during a health crisis.

It is also important to improve the ventilation system in existing wards. By using localized negative pressure technology (Fig. 5) and modern air purification equipment, air circulation can be improved. This helps prevent the spread of airborne viruses.

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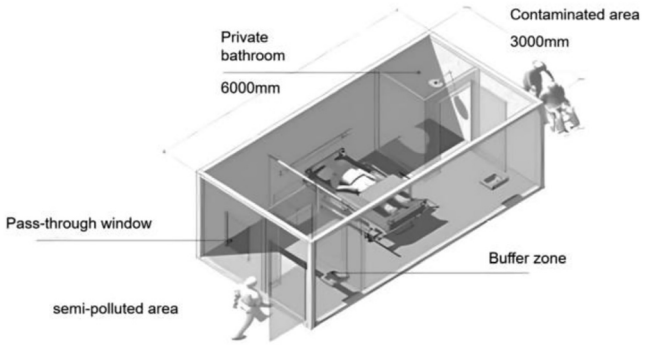

Fig. 4. Taking a single-bed room as an example, divide the area into contaminated, semi-contaminated, and clean zones (*Source*: Authors)

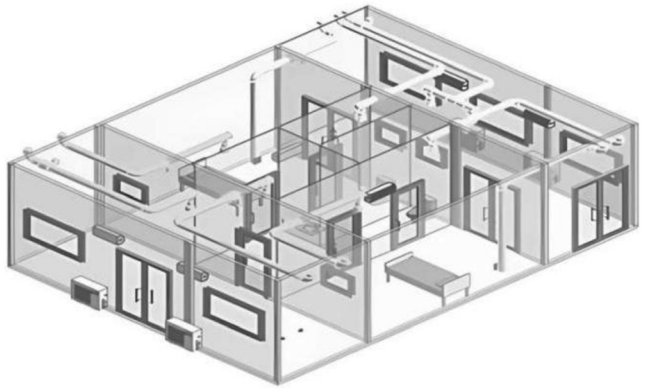

Fig. 5. Adopting localized negative pressure technology (*Source*: Authors)

Also, enough space should be kept for future expansion of wards or other medical areas during an epidemic. With prefabricated technology, the equipment and layout can be quickly adjusted as needed (Fig. 6). This. This offers a flexible solution for epidemic prevention. Prefabricated renovations are faster and cheaper than traditional methods, improving emergency response.

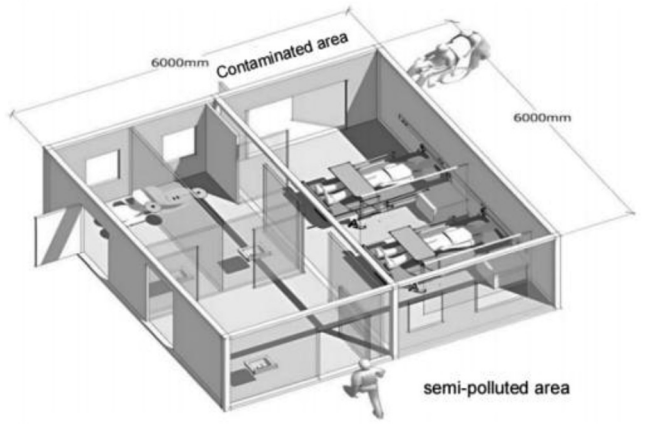

Fig. 6. Spatial optimization and modular renovation (*Source*: Authors)

4.2. Emergency resource allocation and sharing platform

Medical resource sharing refers to a mechanism for the joint utilization of medical resources between different regions and institutions. By sharing medical resources, they can be rationally allocated to meet the needs of various regions and groups, achieving equitable distribution of medical resources. Therefore, it is very important to create a good emergency resource allocation and sharing platform during public health emergencies. The platform utilizes existing buildings and relies on data, real-time monitoring, and spatial scheduling systems [12]. The main tasks of the platform include scheduling spaces and equipment, improving multi-functional spaces, managing supplies and staff, and coordinating resources across regions.

The platform can dispatch equipment and space as needed. In actual operation, spaces used for administration or meetings can quickly be transformed into wards or isolation areas. Existing wards can also be converted into negative pressure rooms or other emergency areas, when necessary, which helps to respond quickly to unexpected situations. The platform should also improve infrastructure including electricity, gas, and water supply to ensure the normal operation of equipment. The platform not only manages the allocation of facilities and equipment but also the storage and distribution of medications, medical supplies, and staff. It can also dispatch staff to ensure that medical personnel can enter and exit as needed. The platform helps to coordinate and share resources between medical centers, ensuring that they are well utilized during peak periods of medical resource usage.

4.3. Phased renovation and uninterrupted medical services

Ward renovation should be carried out step by step under the premise of ensuring normal medical procedures and fire safety, and when there is an opportunity for new construction projects, quickly adjust and utilize the space that has been vacated to advance ward renovation. This flexible strategy enables hospitals to effectively improve the medical environment without affecting patient care. The renovation can be carried out in phases to avoid closing all wards. This renovation strategy allows for the renovation to take place while keeping some wards open to accept regular patients. For example, non-emergency wards, including geriatrics or chronic disease wards can be temporarily closed. This makes space for the renovation of infectious disease isolation wards or the addition of emergency wards. In this way, space is cleared for epidemic prevention while maintaining the opening of regular services. It is very important to balance regular care and emergency services during the renovation period.

Another solution is to set up temporary medical facilities or mobile clinics during renovations. Mobile clinics and wards are flexible and can be moved and changed based on the needs of the epidemic. They provide basic diagnosis and

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treatment. These temporary facilities can help reduce some pressure, but they cannot fully replace regular wards and services. Medical service plans still need to be made to ensure patients get the care they need.

To reduce patient anxiety, especially for elderly patients and those with chronic conditions, telemedicine can be used. Through online consultations and health monitoring, patients can get medical care without going to the hospital. This lowers the risk of infection during the epidemic and ensures patients get health management and support during renovations. This method can help ease the pressure on the medical system during epidemic control and keep patients safe.

4.4. Compliant technical solutions for renovation of aging medical facilities

In practice, older community healthcare facilities often face conflicts between existing building conditions and regulatory requirements. For example, in a community health service center in Shandong Province, the insufficient floor-to-ceiling height of the existing building struggled to meet the general code for civil building design, GB 50352-2005 [13] requirements for medical space clearance. This challenge was addressed by adopting low-profile prefabricated ventilation ducts and integrated ceiling systems to minimize spatial occupation. Pre-assembled modular containers were utilized to achieve plug-and-play functionality. These solutions not only align with policy mandates but also demonstrate how prefabrication technologies can resolve spatial constraints while maintaining legal and functional compliance.

5. CONCLUSION

This study looked at using PBT to renovate wards in CHCs in China. It focused on the problems with space, layout, and facilities in current wards. Prefabricated technology can quickly improve ward use, respond flexibly to space needs during public health emergencies, and is especially important during epidemic prevention.

The study shows that PBT, through modular design, can effectively optimize space layouts, add isolation wards, or adjust the function zones of existing wards, thereby enhancing the emergency response capabilities of medical facilities. At the same time, reasonable resource allocation and phased renovation strategies can ensure that routine medical services remain uninterrupted during the renovation process, minimizing the impact on patients.

In summary, prefabricated building technology provides a feasible solution for the rapid renovation of CHCs, helping to enhance medical facilities' ability to respond to public health emergencies and further improve the emergency response speed and handling capacity of grassroots medical systems during crises including epidemics.

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