

## Towards Providing Temporary Infection Control through Hospital Interior Spatial Systems – Review

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To Link this Article: <http://dx.doi.org/10.6007/IJARBSS/v13-i11/19801> DOI:10.6007/IJARBSS/v13-i11/19801

*Published Date:* 29 November, 2023

### Abstract

By 2020, the number of hospitalizations is decreasing because patients are afraid of contracting COVID-19 if they were hospitalized. Hence, there is a need to rebuild the credibility of the hospital in the hearts of patients if the hospital could demonstrate some form of crowd control and badly managed indoor settings. This study is part of a larger case study research methodology in modifying interior structure in Chinese public hospitals. On contrary to previous researches, this study identifies potential interior spatial systems for hospitals and how hospitals can support the recovery of non COVID-19 resident patients under pandemic conditions. This is a desktop survey covering general interior structure, separation modifications due to COVID-19, and effects of hospital interior design on patients with the aim of reducing the risk of transmissions to the resident patients and medical staff. This paper documents earlier results of a systematic literature review synthesis evaluating the built environment factors of Chinese public hospitals which are expected to influence resident patients' recovery. The results are expected to lead towards developing a theoretical model for Chinese public hospitals with flexible interior design structures. This study contributes in supporting safe recovery for in-patients residents in Chinese public hospitals in the event of pandemic situations.

**Keywords:** COVID-19, Hospital Interior Design, Flexible Interior Spatial Systems, Temporary Infection Control, Build Environment Informatics.

### Introduction

By 2020, the number of hospitalizations is decreasing because patients are afraid of contracting COVID-19 if they were hospitalized. Hence, there is a need to rebuild the

credibility of the hospital in the hearts of patients if the hospital could demonstrate some form of crowd control and badly managed indoor settings. Many studies regarding infectious diseases are about their preventions and curbing spreading of these diseases. Megahed & Ghoneim (2021) propose a conceptual model that tackles the combination of engineering controls, design methods, and air disinfection approaches needed to improve indoor air quality (IAQ). Azuma et al. (2020) state that in a tight, congested, and poorly ventilated interior setting, close-contact aerosol transmission through tiny aerosolized particles is likely to be mixed with respiratory droplets and touch transmission. Actionable and practical counsel is supplied to all indoor employees wishing to minimize the transmission of infectious illnesses through environmentally mediated routes with reference to lessons from controlling SARS-COV-2 and the building environment (Dietz et al., 2020).

Meanwhile, the hospital needs to consider necessary steps to implement once a patient or health care worker has been infected. Fang et al. (2020) highlight three therapeutic methods taken by the Government of China which are creating designated hospitals; building new temporary hospitals; and converting large-scale public venues into Fangcang shelter hospitals. Those three approaches help in quarantining infected patients while separating the general hospitals to treat regular illnesses. Despite the separation approach, there is still risk that there could be already infected patients coming into the general hospitals. Therefore, this study is proposing some form of spatial flexibility for controlling the spread of infectious diseases in Chinese public hospitals. Contrary to previous researches, this study focuses on seeking potential solutions for developing interior spatial systems which could support recovery of non COVID-19 resident patients under pandemic conditions in public hospitals.

In addition, it would be desirable to integrate sustainable design in both in-patient and isolation area. For instant, Rashdan & Ashour (2017) improve indoor air quality by selecting a set of standards for sustainable interior design solutions. Sauni et al. (2013) found moisture damage is a very common problem in both private and public buildings. They are associated with adverse respiratory symptoms, asthma, and respiratory infections in residents very much a concern during COVID-19 pandemic.

This study is part of a larger case study research methodology for developing a guideline for creating flexible interior spatial design for Chinese public hospitals during infectious incidents. This paper documents results of a systematic literature review synthesis evaluating the built environment factors of Chinese public hospitals which are expected to influence resident patients' recovery.

### **Research Methodology**

This study follows the unique "Systematic Literature Review Synthesis Process" (Ibrahim & Kamal, 2018) in Masiran et al. (2020). This process is a stand-alone literature review typology (Rousseau et al., 2008; Xiao & Watson, 2019; Templier & Paré, 2015) known to make sense of a selected body of existing literature leading to decisions regarding the background theoretical context in an early research ideation phase. Topics were identified using Ibrahim's (2011 & 2020) research question's (RQ) construct categorization technique for identifying three different RQ Constructs — "WHO", "WHAT", and "HOW" — in formulating the main research question. "WHO" is defined as the element impacted by the study, "WHAT" is the information or body of knowledge required to solve the problem, and "HOW" is the targeted impact by the study.

This study selected "Develop Interior Spatial System" as the "HOW" construct. 64 literature articles were identified in Scopus and Google Scholar search using keywords related to

“Develop Interior Spatial System” such as, general interior structure in hospital, changes to the interior structure to avoid infection, and the influence of interior design on inpatient and medical staff. After title search and filtering full research papers from 1995 to date, a total of forty-five journal articles were identified. A detailed review was conducted on each article in relations to their respective major findings by prior scholars, how it could support future studies, and what aspects need to be enhanced so as to rebuild the credibility of the public hospitals. The abstracts were then assigned to sub-topics based on their existential importance as any new emerging topics may not have sufficient literature articles.

The outcome of this exercise produced a synthesized summary for each topic for further cross-analysis, integration of possibilities, and prioritization of the synthesized summaries toward obtaining high-probable solutions on developing flexible interior spatial systems for the resident patients in Chinese public hospitals against the spread of dangerous infections. The resulting key summaries are presented in the “Point of Departure (POD) Tree Diagram” shown in Fig. 2. This study used the online EAGLE System to document the literature review synthesis process.

### Developing Interior Spatial System

This section discusses whether the behavior of hospitalized patients can be guided by improving the indoor spatial structure.

### General Interior Structure in Hospital

This study proposes to rebuild the credibility of the hospital in the hearts of patients and their families if a public hospital can demonstrate some form of crowd control and good management of indoor settings. In view of the general interior structure, this study found sustainable design and reasonable functional zoning can improve the interior spatial system (Celadyn, 2018). Similar strategies on indoor epidemic prevention due to SARS (2003), MERS (2012) or COVID-19 (2019) had already been carried out in hospitals in the history of China (Hui et al., 2020; Peeri et al., 2020; Yang et al., 2020).

Compared with other commercial public spaces, this study sees existing internal structure of hospitals has potential to contribute due to its relative minimal structural design changes. Jung and Lee (1998) investigated two general hospitals which had typical layouts in Korea. They found the corridor type (see Fig. 1) is easy to plan but hard to manage the connections from one corridor into multiple wards. Another layout is a hall type (see Fig. 1) that radiates from one central medical station into several corridors which provide the medical staff with wider visual field. Such radiating layout tends to confuse visitors and patients alike, but the medical staff finds the management simpler. However, another study found different layouts affected the number of nursing manpower allocation due to the location of the integrated nursing service counter comparatively (Han & Kwon, 2021). Hence, this study recommends to include consideration for placement of nursing stations and other critical indoor facilities to achieve optimal spatial layout design.

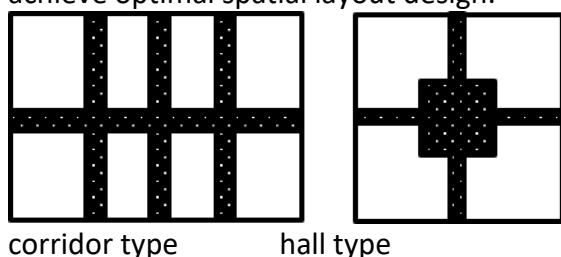


Fig. 1. Two Typical Hospital Layout.

Furthermore, materials used in hospital residence also have some influence of the resident patients. An interior preference study by Mogensen et al. (2015) found 21% of its participants preferred interior design improvements with preference for textile-based furniture and materials while majority participants were satisfied with the existing interior and traditional furniture style. In lieu of potential divisive preferences, this study proposes that more studies are needed whether patients in different regions of China have different preferences for interior space design. Another criteria that is of interest to this study is about sustainability. In this regards, Rashdan and Ashour (2017) highlights lack of studies on the sustainability in interior designing of hospitals. The researchers had proposed a mathematical selection criteria which can provide a scoring system based on each predetermined criterion. This study may refer to the sustainability criteria and proposes to extend those criteria to integrate sustainable design approach for epidemic containment.

Such proposed sustainable-pandemic interior design criteria are recommended to improve the interior spatial design for different prevention spaces during different epidemic. It could avoid the current practice to build makeshift hospitals (such as Fangcang shelter hospitals by China) amid the outbreak. Although the concept of Fangcang shelter hospital was not born in this epidemic, it is a pioneering initiative in China's epidemic prevention and control work. Credits are given to such innovation in lieu of its preventive and control values for epidemic prevention. Chen et al. (2020) report that there are three fundamental features (rapid construction, massive scale, and low cost) and five basic functions (isolation, triage, basic medical care, frequent monitoring and rapid referral, and essential living and social engagement) to prevent control infectious spread into the wards. Hospitals are required to set up three areas and two channels to control the nosocomial infection. Nosocomial infection refers to an infection that a patient obtains while in the hospital (Khan et al., 2015). The three zones are clean, contaminated, and semi-contaminated, and the two channels refer to medical personnel and patients. Consideration for these functions shall be retained in safe interior design criteria of Chinese public hospital.

China has a documented history of medical facility development. It is important to note how medical treatment was given throughout the years indicating how healthcare has transformed in the country. Historically, in the first global pandemic incident recorded in the 25th year of Jiaqing (Yu, 2016), Chinese traditional medical units would be "doctors"—rather than "hospitals"—who would visit quarantined patients in their homes for medical treatment and nursing (Leng & Liu, 2010). Later on, epidemic disease care were handled by medical clinic facilities (Yu, 2001). From the 25th year of Jiaqing (1820) onwards, some Chinese patients would have received modern western medicine treatment provided at the medical clinics. In time, the impression that "the home was considered a place of care for the sick in the early days while hospitals were associated with poverty and death" would soon diminish as more hospital facilities were improved and medical techniques and technology were advanced (Gormley, 2011).

Safety and security in the architecture of healthcare systems have become more critical at the healthcare facilities, more so due to the arising COVID-19 outbreak in China. Emmanuel et al. (2020) recommended to move away from enclosed halls, waiting areas, double-level corridors, and other spaces with little or no airflow. In addition, Kisacky's (2005) investigation isolation tactics at the New York Hospital between 1771 and 1930. The researcher compared the facilities available for isolation with changing reactions to internal illness incidence, changing medical norms and regulations, and altering ward types. In lieu of the ever changing medical norms and internal reactions to infections, this study strongly agrees with Saunders-

Hastings and Krewski (2016) to develop flexible strategies for isolation in Chinese public hospitals. Due to the dearth of studies on indoor epidemic prevention by the hospitals, this study is directed to review the current interior spatial structure in hospitals as an alternative method for reducing infections.

### **Interior Structural Changes to Prevent Infection**

The pandemic outbreaks have caused many unplanned changes to the interior structures of public hospitals. During SARS, hospital managements were more inclined towards having flexible size and area for ward spaces (Maben et al., 2016). The priority was maximizing the capability to change indoor space systems so hospitals could effectively control the spread of infectious diseases despite being located at different locations.

Changes in climate and indoor space systems at different locations could additionally directly or indirectly affect the transmission of viruses in the air. Vardoulakis et al. (2015) highlight the effects of climate change in UK homes pose public health challenges. The impact of weather on hospital patients is also common in China. It is critical to note that China is a vast country with large climatic differences between the east to the west, and the north to the south. For example, the humid climate in the south has been causing floodings, where airborne mold from moldy walls could be inhaled into a human body thus aggravating a patient's disease. Researchers recommend that the design for a hospital should emphasize the healing environmental characteristics (Alhmod et al., 2020). Among the characteristics include temperature, wind direction and humidity. This study supports that hospital designs must respond to the local climatic conditions.

An important non-pharmacological strategy in preventing hospital-acquired infections is maintenance of 'heating, ventilation, and air-conditioning (HVAC)' systems to follow good 'indoor air quality' (Saran et al., 2020). Such transformation could give traditional hospitals a new approach to safer air circulation. Azuma et al. (2020) highlighted that among the cluster cases, close-contact aerosol transmission through smaller aerosolized particles is likely to be combined with respiratory droplets and contact transmission in a confined, crowded, and poorly ventilated indoor environment. For example, Mr. A did not know he was an infected patient and had been having 3 dinners in Nanchang City. Since the restaurants were mostly semi-open or had confined Spaces, ten people became ill which in turned, caused transmission to their respective families and their workplace units thus making 16 additional people became ill (Deng et al., 2020). To reduce further infectious spread, good ventilation and hand washing are emphasized rather than infection prevention related to facility standards in such cluster cases. Hence, this study proposes an open prevention strategy by increasing advisory notifications to resident patients that would increase their knowledge awareness about epidemic prevention as part of affordable hospital management strategies, which could effectively control infection and cut off the source of infection.

This study believes the spread of the epidemic can be controlled to the greatest extent by optimizing the space of the ward and supporting the hospital management strategy to optimize the patient's route of action. It is not surprising if most patients would request preference for single rooms, which did not show that single rooms have any impact in reducing infection rates (Maben et al., 2016). However, if a single ward is not possible, the researchers indicated that patients could be isolated by building a multi-person ward with natural ventilation of 60 liters per second for each patient. In such case, beds are recommended at least one meter apart and hand hygiene facilities, such as hand-washing facilities, are provided (Han & Kwon, 2021).

According to Kenanidis et al. (2020), two special cubicles are recommended in the area located in front of the emergency department and outside the hospital for COVID-19 triage. No patient could enter the emergency department or outpatient clinics without first passing through COVID triage. This study believes this triage strategy must be extended in response to the socio-cultural behaviors for patient visitation and escorts of friends and families in the inpatient department. According to Han and Kwon (2021), there are three categories of general ward building plans. First, the spatial composition is for the nursing unit and ward zoning incorporation minimal design standards for each care unit and its beds. Second is the spatial plan for ward's space conversion in normal and crisis situations that allows multiple spatial functions during and after an outbreak. Finally, the bed-space plan would have an effective ward dimensions and area to make the individual private space around the bed reasonable.

Based on above analysis, this study found several management approaches can be made to the interior spatial design to prevent infectious spread. The study recommends to further analyze how the combination of a hospital environment—such as climate, spatial structure, and materials—factors can be made more effective in preventing infection and securing resident patients' safety.

### **The Influence of Interior Design on Resident Patient**

Some studies (such as Dinis et al. (2013)) have demonstrated that having interior design features may stimulate pleasant feelings among hospital patients, hence aiding their healing process. Among the features include such as artwork, nature, and home aspects. This study posits that interior design could affect the psychological and physical aspects of resident patients where a physical intervention is a direct approach to control a medical infection.

Dijkstra et al. (2008) state that the notion of healing settings implies that the physical environment of a healthcare center may promote healing and patients' emotions of well-being. The combination of physical stimulation of different degrees would have different therapeutic effects on patients. If visitors spend more time with patients to provide social support, indoor plants in the hospital room could alleviate stress by increasing the perceived beauty of the space (Dijkstra et al., 2008). In lieu of such situation, Lenfestey et al. (2013) had highlighted the need to assess the knowledge, perspectives, and experience of experts in various relevant fields to make a hospital interior design not only medically functioning, but also to provide socio-psychological support to patients, visitors and medical staff alike in one built environment. From this perspective, this study establishes the importance of the built environment in the acquisition and transmission of healthcare associated infections (HAIs) through facility design decision considerations and implementation of their intervention strategies.

A study by Samah et al. (2012) recommends assessment of the physical design of healthcare facilities from the perspective of the patients and their family members (or visitors) in order to understand their expectations, preferences, and experiences. Waroonkun (2018) concurs with the beliefs that environmental aspects are critical to a pleasant user experience. Additionally, Rashdan and Ashour (2017) recommend interior designers to evaluate their design solutions, interior finishes, and furniture selection based on high performance sustainable interior design solutions. In the case of medical workers, Cetin (2018) finds healthcare interior design quality a significant criteria for working areas especially for nurses. Another study by Morgan et al. (2021) finds the internal structure of primary care practices has important impacts on staff collaboration and care is recommended to maximize brief

face-to-face interactions in well-designed shared spaces within primary care practices. Well-designed shared spaces also help the patient recover faster. This study posits that physical intervention is a good way to improve interior design, control infection and provide patients with safer experience. These interventions would lead to improved psychological intervention in interior design.

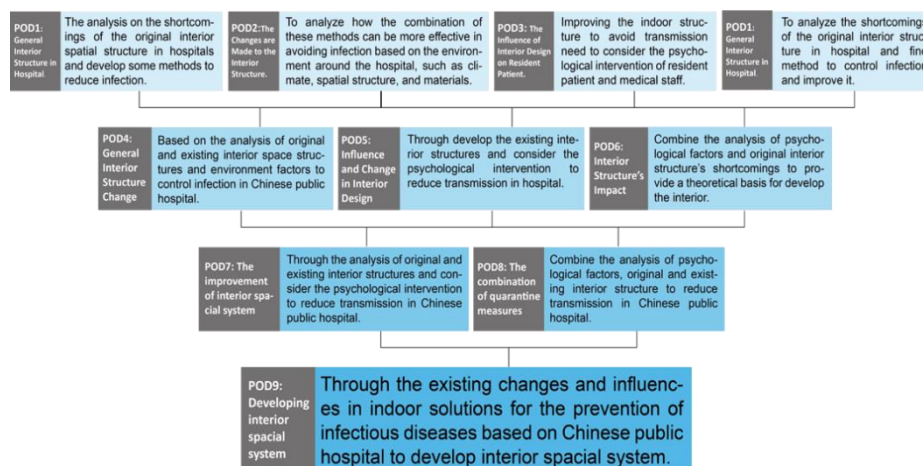
The necessity for isolation is the first thing that comes to mind when people discuss about having COVID-19. Isolation is necessary, but isolation is the source of some psychological problems to patients. This study proposes further study if any psychological interventions could be performed through interior spatial intervention which would help resident patient healed along with their medical treatment. The recommends agrees with Tran et al. (2017) who found isolation precautions could have negative effects on patient's safety, psychological well-being, and healthcare worker contact. Another study by Karanikola et al. (2020) compared comfort and health of occupants across departments and tenant categories due to hospital indoor and outdoor spaces in relation with selected environmental parameters (such as odor, noise, light, color). Furthermore, medical workers were typically dissatisfied compared to patients (Eijkelenboom et al., 2019). To increase patient safety, Khammar et al. (2019) recommends to improve nurses' dissatisfaction about their indoor working conditions with longer resting periods or higher monetary compensation by the hospital administrators. In view of how the interior design could help resident patient recover quickly and safely, this study finds it is necessary to provide not only physical, but include psychological intervention. Therefore, this study posits improving the indoor structure to avoid transmission must include consideration for the psychological intervention for both patients and medical staff.

In summarizing the literature review, this study concludes that there is need to mitigate the shortcomings of the original interior structure in hospital spatial layouts and recommends potential methods to control infection spread through improvements to the general interior structure at that hospital. It proposes to combine the interior spatial interventions with considerations of climate, spatial structure, and materials. Furthermore, there is a need to consider the psychological intervention of patients and medical staff together with the improvement to the indoor structure for controlling infectious transmission.

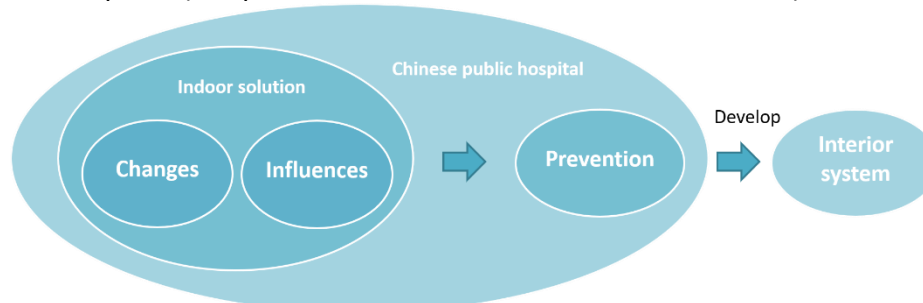
## **Discussion**

This section presents the cross-analyses resulting in the Point of Departures for Figure 2 based on the conclusion of each sub-topic for this study on developing interior spatial system. In analyzing the shortcomings of the original interior structure in hospital and finding methods to control and prevent infection, there are potential combinations for effective design in avoiding infection when hospital management would consider the environmental situations of around the hospital, such as climate, spatial structure, and materials. Such approach may provide a controlling mechanism which could treat patients more leisurely.

In analyzing the impact of environmental conditions of a hospital, there is a possibility to design with environmental strategies that could naturally alleviate the psychological state of resident patients and medical staff. Further studies are recommended to extend the existing interior hospital structures for reducing transmission in hospitals, but with an added consideration for these structures to act as psychological intervention for patients and medical staff alike. Hence, alleviating the psychological factors and mitigating the shortcomings of the original interior structures could provide the foundation for a potential solution in developing a flexible interior spatial system for public hospitals in China. The results of the discussion are presented in Fig. 2 and Fig. 3 below.



**Fig. 2.** Point of Departure (POD) Tree Diagram for Study on Developing Interior Spatial System for Hospitals (Adapted from Ibrahim & Mustafa Kamal, 2018)



**Fig. 3.** Proposed Conceptual Framework for Developing Interior Spatial System for hospitals (Adapted from Ibrahim & Mustafa Kamal, 2018).

**Conclusions**

This study presents the results of a desktop survey covering general interior structure, modifications due to COVID-19, and influence of hospital interior design on patients with the aim of identifying potential interior spatial systems for hospitals and how hospitals can support the recovery of non COVID-19 resident patients under pandemic conditions. This study would like to recommend hospital management to provide a flexible interior spatial system that considers both the hospital environment—such as climate, spatial structure, and materials—and adding psychological intervention value which can make these flexible interior spatial systems effective in preventing infection and securing resident patients safety. Results of this study will benefit hospital managements in providing public hospitals that are better managed as a safe area where the public and their families will no longer be afraid if they were hospitalized. The study contributes towards developing a conceptual theoretical model for Chinese public hospital with flexible interior design structures that support safe recovery for in-patients residents in Chinese public hospitals in the event of pandemic situations. The proposed is expected to improve the interior design for inpatient and medical staff in hospitals during a pandemic. Future study recommends to develop a flexible interior spatial system prototype for public hospitals in China.

The conceptual framework obtained through literature review illustrates the theoretical proposition that combining the influence of different hospital interior design and infection prevention methods on inpatients during the pandemic can provide a better interior system for future hospital construction and make inpatients live safely and cozily. In the early stage



of the epidemic, the medical system is on the verge of collapse, and the hospital did not have corresponding indoor measures to cope with this sudden situation. Through the feedback of inpatients and the means of epidemic prevention and control, the appropriate space proportion and flexible space layout are found. At this time, the flexibility and security of the indoor space will provide a basis for peace of mind for resident patients when receiving treatment. It also provides a theoretical basis for the future hospital interior design.

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