

Evaluating the Adoption of International Emergency Architecture Standards in Jordanian Field Hospitals During Pandemic Conditions

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Abstract:

Pandemic outbreaks reveal the vulnerabilities of emergency healthcare infrastructure in case the field hospitals do not have clear-cut, evidence-based principles of building construction, which enhance the risk of infections, congestion, and staff burnout. This study appraises the implementation of international emergency architecture requirements in the Jordanian field hospitals under COVID-19 conditions. Based on the WHO Safe Hospitals indicators, field hospital advice, a qualitative comparative case study compares field hospital Al-Zarqa with the modular Leishenshan model in China in terms of document analysis, a structured WHO checklist and thematic content analysis. It has been found to have an acceptable compliance with location, access, modular construction, and basic functional zoning, but lacks seismic-resilient design, standardised yet continuous negative-pressure check-up, lighting coverage, alternative water supply, and pre-treatment of wastewater. The study suggests the revision of the national codes, introduction of the checklist-based audit, and enhancement of the resilience of the ventilation and utility systems. Implications favour a consistent, pandemic-prepared field hospital design in Jordan and other similar situations

Keywords: Emergency architecture; Field hospitals; WHO safe hospital indicators; Modularity; Pandemic preparedness

1. Introduction

The nature of a crisis imposes excessive demands on the work of healthcare systems, revealing the weak line between the standard delivery of services and emergency management. In the situation when pandemics, natural disasters, or unexpected mass casualties occur, hospitals can be overloaded in terms of space, technical, and organisational aspects, and health authorities need to find some quick, flexible and resilient solutions. Such situations make the planning of healthcare space not a technical issue anymore, but a question of life and death, security, and confidence of the population. Lack of clear and evidence-based architectural principles in emergency health care facilities may result in overcrowding, inefficient patient traffic, higher chances of transmitting the disease, and medical personnel burnout. This study believes that the efficiency of emergency response is not defined only by the medical capacity, but by the manner in which healthcare settings are designed, built, and operated during crisis scenarios, especially where preparedness and standardised evaluation frameworks are not well established.

Hospitals are key in the provision of necessary healthcare services in case of emergencies, but even a slight increase in the number of patients would overstretch the facilities available. According to the World Health Organization (WHO), in case of disasters and epidemics, healthcare facilities should be able to maintain functional continuity, offer safety to both the staff and patients, and respond quickly to the growing demands (WHO, 2010). Field hospitals are a solution of necessity when permanent hospitals are unable to accommodate the number of patients they have to handle. This type of facility is usually a temporary, fast-deployable unit meant to offer medical care on-site until patients can be transported to more permanent facilities (Durent, 2011; Khan et al., 2019). Their presence has come into the limelight, especially when global health emergencies hit with the velocity of deployment and the quality of spatial organisation playing a direct role in patient outcomes and control of infections.

Emergency architecture has been theorised as a quick architectural reaction to humanitarian and general health crises, which includes temporary housing, treatment centers, and modular healthcare centers, which can be rolled in and redesigned according to the evolving circumstances (ArchDaily, 2020). According to Onay (2018), this kind of architecture is described as modular, flexible, and geared towards addressing simple human and clinical needs in a limited set of circumstances. Regarding design, the efficiency of field hospitals is determined by a few related issues, such as modular construction systems, site planning, functional zoning, material choice, and well-defined circulation axes dividing patients, staff, and supplies (Smolova and Smolova, 2021). These aspects are not just architectural fancies, and they have a direct bearing on clinical performance, infection prevention and operational efficiency.

The COVID-19 pandemic provided a demonstration on the international level of how emergency architecture may be mobilised at a scale never seen before. The example of the Leishenshan and Huoshenshan hospitals in Wuhan, China, designed and constructed in days using modular composite forms of building, is one of the most referenced (Chen et al., 2021). These centers incorporated generalised units of isolation, negative pressure ventilation systems and controlled routes of circulatory to lessen the transmission of air and better patient safety. Studies have continuously indicated that the ventilation design is determining when it comes to curbing the transmission of infectious agents in a healthcare setting, especially in respiratory pandemics (Li et al., 2007; Qian and Zheng, 2018). Downward ventilation strategies and negative-pressure rooms have been linked with a lesser risk of cross-infections,

which again underlines the significance of technical building systems as an element of emergency architecture (Al Benna, 2021; Nielsen et al., 2010).

Although such advances have been made, prior research findings reveal that there are still numerous hospitals across the world that are not adequately in tandem with the international standards of disaster preparedness and emergency architecture. According to Murphy (2020) and WHO (2010), spatial planning, functional resilience, and integration of non-structural systems (ventilation, communication networks, and logistics pathways) are often lacking in spatial planning. The number of tools and checklists designed to assess hospital disaster preparedness points to the same areas of weakness in surge capacity, isolation sites, and the flexibility of current infrastructure to meet the changing clinical needs in a very short period of time (Nekoie-Moghadam et al., 2016). Such gaps have the potential of not only undermining patient care but also the safety and well-being of healthcare workers, who are at risk of being more exposed and stressed because of prolonged crises (Shah et al., 2020).

Emergency architecture has become an increasingly popular concept in the Middle Eastern context, both as a reaction to natural disasters and to the health issues of the population. According to Alshawawreh (2019), the region has its own peculiarities in terms of climate, urbanisation, and political unrest; all these factors influence the creation and implementation of temporary healthcare facilities. Modular construction has been introduced as a solution to these issues because of its low cost, rapid building, and flexibility (Gatheeshgar et al., 2021; Lawson et al., 2012). Nevertheless, their efficacy is determined by their correspondence with the international principles of functional and safety indicators, especially those suggested by WHO and the Pan American Health Organization (WHO-PAHO, 2003; WHO, 2010).

The healthcare system in Jordan has been described as one of the most advanced in the region, which is a mixture of both non-profit, private, and publicly-provided healthcare providers. It is provided by the public sector, which occupies about 67 per cent of hospital beds in the country associated with the Ministry of Health (MOH), Royal Medical Services, and large university hospitals, and its national rate is estimated at 18 beds per 10,000 residents (Nazer and Tuffaha, 2017). Although this number is relatively high compared to some of the neighbouring countries, it is lower than the average value of other countries across the world; this is problematic in terms of surge capacity during massive emergencies. The coronavirus situation unveiled systemic and operational strains in the system, especially the isolation

capacity, patient flow management, and the quick deployment of temporary treatment facilities.

In spite of the considerable achievements of Jordan in delivering healthcare, there is a scarcity of empirical research that provides a systematic assessment of the architectural readiness of the field hospitals in Jordan as compared to the global emergency design requirements. The literature available is inclined to address clinical performance or health workforce problems or discuss the general crisis management instead of considering the spatial and technical aspects of emergency healthcare infrastructure (Momani, 2021; Pathirathna et al., 2020). This is a big disparity because the built environment is very crucial in determining infection control and the effectiveness of communication, as well as the psychological comfort of patients and staff (Curtis et al., 2007; Dalke et al., 2006).

As a consequence, the aim of the study is the evaluation and enhancement of emergency architecture in the Jordanian field hospitals through benchmarking of the existing practice against the international design principles, especially the ones formulated by the World Health Organization. It aims to find out structural, functional, and non-structural vulnerabilities of the current emergency healthcare infrastructure, including the pandemic response and management of infectious diseases in particular. Through this gap, the study can add a context-specific assessment framework that combines international guidelines with local healthcare realities and provides applicable design and policy suggestions to improve preparedness, resilience, and confidence of the people in the emergency healthcare infrastructure in Jordan (Chen et al., 2021; WHO, 2010).

1.1 Statement of the Problem

This research offers a comprehensive and evidence-based evaluation of epidemic and pandemic design criteria of emergency architecture within Jordanian field hospitals to locate the local practices in the context of internationally accepted and best-practice standards. The research will assist policymakers, architects, and healthcare planners to make informed decisions by identifying structural, spatial, and operational gaps in the present emergency designs. The results play the role of improving national preparedness, patient and staff safety, and strengthening the functional resiliency of temporary and permanent field hospital capacity. Finally, the research will further encourage sustainable, flexible, and responsive

healthcare systems that can adequately respond to future emergencies of the population's health.

The study aims to answer the following questions:

1. What are the international design standards for emergency architecture in field hospitals?
2. Have international design standards for emergency architecture been implemented in Jordanian field hospitals?
3. What are the weaknesses in the design of field hospitals for the pandemic?

2. Literature Review

2.1 International Design Standards for Emergency Architecture in Field Hospitals

Emergency architecture is always described by international literature as a system of modular, fast-deployable, self-sufficient structures intended to react to health crises, disasters, and pandemics. The conceptualisation of field hospitals by the World Health Organization (WHO) and the Pan American Health Organization (PAHO) is portable and scalable healthcare facilities that can rapidly deploy themselves to disaster-affected regions and act autonomously (WHO-PAHO, 2003). In this definition, speed, functionality, and resilience have been defined as a global standard in the architecture of speed, functionality, and endurance.

The principles of modularity, adaptability, and sustainability become the primary ones in the design system on the international level. Onay (2018) contends that emergency architecture has to incorporate modular and flexible interior systems, which can be reused and reconfigured as and when the user requirements change. The strategy facilitates continuity of care in dynamic crisis operations, especially when the profiles of patients, medical operations, and the staff's needs vary swiftly. Likewise, Smolova and Smolova (2021) indicate that modular construction is one of the key strategies that can be used in the design of the pandemic response and show how it allows healthcare facilities to increase the isolation capacity in highly populated urban environments with a minimal amount of time and material wasted.

Another standardistic feature of emergency architecture is rapid construction. Chen et al. (2021) prove that standardised production, prefabrication, and modular design have been implemented to construct Leishenshan Hospital in Wuhan at an accelerated pace. They underline that macro-level site planning, meso-level functional zoning and micro-level room

design should be united in one architectural design and achieve the necessary speed and clinical efficiency. This stratified planning model has been massively referenced as a universal guide to building emergency hospitals.

International standards also entail environmental quality and infection control. Research on the ventilation systems in hospitals emphasises the role of negative pressure rooms and airflow control, as well as indoor air quality in combating airborne transmission of infectious diseases (Fraser et al., 1993; Li et al., 2007; Al Benna, 2021). Such standards connect architectural design to patient and staff safety directly, and this aspect of building systems supports the active involvement of building systems in the intervention of the health of the population, as opposed to a passive physical shell.

The WHO (2010) also applies extended emergency architecture standards to the physical construction with the non-structural and functional indicators. Indicators based on structural aspects are concerned with building resilience and vulnerability to hazards, non-structural indicators are concerned with the systems of power, water, and medical equipment, and functional indicators are concerned with hospital leadership, personnel preparedness, and processes. A combination of these indicators comprises a comprehensive international model of hospital preparation and performance in case of emergencies.

2.2 Implementation of International Standards in Field Hospitals

Local governance structures, availability of resources, and institutional coordination usually influence the usage of the international emergency architecture standards. Daclin et al. (2017) also suggest a maturity model that can be used to assess the field hospitals and state that their effectiveness requires a close connection between architectural design, operating capacity, and crisis management systems. According to their structure, the field hospitals should not only be evaluated based on their physical presence but also on their capability to change, grow, and connect with the system of the national emergency response.

The Chinese reaction to COVID-19 has already transformed into a standard of reference in the world in terms of the practical application of emergency design standards. Chen et al. (2021) indicate that the fast erection of Leishenshan Hospital has benefited through the collaboration of the architects, engineers and the government authorities with the aid of the standardised building elements and prefabrication technologies. The case demonstrates that

the principles of international design can be operationalised by means of centralised planning, leadership of institutions, and integration of technologies.

Within the Middle Eastern framework, Alshawawreh (2019) notes that the problem of emergency architecture can easily overlap with the social and political reality, even in areas where displacement and war are common. The study claims that the architectural solutions should be balanced between international standards, cultural practices, and space limitations. This approach implies that the implementation process cannot be considered entirely technical but also socio-cultural, where it is necessary to adapt it instead of copying the international models.

The scale of the city's consideration also affects the implementation of the emergency architecture standards. Alraouf (2021) argues that the COVID-19 pandemic created the necessity to incorporate health-responsive design into wider urban planning systems. Transitional areas, open spaces and flexible public infrastructure are seen as paramount extensions of emergency-based architecture within a hospital. The opinion is consistent with Maturana et al. (2021), who believe that post-pandemic design needs to establish the linkage of physical and digital spaces to maintain continuity in healthcare provision and crisis communication.

Emergency management in Jordan has been institutionalised in the form of the National Centre of Security and Crisis Management, which was central to organising the pandemic response strategies (Momani, 2021). Although this type of governance offers a basis in the application of international standards, the literature indicates that implementation is successful based on the level of integration of the architectural, logistical and administrative systems. WHO (2010) highlights that hospitals have to be accessible, operational and safe during crises, and as such, coordinated planning, in health, infrastructure, and public service domains, is required.

2.3 Design Weaknesses and Gaps in Pandemic-Oriented Field Hospitals

Although international standards are available, a number of studies detect lingering flaws in the design and operation of field hospitals. Among the key gaps is related to the infrastructure

in connection with infection control, especially ventilation and isolation systems. Conclusively, Fraser et al. (1993) discovered that most of the hospitals did not have properly tested negative pressure rooms and properly tested airflow pathways in the high-risk sections of the hospital, like emergency units and intensive care wards. Such weaknesses cripple the efficacy of respiratory isolation strategies, particularly during the emergence of an outbreak of an airborne illness.

The choice of materials and the way of construction is also a challenge. According to Gatheeshgar et al. (2021), despite its quick deployment and structural stability, steel-framed modular systems can be effective only in cases of effective integration of ventilation panels and internal air quality controllers. In the absence of these characteristics, modular units are likely to become vectors of disease instead of holding the infection. This points to a recurrence of a conflict between speed of construction and long-term performance.

Another dimension that has not been researched is the spatial design and psychological well-being. Curtis et al. (2007) indicate that therapeutic landscapes, such as access to green spaces and visually supportive environments, are very important in the recovery of patients and staff morale. These considerations are, however, usually relegated to the emergency hospital design, with functional efficiency usually taking a preeminent place in the planning sphere. The same is pointed out by Dalke et al. (2006), who note that lighting and colour schemes affect the well-being and recovery rates of patients and propose that aesthetic and sensory factors must be considered in emergency architecture requirements.

Design weaknesses are also aggravated by overcrowding and urban density. As stated by Qadir and Kamal (2022), in the COVID-19 pandemic, parks and community facilities were reconfigured into temporary healthcare facilities because of the lack of sufficient hospital facilities. This responsive measure indicates an absence of reactive architectural design for massive health emergencies, especially in fast-growing cities.

Lastly, the effectiveness of the field hospitals is still hampered by organisational and managerial gaps. According to Nekoie-Moghadam et al. (2016), the disaster preparedness in hospitals is suboptimal, with logistics, communication systems, staff training, and surge capacity planning being the weak areas of hospital disaster preparedness. These dysfunctional

gaps indicate that architectural standards are not enough, unless they are augmented with a well-structured emergency management infrastructure and sustained institutional evaluation.

3. Methodology

3.1 Research Design

The present study is a qualitative, comparative case study design, which investigates emergency architecture practices in two field hospitals built during the COVID-19 pandemic: the Jordanian field hospital and the Chinese modular hospital model. The qualitative design is suitable as it will enable in-depth discussion of contextual, structural and functional aspects of hospital settings in their operation during emergencies (Jennings, 2005). The comparative design allows defining convergences and variations in architectural readiness, space arrangement, and functional performance according to the international standards, especially the WHO Emergency Architecture Assessment Checklist (WHO, 2010).

3.2 Research Philosophy

An interpretivist research philosophy informs the study, as it presupposes that the built environments and emergency response are socially constructed and influenced by the cultural, institutional, and contextual factors. In this view, the architectural preparedness is neither a technical product nor merely a response to organisational values, regulatory frameworks, and priorities of the society. Such a position is in line with qualitative traditions that accentuate meaning and practice in real-world situations other than testing pre-established hypotheses (Jennings, 2005).

3.3 Sample of the Study

The sample is two purposely chosen cases of field hospitals. The former is a Jordanian field hospital that was launched to address the COVID-19 admissions, which are a regional reaction to the local socio-economic, cultural, and climatic factors. The second is a Chinese modular field hospital, which bases its work on the experience of implementing the rapid construction and use of the emergency facilities of the type Leishenshan and Huoshenshan hospitals in Wuhan that are documented (Chen et al., 2021). The selection of these cases stems from the fact that they represent various degrees of technological capacity, speed of

construction, and modular development of design strategies under a common global health crisis.

3.4 Instruments of the Study

The WHO Emergency Architecture Assessment Checklist was the primary instrument used in the collection of data. This checklist consists of structural, non-structural, and functional indicators for assessing the hospital safety and preparedness in the event of an emergency (WHO, 2010). The tool was complemented with document analysis of published case studies, architectural reports, and peer-reviewed literature on the topic of modular construction, ventilation, and infection control in emergency healthcare facilities (Li et al., 2007; Smolova and Smolova, 2021).

3.5 Validity of the Instrument

The assessment criteria were based on internationally known WHO guidelines and were supported by empirical research on hospital preparedness and modular emergency facilities to ensure content validity (Nekoie-Moghadam et al., 2016; Chen et al., 2021). The combination of checklist indicators with academic references and case reporting enhanced the role of the tool in assessing emergency architecture in various settings and its sufficiency.

3.6 Reliability of the Instrument

The reliability was improved by using the same checklist criteria in the two case studies. The same architectural factors were evaluated multiple times, and the processes used to evaluate standards minimised the bias of interpretation and enhanced the similarity of observations across the comparative analysis (WHO, 2010).

3.7 Data Collection

The systematic review of the architectural designs, operational reports, and published research of the two field hospitals was used in data collection. The peer-reviewed articles concerning the emergency modular construction, the ventilation systems, and the operations of the pandemic hospitals were used as secondary data sources (Li et al., 2007; Gatheeshgar et al., 2021). The contents of these materials were evaluated to retrieve evidence about each checklist criterion.

3.8 Data Analysis

Thematic content analysis was used to interpret the data, in which the architectural and operational characteristics were coded based on the WHO checklist domains. To determine the rates of compliance, innovation, and contextual adaptation in emergency architecture, the patterns and differences in the Jordanian and Chinese cases were detected (Smolova and Smolova, 2021).

3.9 Ethical Considerations

In this research, ethical issues were considered based on the use of the publicly available documents, institutional reports and literature only, and no personal and sensitive patient information was accessed or analysed. The study also recognises the internalised understandings of the emergency architecture to the overall wellbeing of the population through their health, sustainability, and employee safety, especially in areas that are susceptible to risks like pandemic response centres (Maturana et al., 2021; Shah et al., 2020). In addition, there are restrictions on the use of secondary information and a lack of direct access to the secondary data through observation, which are identified as limiting the richness of the spatial and experiential information. In spite of such limitations, the combination of global standards and confirmed academic resources can make the comparative evaluation and policy-based suggestions very strong.

4. Result

4.1 Functional Diagram

It should be clarified that the conceptual logic behind the proposed framework is as follows, before presenting the functional relationships as shown in Figure 1. This study adopts an integrative, systems-based approach according to which pandemic-resistant hospital design is not an architectural or technical intervention, but a product of coordinated relationships between experiential knowledge, situational factors, and design principles. As a result, the framework unites the experience gained in the course of the past and the current test-based evaluations and aligns them with the fast-enhanced construction operations, emergency architecture, and region-related norms. It will help to create a holistic design scenario that will consider the international best practices and local environmental, socio-cultural, and

economic realities, thus empowering the creation of a robust and flexible model of a field hospital that may respond to the epidemic and pandemic conditions.

The following *Figure 1* represents the functional diagram for this research.

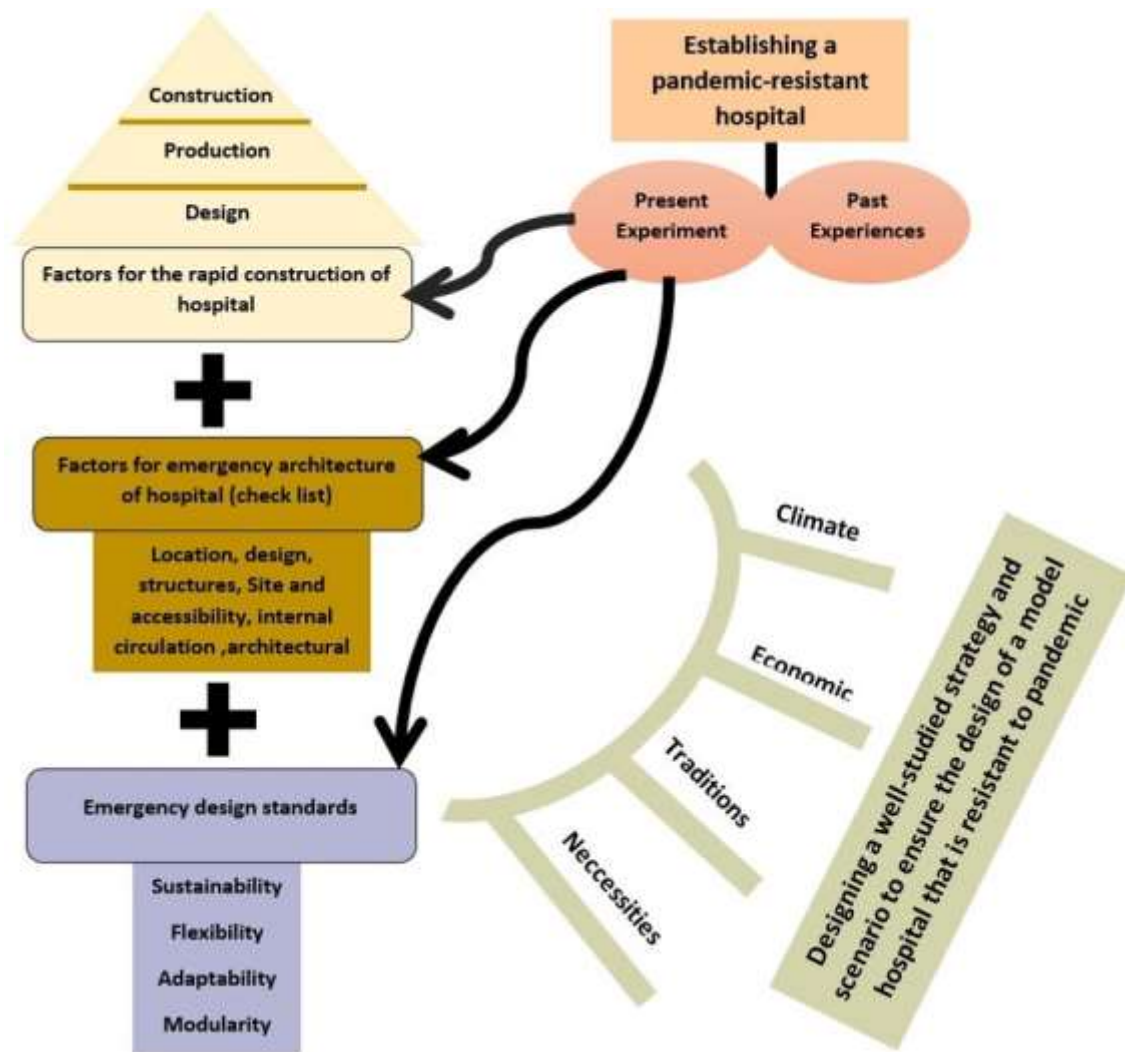


Figure 1: The Functional Diagram for the Study

The previous figure explains that to establish a resistant field hospital that may control any epidemic under any circumstances, the experiences gained from the global cities and the surrounding region must be considered, as well as current situations and realistic studies of the region, with the integration of the following:

- Hospital rapid construction factors: construction, production, and design
- Hospital emergency architecture factors: location, design, structures, site and accessibility, internal circulation, and architectural
- Emergency design standards: sustainability, flexibility, adaptability, and modularity
- The standards of the area where the hospital is to be established: climate, traditions, economy, and necessities

A well-thought-out scenario is produced to ensure the design of a model hospital that is resistant to the pandemic.

4.2 Summary of the Strategy and the Studied Scenario

To ensure that the design of a Model Hospital is resistant to the pandemic, the researcher studied the architectural description of the field hospital in Jordan, and a field visit to the site was conducted. This was done considering Jordan's traditions, climate, and economic situation.

The researcher considered that the epidemic has the highest priority, and the study concluded that the design criteria in case of emergency were taken into account in the Jordanian field hospitals in an acceptable manner.

To clarify the essential criteria, *Table 1* represents the recommended checklist for the field hospital of the strategy and the studied scenario to ensure the design of a model hospital resistant to the pandemic .

Table 1: Recommended Checklist for the Field Hospital

Scope	Description
Location	<ol style="list-style-type: none"> 1. The hospital is not located in a dangerous area away from torrents, valleys, and floods. 2. The hospital should contain appropriate provisions for the treatment of rainwater drainage and dams.
Design	<ol style="list-style-type: none"> 1. The hospital should have a simple, flexible design when exposed to earthquakes.
Structures	<ol style="list-style-type: none"> 1. Lack of cracks and cracks on the hospital's structures. 2. Maintenance of small or poetic cracks due to paint or short.

	<ol style="list-style-type: none"> 3. The structures are made of fire and non-toxic materials. 4. Ramps are in appropriate areas for moving bed patients and for use by people with disabilities.
Site and Accessibility	<ol style="list-style-type: none"> 1. The hospital site should be served in good ways and with means of transportation. 2. No obstructions on the roads leading to the hospital. 3. Stairways with safe and adequately secured railings must be at least 112-120 cm wide. Each step must be less than 17 cm high and made of concrete.
Internal Circulation	<ol style="list-style-type: none"> 1. The nursing station inside the hospital is a customer and can be reached by patients to supervise the wings. 2. Healthy toilets that take into account gender differences.
Architectural Elements	<ol style="list-style-type: none"> 1. Architectural promotion and brackets (inference on the main entrance) are free of cracks, and maintenance is done if it is found. 2. The main doors are dual swinging, and the bathroom door swings. The doors of the emergency room swing inside and outside. (Fan-type door). 3. Main doors are double swing; bathroom doors swing out; emergency room doors swing in and out. 4. The hospital contains the operating room (OR), the intensive care unit (ICU), the resuscitation room (RR), the delivery room (DR), the birth room (BR), and the isolation rooms (IR). 5. The air-conditioned electricity generators on a base made of reinforced concrete are raised above the Earth's surface. 6. Sufficient lighting in all hospital areas, including the external squares, on the hospital campus.

5. Discussion

5.1 Evaluation of Hospitals' Standards for COVID-19 in China Field Hospital (international case study)

In their research, both Chen et al. (2021) and Smolova & Smolova (2021) studied Leishenshan Hospital in China. Both articles, combined with Onay's (2018) research, were used to generate a general description of the Leishenshan hospital, the factors to ensure the rapid construction of that hospital, and the emergency design standards, as shown in *Table 2*.

Table 2: General Description of the Hospital in China

NO	Clause	The description	Notes
1.	Building area	79,000 m ²	
2.	Designed by	Zhongnan Architectural Design Institute	
3.	Costs	47 million dollars	
4.	Capacity	1,500 beds	
5.	Duration of work	14 days	
6.	Modular Planning Framework as shown in <i>Figure 3</i>	<ul style="list-style-type: none">• Isolation medical area• Living area for medical staff• Support area	<ul style="list-style-type: none">• Fishbone layout, as shown in <i>Figure 4-a</i>• The medical staff passage serves as its central axis• To be within the negative pressure for the spread of viruses• The units are 12 m apart• The presence of connecting corridors between units• The presence of one corridor that connects the units with functional units such as the intensive care unit and the laboratory unit

- Each module contains a clear boundary and free capacities and is associated with the others through the central pivot. This encourages synchronous plans and contaminated areas, semi-contaminated areas, and hygienic areas, as shown in *Figures 4-b, 4-c, and 4-d.*

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- | | |
|----------------------|---|
| 7. Functional Layout | <ul style="list-style-type: none"> • Essential ward module. • Medical staff working zone • Assistant restorative zone. (contaminated area, semi-contaminated area, and hygienic area) • When the base units at the foot are appropriately completed, the healing centre can keep up with comprehensive quality within the quick development handle and meet the high-level restorative handle requirements of infectious disease healing centres. |
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8. Materials All modules are prefabricated in the factory, as shown in *Figure 5*. Transported to the roads around the site for assembly, and hoisted in place on-site, the Steel-Frame Structure System, as shown in *Figure 7*.

9. Emergency design standards	Sustainability	Steel composite panels. The box roof is equipped with a waterproof and thermal insulation system, and drainage systems are hidden in the four corners. All modules are pre-assembled within the manufacturing plant, transported to the streets around the location, assembled exterior of the zone, and raised.
	Modularity	The steel frame is modular and cubic.
	Adaptability	The modular frame allowed it to be adaptable for different uses and locations.
	Flexibility	In a pandemic, the goal was to keep the level of health care within the correct and positive level.

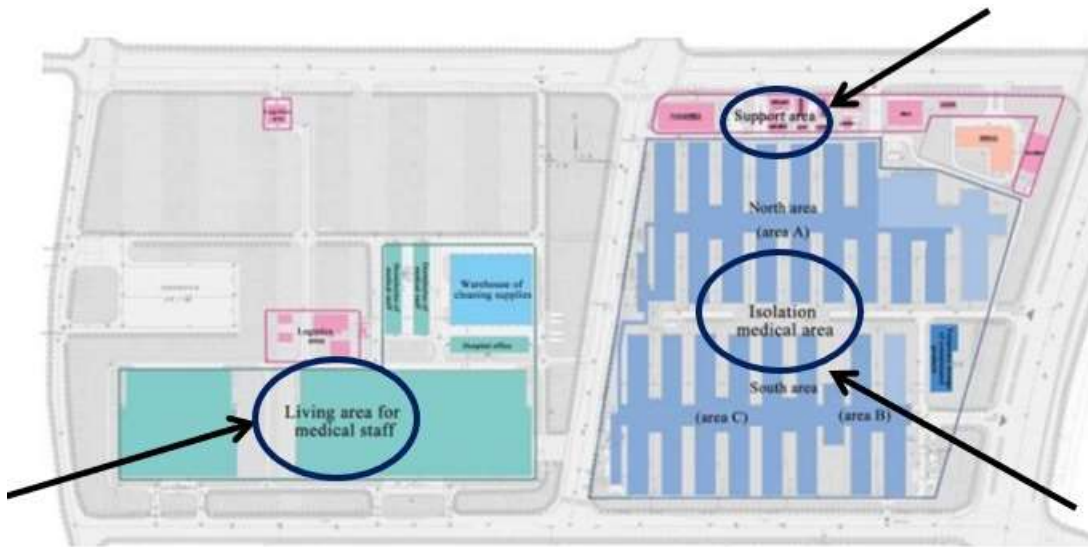


Figure 2: (Modular Planning Framework) Functional Areas of the Project (Chen et al., 2021)

Leishenshan Hospital is separated into three primary modules: a restorative confinement range, a living zone for restorative staff, and a back range, of which the restorative segregation zone gives the most work (Chen et al., 2021) (Smolova & Smolova, 2021).



(a)

(b)

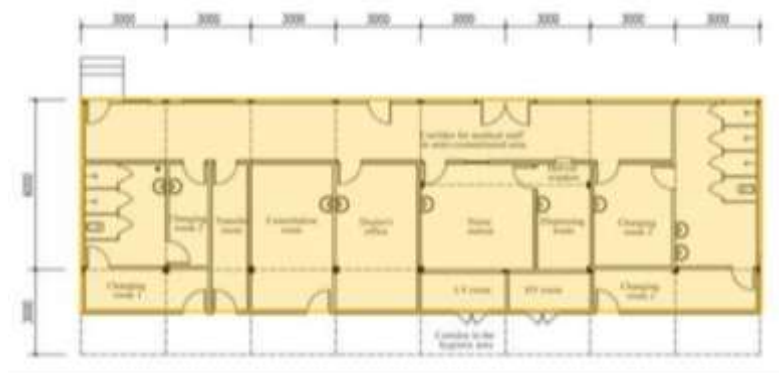
Figure 3: (a) Fishbone layout, (b) Contaminated Area (Chen et al., 2021)

The development of healthcare offices with full confinement is particular and, thus, requires a useful zoning subdivision (Smolova & Smolova, 2021). *Figure 4-a* shows the fishbone shape that was used because the simplest architectural form is the square that can stick two squares and become a rectangle, and so on, and also can make spatial spaces between the squares and provide ventilation and natural lighting (Smolova & Smolova, 2021).

As the form when assembling units in two verticals and one horizontal between them appears H-shape, which is evidence of a hospital's existence and should not be bombed in case of war, especially in the air, brief activity stream and less concentration of defilement. Rotating sort gives superior lighting and association confinement units with open-air spaces serving potential for a plan of outside gardens (Smolova & Smolova, 2021).

As shown in *figure 4-b* -the basic shape- The accessible approaches for the fastest conveyance and the potential natural impacts, Concurring to the Office of Wellbeing, Domains and Offices, the plan of segregation rooms ought to meet essential prerequisites counting an encased space for irresistible people, controlled get to and supply, controlled administration of sullied squander, and accessibility of nursing basics and a conducive walled in area condition (Smolova & Smolova, 2021) (Gbadamosi, Oyedele, Olawale, & Abioye, 2020).

To reduce the introduction of defilement, tall, discuss the altered rate and layout of openings ought to be considered (Qadir & Kamal, 2022) (Nielsen, Li, Buus, & Winther,



2010).

Figure 4: Semi-contaminated Area (medical staff) (Chen et al., 2021)

As shown in *Figure 4*, Healthcare offices working in total separation are isolated into clean, semi-contaminated, and contaminated zones. Development channels embrace a subdivision of understanding and restorative staff areas. The development design is isolated between clear, uncontaminated zones and influenced ranges to prohibit conceivable defilement through the channels (Aalto et al., 2019) (Zhang, S. Cheng, Q. Cheng, 2020).

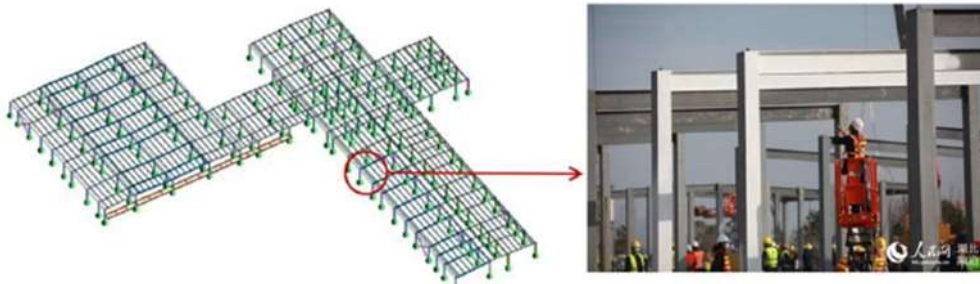


Figure 5: Hygienic area (Doctors' work, Tool warehouse, operating room, doctors' toilets, and readiness to work) (Chen et al., 2021)

Figure 6: Container-type Prefabricated House (Chen et al., 2021)



Over 95% of the building materials of Leishenshan Hospital are prefabricated. *Figure 5* shows the production line, such as buttresses of pre-assembled houses within the therapeutic



range and steel structure box-type measured houses. Concrete exterior walls of Computed Tomography (CT) room standard prefabricated components can be reused, dismantled, and reassembled, sparing vitality and securing the environment (Chen et al., 2021).

The advantages of the prefabricated building, according to Lawson, Ogden, and Bergin (2012), are:

- Estimate the economy within the make of different visit units.
- The establishment speed at the location.
- Progressing quality and precision in manufacturing.

Figure 7: Steel-Frame Structure System (Chen et al., 2021)

- Standard buildings are likely to be disassembled and utilised, thus keeping up the value of their resources effectively.

The advancement of measured pre-assembled frameworks plays a crucial part in worldwide readiness for disastrous occasions and events of novel illnesses where crisis reaction is required, and thus reflects on the number of lives that can be saved. The integration of secluded frameworks permits a shortening of development time and the amount of work on the location compared to traditional development processes. Appraise conveyance time of building, which comprises measured frameworks, is based on the preparedness of modules of

location, and so might be possibly arranged in development in case of a crisis for a prompt reaction (Lawson et al., 2012) (Liew, Chua, & Dai, 2019).

5.2 Evaluation of Hospitals' Standards for COVID-19 in Jordan Field Hospital (Local Case Study)

According to Petra News, the first field hospital built during the pandemic to treat many COVID-19 patients was Al-Zarqa field hospital. Thus, it was included in the current study.

The first military field healing centre for coronavirus patients was opened on Monday, 7th of December 2020, at the Prince Hashem hospital in Zarqa to back up the government's endeavours in controlling the epidemic ([Petra News](#)).

Table 2 General description of the Field Hospital in Jordan, the factors to ensure the rapid construction of the Field Hospital in Jordan, and the emergency design standards (Chen et al., 2021) (Onay, 2018) (Smolova & Smolova, 2021).

Table 3: General Description of the Field Hospital in Jordan

NO	Clause	The description	Notes
1.	Building area	5200 m ²	
2.	Designed by	Directorate of Housing and Military Works Corporation	
3.	Costs	12 million dollars	
4.	Capacity	300 beds	
5.	Duration of work	14 days Two weeks	
6.	Modular Planning Framework as shown in <i>Figure 7</i> .	Starting with the preparation process of the land, since it was designated as a parking lot inside Prince Hashem Al-Zarqa Hospital, it is made of asphalt and has no sharp contour lines.	<ul style="list-style-type: none"> • Fishbone layout, as shown in <i>Figure 8</i>. • The passage of the medical staff is a central hub • Contain the virus spreading by taking into consideration the negative pressure standards • Units are not 12m apart.

- The presence of connecting corridors between the units.
- The presence of a single corridor that connects the units to the functional units, such as the intensive care unit and the laboratory unit.
- Each unit has a clear limit and free capabilities and is connected through the central axis. This encourages simultaneous planning of the contaminated and sanitary areas, as shown in *Figure 9*.

7.	Functional Layout	The nursing unit of the isolated therapeutic area, as shown in <i>Figure 9</i>
8.	Materials	All modules are prefabricated in the factory, as shown in <i>Figure 10</i> . Transported to the roads around the site for assembly and hoisted in place on-site, the Steel-Frame Structure System, as shown in <i>Figure 12</i> .
9.	Emergency design standards	Sustainability Steel composite panels. The box roof is equipped with a waterproof and thermal insulation system, and drainage systems are hidden in the four corners. All

modules are pre-assembled within the manufacturing plant, transported to the streets around the location, assembled exterior of the zone, and raised.

Adaptability

The modular frame allowed it to be adaptable to different locations. The ability to adapt to the pandemic, but if it ended, the building would be removed.

Flexibility

The same space can be utilised for specific exercises several times. In this manner, the arrangements can be supplanted and improved effortlessly.

Modularity

Steel cubic structures are shown in *Figure 10*.

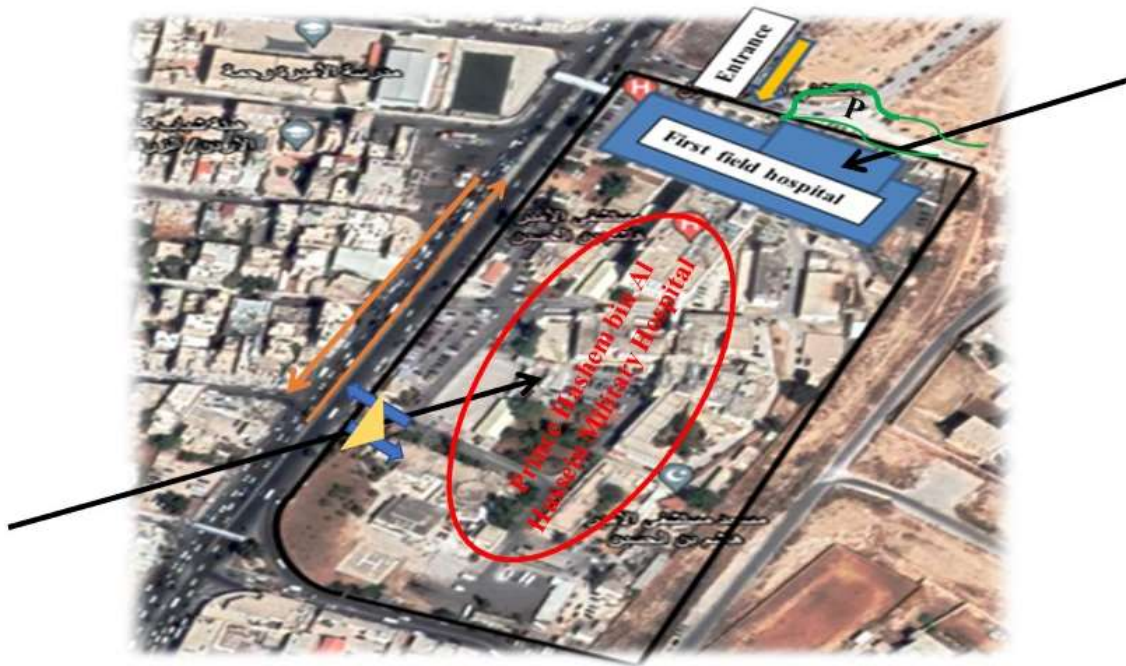


Figure 8: (Modular Planning Framework) Functional Areas of the Project (Google Earth)



Main Entrance to Prince Hashem bin Al Hussein Military Hospital.

As shown in *Table 3* and *Figure 8*, the site of the field hospital is served by transportation, a temple, and its main entrance is separated from the main large military hospital, and there is a site for cars on the side of the field hospital serving the field hospital.

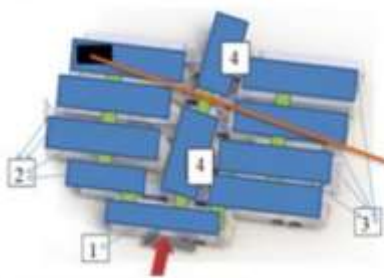


Figure 9: Fishbone layout (Google Earth) + (A field visit)

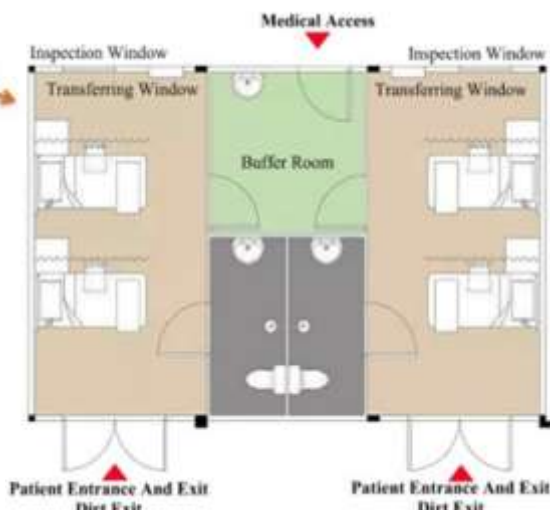


Figure 10: Nursing Unit of the Isolated Therapeutic Area. (Chen et al., 2021)

Note that there is a connection from inside the campus between the military hospital and the field hospital, as there are nurses' and doctors' lodging. The general shape of the field hospital on the fishbone within the spaces is shown in *Figure 9*.

Distribution of activities inside the first field hospital in Zarqa :


1. Reception + emergency entrance
 2. 48 beds for intensive care (ICU)+ emergency cases
 3. Six beds for moderate cases and 120 beds for normal cases
-  Paths. (A field visit).

Figure 10 also shows the isolation unit with a nursing unit for the monitor, which is the basic unit of any field hospital, within the standard dimensions of (3m * 6m).



Figure 11: Container-Type Prefabricated House (Petra News)



Figure 12: Steel-Frame Structure System (Petra News)

There is a health traffic unit, a nursing unit, a medical technology unit, a reception area, and an emergency department (A field visit).

The construction of the first field hospital took 14 days, starting with the preparation process of the land since the land was designated as a parking lot inside Prince Hashem Al-Zarqa Hospital, meaning that it is made of asphalt and does not have any of the sharp contour lines (A field visit).

The land with waterproofing materials for pouring and networking the foundation with the columns is according to the plan. Considering the disposal of waste, the establishment of electricity and ventilation systems, and the end of which the structural units are completed with prefabricated panels (Chen et al., 2021) (Smolova & Smolova, 2021).

Secluded units can be subdivided into load-bearing divider modules and corner post-supported modules. Load-bearing modules permit stack dispersion to the establishment through dividers, whereas corner post modules exchange stack through corner posts. Corner post modules permit the development of greater open spaces; subsequently, modules can be put on top of each other for vital ceiling height, as shown in *Figure 11* (Chen et al., 2021; Smolova & Smolova, 2021). Modules can be put on the beat of each other for vital ceiling height, as shown in *Figure 11* (Chen et al., 2021; Smolova & Smolova, 2021).



(a)

(b)

Figure 13: Examples of Interior Rooms in Hospital (A field visit)

In general, three types of ventilation can be coordinated in clinic development:

- Normal ventilation framework
- Mechanical ventilation framework
- Mixed ventilation framework

Regular ventilation associated with the modules can cause potential contamination (Nielsen et al., 2010). Therefore, the concentration is measured at different air change rates, and the different conditions of patients, and a cloth separator is used between the beds, as shown in *Figure 12*.

Negative-pressure ventilation (NPV) chamber uses lower atmospheric pressure to allow outside air into the separated environment (Qian & Zheng, 2018). This traps and keeps potentially harmful particles inside the negative pressure chamber by preventing indoor air from leaving the space. Negative-pressure rooms in medical facilities isolate patients with infectious diseases and protect people outside the room from exposure (Li et al., 2007).

NPV room primarily maintains the air inside the room with ventilation control only, a room with negative pressure, i.e., closing the room door and operating a high-quality and effective fan (Seppanen & Fisk, 2004) (Al Benna, 2021). As studies suggest, a high air change rate and the low placement of openings should be considered to minimise contamination exposure (Corrado & Gorini, 2002).

5.3 Checklist Table

As shown in *Table 4*: Factors in hospital emergency architecture (WHO, 2010), and based on previous studies and the previous description of the hospital and its distribution to hospital managers, departments, and experienced people, the following *Table 4* is filled.

Table 4: Applicability of Emergency Architecture in Jordan Checklist (WHO, 2010)

Code	Clause	Description	Remarks
A	Location	1. The building is not located in a hazardous area.	✓
		2. The building has appropriate provisions for addressing hazards related to a location, such as rainwater drainage and dikes	✓
B	Design	1. The building has a simple shape and is symmetrical, making it resilient when subjected to stress produced by an earthquake.	
		2. The number of building floors is less than five, especially in areas vulnerable to earthquakes.	
C	Structures	1. No major structural cracks on structural members. Minor or hairline cracks are to be localised and repairable	✓
		2. Structures built with fire-resistant and non-toxic materials.	✓
		3. Ramps are in appropriate areas for moving bed patients and for use by people with disabilities.	✓
D	Site and Accessibility	1. located along or near good roads and adequate means of transportation readily accessible to the community.	✓

		2. No obstructions on the roads leading to the hospital.	✓
		3. Stairways with safe and adequately secured railings must be at least 112-120 cm wide; each step must be less than 17 cm high and made of concrete.	
E	Internal Circulation	1. Nurses at the stations can oversee the wards and are accessible to the patients.	✓
		2. Gender-sensitive wards and sanitary toilets.	✓
F	Architectural Elements	1. The arches, balconies, or overhangs' undersides are free from structural cracks and falling cement plasters.	
		2. Doors in rooms for less than 50 people should be 112 cm wide; doors in rooms for more than 50 people (conference rooms, function rooms) should be 122 cm wide, remotely located from each other, and swing out.	✓
		3. The main doors are double swing; the bathroom door is a swing-out; emergency room doors swing in and out.	✓
		4. Smoke partition doors located along hallways and corridors should be double swing per group of rooms or sections.	✓
		5. The operating room (OR), intensive care unit (ICU), recovery room (RR), delivery room (DR), labour room	✓

(LR), and isolation rooms (IR).

6. Generator housing or powerhouse ✓
protected from natural and man-made disasters; made of reinforced concrete; elevated from the ground line.

 7. Adequate lighting in all areas of the hospital, including the grounds.

 8. Alternate water source provided.
-

6. Conclusion

The purpose of this study was to assess the architectural and operational preparedness of the Jordanian field hospital regarding the control of the spread of infectious diseases and effective response to the conditions of the pandemic and crisis. The study was based on the World Health Organisation (WHO) field hospital checklist to determine the strengths, gaps, and design-based opportunities that can be used to improve resilience, safety, and functional efficiency in emergency healthcare infrastructures. The sample comprised key stakeholders involved in planning, management, and operation. Data were also collected through structured site visits and on-site observation. The study employed a qualitative, checklist-based evaluation approach and descriptive synthesis to examine alignment with international standards and contextual suitability to the environmental and seismic conditions of Jordan in a systematic way.

According to the findings, the hospital has a number of structural and operational strengths that promote successful disease control. These strengths include a non-hazardous location, adequate rainwater drainage, absence of visible structural cracking, and a nursing-station layout that supports access and oversight. However, gaps were identified in seismic performance, circulation dimensions, negative-pressure continuity, lighting, alternative water supply, and wastewater pre-treatment before releasing their discharge into municipal sewerage systems.

These results have implications for policymakers, planners, and healthcare engineers because of their strong emphasis on the need to consider resilience-based and pandemic-responsive design principles in national strategies to address healthcare infrastructure. The study provides a contribution to the field, as it translates the WHO checklist into a context-specific, operational design framework in accordance with the geographic, environmental and institutional realities of Jordan. Its newness is related to its ability to bridge international standards and local field-based evidence to provide a practical and replicable model of assessment and upgrading of field hospitals in similar regional settings.

However, the study is limited by its qualitative scope and focus on a single facility. This implies that the findings of the study cannot be generalised to other facilities. Checklist-based assessment and assessor feedback may introduce subjectivity, and it is important to state that future studies should use quantitative performance measures and comparative studies across the different facilities.

The study suggests that the adoption of standardized, modular, and flexible design strategies, updating building codes to be consistent with the requirements of pandemic and seismic resilience, continuous maintenance regimes, improvements in the wastewater and water supply systems, and formal incorporation of the proposed action plan in the national crisis and disaster management frameworks of the Ministry of Health, the Jordanian Engineers Association, and Civil Defense should be adopted based on the results. Future studies should extend this framework to other field hospitals and adopt mixed-methods designs to confirm its effectiveness, enhance its scalability, and enhance its national preparedness to future emergencies in the field of public health.

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