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EMERGENCY ENGINEERING AND KEY SOLUTIONS FOR CREATING ISOLATION AREA AFTER (COVID-19)

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ABSTRACT

Hospitals suffered unprecedented strain to deal with the increasing number of patients affected by COVID-19. We are seeking alternative ways and solutions to accommodate these increases. This was a major challenge for architects mainly because it was new to all stakeholders, and there was no model to follow. Based on this, this research will propose converting existing buildings to field hospitals that are equipped in the shortest time and at the lowest cost. It is considered one of the quick emergency solutions that can be resorted to get out of the crisis. The purpose of this research is to study how to deal with crises and emergencies, and what the Corona pandemic has produced in terms of redesigning health facilities. It also studies the manifestations of the impact of epidemics on architecture in design and implementation, as they have an impact on the new design standards for health facilities. This crisis has produced a change in these standards, as they must be expandable. The research also studies the best methods for using light buildings in emergencies. The hypothesis on which the study is based is that the standards and determinants that are concluded from the study will lead to improved performance efficiency of architectural spaces as well as facing any emergencies with plans and solutions ready for implementation in the shortest time. The more we are able to create spaces that enjoy flexibility of movement while maintaining the quality of the internal environment, the more we can benefit from this research. The research relies on a theoretical study with a descriptive analytical approach, and then an applied study that relies on an analytical inductive approach. Then the result of the research comes in the form of developing a mechanism for field hospitals, which will be studied in a way that achieves the comfort of users, in order to reach the best architectural solutions as a rapid solution for epidemics in the future.

KEYWORDS: Emergency engineering, shelter hospital, field hospital, mobile hospital.

هندسة الطوارئ والحلول الرئيسية لإنشاء مساحات العزل بعد جائحة كورونا (كوفيد 19)

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الملخص

عانت المستشفيات من إرهاق غير مسبوق للتعامل مع زيادة عدد المرضي المتأثرين بكوفيد -19 ونسعى لإيجاد طرق بديلة وحلول لإستيعاب تلك الزيادات ، فكان هذا تحديًا كبيرًا للمهندسين المعماريين بشكل أساسي لأنه كان جديدًا على جميع المعنيين ، ولم يكن هناك نموذج يجب إتباعه ، وبناءًا على ذلك فى هذا البحث سيتم إقتراح تحويل مبانى قائمه إلى مستشفيات ميدانيه يتم تجهيزها فى أقل وقت وأقل تكلفة وهى تعتبر أحد الحلول السريعه الطارئه التى يمكن اللجوء إليها للخروج من الأزمه ،و **الغرض من هذا البحث** هو دراسة كيفية التعامل مع الأزمات والطوارئ وما أنتجته جائحة كورونا من إعادة تصميم المبانى الصحيه ودراسة مظاهر تأثير الأوبئه على العمارة فى التصميم والتنفيذ لما لها من تأثيرعلى معايير التصميم المستجده على المبانى الصحيه حيث أن هذه الأزمه أنتجت تغير عليها حيث أنها لابد أن تكون قابله على التوسع ، وكذلك الطرق المثلى فى إستخدام المبانى الخفيفه فى الطوارئ ، حيث تتعدد هذة الطرق وتتنوع فى أساليبها ومعطياتها وبالتالى أشكال نتائجها، أما **الفرضيه التى تقوم عليها الدراسه فهى** أن المعايير والمحددات التى يتم إستنتاجها من خلال الدراسة تؤدى الى رفع كفاءة الأداء للفراغات المعماريه وكذلك مواجهة أى طوارئ بخطط وحلول جاهزة للتنفيذ فى أقل وقت وأقل تكلفة، وكلما تمكنا من خلق فراغات تتمتع بمرونة الحركة مع المحافظة على جودة البيئه الداخليه كلما أمكن الاستفادة من هذا البحث. **ويعتمد** البحث على دراسة نظرية بمنهج وصفى تحليلى ثم دراسة تطبيقيه تعتمد على منهج تحليلى إستنباطى ، ثم تأتى نتيجة البحث متمثلة فى وضع آلية لمستشفيات الإيواء حيث سيتم دراستها بما يحقق راحة المستخدمين وذلك بهدف الوصول الى أفضل الحلول المعماريه كحل سريع للأوبئة فى المستقبل .

الكلمات المفتاحية : هندسة الطوارئ ، مستشفى إيواء ، مستشفى ميدانى ، مستشفى متنقل .

INTRODUCTION:

With emergency rooms and intensive care units overflowing with COVID-19 patients, the world rushed to convert hotels, convention centers, city parks, and universities into spaces for new temporary hospitals. The COVID-19 pandemic has led to significant changes in the design and implementation of healthcare facilities, making them more flexible and scalable to meet the growing needs of patients during crises and emergencies.

Despite these changes, there are a number of challenges that still face the design and implementation of healthcare facilities in crises and emergencies, including the need to find economical and resource-efficient solutions to meet the growing needs of patients during crises and emergencies.

As a result,This research paper explores how to deal with crises and emergencies, and what the COVID-19 pandemic has produced in terms of redesigning health facilities. It also studies the manifestations of the impact of epidemics on architecture in design and implementation, due to its impact on the emerging design standards for health facilities. As this crisis has produced changes to them, as they must be expandable. It also explores the best ways to use light buildings in emergencies, as these methods vary in their methods and data, and therefore the forms of their results. Therefore, the architect must study all the methods environmentally, economically, and temporally using various simulation applications and programs that help the designer to make decisions in order to reach the best solutions that are suitable economically, environmentally, and temporally:

1-1 Research problem:

The research problem is:Lack of flexibility in the design of hospitals, as well as their inability to accommodate infected cases. Despite the many theses and studies that have addressed hospitals, they have been characterized by a lack of specialization in addressing rapid engineering solutions in the event of crises**.**

1-2 Research objective:

This research aims to study several points, including:

- Producing a database of the latest design standards to improve the efficiency of the use of internal spaces in health facilities.

- Evaluating the efficiency standards of internal spaces within existing, field, and mobile hospitals during the COVID-19 pandemic.
- Reaching the necessary determinants and standards when operating a field hospital and putting in place a mechanism for dealing with crises and emergencies that guarantees good and efficient performance of health facilities.

1-3 Research hypothesis:

The hypothesis of the study is as follows:

The standards and determinants that are derived from the study, using technological tools and computer-aided design programs, lead to improved performance efficiency of architectural spaces, as well as facing any emergencies with ready-to-implement plans and solutions in the shortest possible time. This will allow us to reach improved efficiency of spaces within health facilities. The more we are able to create spaces that enjoy flexibility of movement while maintaining the quality of the internal environment, the more we can benefit from this study in improving the efficiency of health facilities and raising the quality of the architectural product.

1-4 Research methodology:

The research methodology is as follows:

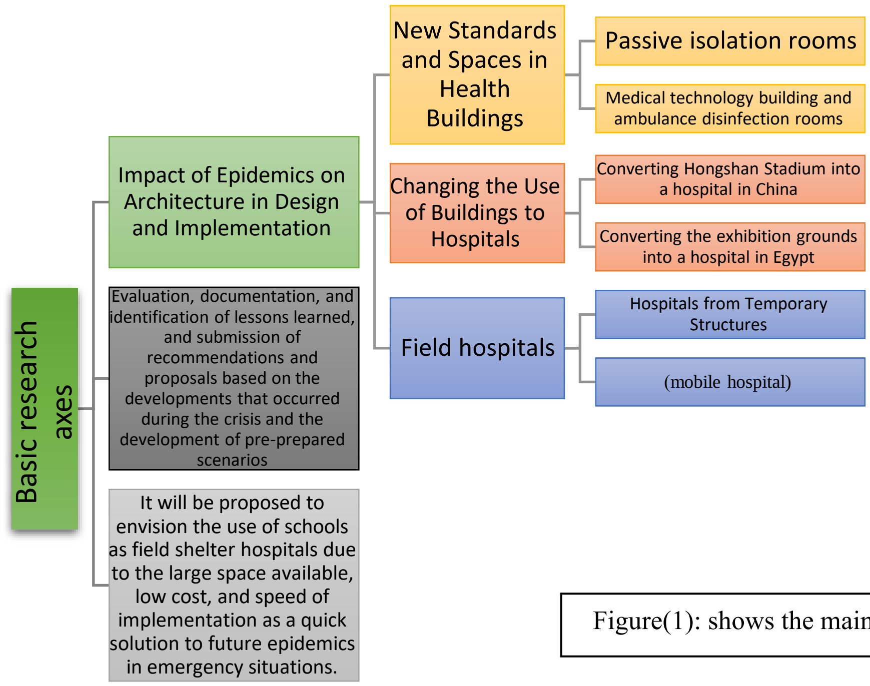
Stage 1: Theoretical Approach:

- The study of emergency engineering and its impact on the development of health facilities, as well as the study of the impact of epidemics on architecture in design and implementation.
- Reviewing emergency solutions and plans in the event of any disaster and analyzing the performance of these solutions within health facilities in order to reach a set of considerations and standards that lead to the optimal exploitation of spaces within health facilities.
- The study of field and mobile hospitals and the factors affecting their design.

Stage 2: Applied study:

Through the theoretical study, a set of considerations and criteria are identified that are relied upon in the Applied study, as well as the application of those criteria that have been deduced to improve the efficiency of internal spaces within healthcare facilities with the requirements of the crisis.

Then, a mechanism for shelter hospitals will be put in place, which will be studied to achieve the comfort of users, with the aim of reaching the best architectural solutions to improve its efficiency to reach the highest possible percentage compared to standalone hospitals. Then, the research results will be extracted and a plan that can be referred to in emergency cases will be made.

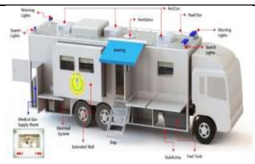


Figure(1): shows the main research axes.

1-5 The following table reviews the most important previous research studies:

Table (1): reviews the most important previous research studies

Previous research studies	the year	Study Title	Purpose of the study	Figure
First, studies related to converting existing buildings into temporary shelter hospitals.	Research paper 2021	Disease Outbreak Surge Response: How a Singapore Tertiary Hospital Converted a Multi-story Carpark Into a Flu Screening Area to Respond to the COVID-19 Pandemic	Documenting the experience of converting a garage building into a hospital in Singapore in order to accommodate the numbers resulting from the Corona crisis. The study recommended that a separate area or facility should be planned to deal with the increasing number of patients to reduce the impact on the daily workload in hospitals in order to reduce the number of deaths.	 Figure (2): MSCP is an existing building that serves as a car park [1]
	Research paper 2020	Large-scale public venues as medical emergency sites in disasters: lessons from COVID-19 and the use of Fangcang shelter hospitals in Wuhan, China	In this study, buildings were reused and converted into hospitals in Wuhan, China, such as the conversion of Hongshan Stadium into a hospital, where there are many forms of shelter, including temporary structures made of plastic panels, tents, prefabricated structures, existing large buildings, etc. The optimal solution depends on various factors, such as the type of disaster, climate, economy, and estimated age. Schools, religious facilities, and community centers can also be used as shelters during disasters. These solutions will contribute to disaster preparedness and mitigation in the future.	 Figure(3) :The layout of the Fangcang shelter hospital of Hongshan Stadium[2]

	June 2020	Equipping the Armed Forces Hospital Complex for health isolation at the exhibition grounds in Egypt	Implementing the state's plan to confront the threat of the new Corona virus and contributing to providing distinguished medical services to citizens to prevent monopoly and exploitation of the situation. It can also be paid to work in isolated places, relying on its own capabilities if the infrastructure of water, electricity and sanitation is not available.	 Figure(4) : Equipping Hospital Complex for health isolation at the exhibition grounds in Egypt [3]
	Research paper 26 October 2022	COVID-19 Surge Capacity Solutions: Our Experience of Converting a Concert Hall into a Temporary Hospital for Mild and Moderate COVID-19 Patients	This paper documents the temporary hospital project, describeing the site, the layout and the equipment, the idea behind structural choices, and the staff involved. The aim of the work is to share the experience and to provide some practical recommendations to other professionals who are fighting the COVID-19 pandemic worldwide.	 Figure (5): OGR Temporary Hospital [4]
	Research paper April, 2023	Operational resources in humanitarian setting: the Mozambique case after the Cyclone Idai, disaster and recovery phases	Converting a public parking into an urban field hospital it is aimed at health care professionals engaged in disaster contexts and proposes a model that can be scaled up in similar settings, when demand exceeds hospital capacities. In addition, the experience gained during the development of these kind of emergency hospitals will allow for better preparation of further such units and more optimal use of medical personnel and equipment.	 Figure (6):Valentino Temporary Hospital [5]
Second: Studies on field hospitals:	Research paper 2021	Modular composite building in urgent emergency engineering projects: A case study of accelerated design and construction of Wuhan Thunder God Mountain/Leishenshan hospital to COVID-19 pandemic	This study aims to take the construction of Leishenshan Hospital as an example to illustrate how to adopt BIM technology and other high-tech technology such as big data, artificial intelligence, drones, and 5G for the fast construction of the fabricated steel structure systems in emergency engineering projects.	 Figure (7): Leishenshan field Hospital [6]
Third: Studies on mobile hospitals	2021	SUNNYDA mobile hospital	SUNNYDA is specialized in manufacturing mobile hospitals in China and can provide a comprehensive solution for a general or infectious disease hospital. The units are 6055 mm (length) * 2435 mm (width). The advantage of using a uniform size is to save the cost of materials in addition to saving installation time. It is the fastest, as a hospital can be built in 12 days	 Figure (8): SUNNYDA mobile hospital [7]

2-First: Theoretical Approach:

2-1-Definitions:

2-1-1 Emergency Engineering:

Emergency engineering and its standards are not completely new, but have been studied for years as: (Engineering that deals with facing disasters that occur to societies without expectation).

In disasters, society resorts to emergency engineering in two cases in general, the first: providing urgent or temporary shelter for victims of natural disasters such as earthquakes, cyclones, and the like. Its design is then characterized by a temporary standard solution that meets the basic needs of man, that is, an architectural shelter for protection with less focus on interior design.

The second, more complex case, aims to provide emergency units such as temporary hospitals, which provide not only protection and basic needs, but also sterile medical equipment and intensive care units.

2-1-2 Shelter hospitals:

Shelter hospitals are a new concept in public health. They were first implemented in China in February 2020 to respond to the COVID-19 outbreak. Shelter hospitals in China were large-scale temporary hospitals, built quickly by converting existing public spaces, such as stadiums and exhibition centers, into healthcare facilities. They worked to isolate patients with mild to moderate COVID-19 from their families and communities, while providing medical care, disease monitoring, food, shelter, and social activities. Their three main characteristics (quick construction, wide scale, and low cost) and five basic functions (isolation, triage, basic medical care, repeated monitoring and rapid referral, basic living and social participation) make them a strong solution for national responses to the COVID-19 pandemic as well as future epidemics and public health emergencies [8].

3-1-2 Field hospital:

Field hospital: A mobile medical unit that is quickly deployed temporarily to provide rapid field intervention for victims and injured people at the site before they are transferred to a safe place or to a larger and permanent hospital. Field hospitals are divided into several types according to their medical capabilities:

- First-class field hospital: This hospital is non-surgical (dispensary) and performs triage and first aid.
- Second-class field hospital: This hospital is a simple surgical hospital for minor surgical cases such as fractures, childbirth, and simple surgical procedures.
- Third-class field hospital: This hospital is a complex surgical hospital for complex and critical surgical cases such as heart and brain surgery.

2-1-4 Mobile hospital:

It is a medical trailer that is equipped according to the best specifications and must withstand any harsh weather conditions. It is very important to ensure that the temperature inside the unit remains completely constant and safe wherever the unit stops or moves and under any conditions, in order to avoid expensive maintenance of the equipment and ensure that it works accurately.

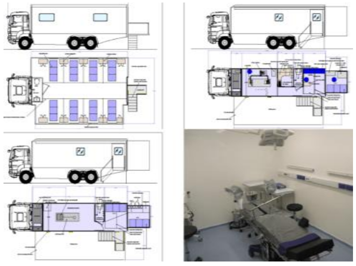


Figure (9): shows the shape of the mobile hospital [9]

2-2-The main possibilities for creating an isolation space to treat COVID-19 patients:
The most important challenge facing the built environment and the construction industry is to provide healthcare isolation spaces quickly to treat mild, moderate, and severe cases of COVID-19 and effectively contain the spread of the pandemic. Therefore, there are six main options for isolation space creation measures to treat COVID-19 patients, including:

- 2-2-1 Self-isolation at home;
- 2-2-2 Isolation at regular hospitals (public and private);
- 2-2-3 Isolation at existing epidemy hospitals;
- 2-2-4 Isolation at retrofitted temporary Covid-19 hospitals;(Shelter hospitals)
- 2-2-5 Isolation at newbuild Covid-19 hospitals; (Field hospital)
- 2-2-6 Isolation at mobile hospitals.

2-2-1 Self-isolation at home:

Self-isolation at home can be effective in reducing the rate of spread, but it is not enough to effectively contain the spread of the virus[10].

2-2-2 Isolation at regular hospitals (public and private):

Isolation in regular hospitals threatens other healthcare services due to the inflexibility of the premises, leading to increased risks to public health[11].

2-2-3 Isolation at existing epidemy hospitals:

Using existing disease control hospitals is very effective to contain epidemic outbreaks at the early stage It is important to prepare for a huge increase in the number of patients [12]. Therefore, utilizing existing epidemiological hospitals comes with the challenge of low capacity and the need to expand capacity for more cases.

2-2-4 Isolation at retrofitted temporary Covid-19 hospitals; (Shelter hospitals)

The rapid need to expand capacity to contain the COVID-19 pandemic led to the emergency conversion of other building facilities to meet demand. Shelter hospitals are a new concept in public health. They were first implemented in China in February 2020 to respond to the COVID-19 outbreak. Shelter hospitals in China were large-scale temporary hospitals, which were rapidly built by converting existing public spaces, such as stadiums and exhibition centers, into healthcare facilities. Patients with mild to moderate symptoms were isolated. Their main characteristics are three (rapid construction, wide scope, and low cost), and it has five basic functions (isolation, triage, basic medical care, frequent monitoring and rapid referral, basic living and social participation). Shelter hospitals can be one of the powerful solutions for national responses to the COVID-19 pandemic as well as future epidemics and public health emergencies[13].

The main characteristics of residential hospitals:

The three main characteristics of shelter hospitals are:

- **Speed**: Shelter hospitals can be built quickly because they are converted from existing buildings with existing infrastructure (such as sports arenas or exhibition centers).
- **Scale**: Shelter hospitals are typically large-scale facilities that can accommodate a large number of patients.
- **Cost**: Shelter hospitals are relatively inexpensive to build and operate. This is because they are converted from existing buildings, which avoids the cost of expensive facilities. Once the pandemic subsides, the structures can be returned to their original purposes.

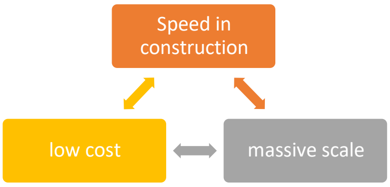


Figure (10): shows the main characteristics of shelter hospitals.

2-2-5 Isolation at newbuild Covid-19 hospitals; (Field hospital)

Due to the large number of factors that affect the containment of the spread of COVID-19, it is difficult to measure the impact of the rapid delivery of hospitals such as the Wuhan [14] Huoshenshan and Leishenshan COVID-19 hospitals in containing the spread of the pandemic.

Features of a field hospital:

There are several advantages and benefits of a field hospital, including the following:

- **Mobility**: Field hospitals can be easily moved to another location. They are made of lightweight materials that make them easy to transport.
- **Easy of installation**: Field hospitals can be installed easily if the planned procedure is followed. They are also relatively inexpensive because they are made of modular materials.
- **Easy of disassembly**: Field hospitals can be disassembled easily.
- **Ability to adapt to different weather conditions**: Field hospitals can adapt to different weather conditions by using appropriate climate control devices. This allows them to be transported to different locations around the world.
- **Dependence on inexpensive energy sources**: Field hospitals can rely on inexpensive energy sources, such as solar panels, which make them self-powered, or electrical generators.

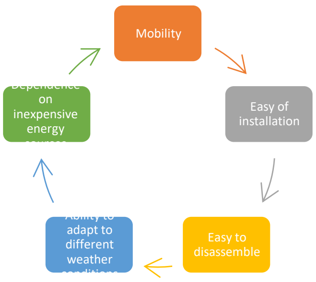


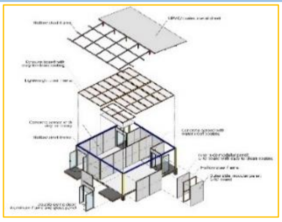
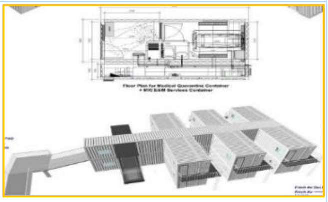
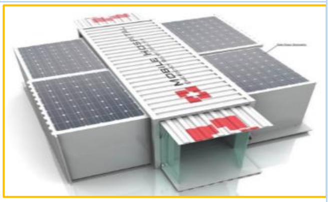
Figure (11): shows the field hospital and its features.[15]

Is the field hospital built on site or assembled in the factory?

Most of the field hospital is produced and completed in the factory, leaving the minor things on site. It depends on prefabrication, Prefab hospital.

In this part of the research, the types of modular isolation units for the field hospital will be studied, made of iron as well as made of tents (PVC):

Table (2): shows of the most important examples of the standard isolation units (modular) that can be replicated to create a field hospital.

Standard insulation units (modules)	Description	**Figures**
Isolated Recovery Home (IRH)	The IRH is a design for adaptable isolation units that is applicable in different contexts in a pandemic or other major healthcare emergencies. By carefully combining the standards for the installation of isolation spaces and modular building systems, the IRH is a potential low-tech isolation space that does not neglect the minimum standards required for an isolation space. Furthermore, the modular system embedded in the design not only provides an opportunity for rapid construction and the ability to adapt in different contexts, but can also be disassembled for use in the post-pandemic phase. However, like other healthcare facilities, the IRH must be accompanied by other isolation and healthcare procedures when implemented, such as clinical procedures, cleaning procedures, and staff safety standards.	 Figure (12): [16]
Converting a shipping container into a high-tech isolation room	The modular system developed by a pro bono team can be used to build a fully operational isolation hospital in six weeks. As Hong Kong prepared for the peak of the COVID-19 pandemic, a group of leading local engineers developed a potential solution to quickly increase the capacity of the isolation ward. Two WSP engineers were part of this team – Thomas Chan, Executive Director, Building MEP, and Technical Director Kwok-Fai Tsui, Building MEP who worked on a design to convert a 20-foot container into an isolation unit.	 Figure (13): [17]
The use of containers in the design of a field hospital designed by designer Kukil Han.	The treatment unit is divided into four sections, each of which is three connected containers, to triple the surface area of the medical structure from its original size, to form a structure that can accommodate a larger number of beds, supplies, and medical equipment. The designer assembled four units orthogonally to create a four-wing miniature hospital. The design concept is based on the principle of "go anywhere" to provide medical assistance to victims around the world from natural disasters such as floods and earthquakes. This mobile hospital can be deployed anywhere in the world.	 Figure (14): [18]
Therapeutic units model (by Anshen + Allen)	Anshen + Allen is a design and engineering firm that has produced a series of clinics to serve in disaster relief and healthcare. They are equipped with all the necessary equipment to treat women and children. The firm works to develop service spaces in areas in need of humanitarian assistance. It does this by rehabilitating containers and converting them into preventive care units for poor and rural communities. This is a type of design solution to some community problems to provide quality healthcare units that meet the needs of the population who are deprived of medical services in remote or isolated environments or in areas where a traditional hospital is not available.	 Figure (15): [19]

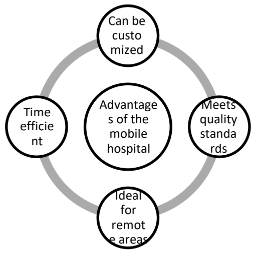


Figure (19): shows the main characteristics of mobile hospitals.

Modular unit of Suzhou Zhongnan Steel Structure Company	**The unit is characterized by the following:** - It has dimensions of 392.80. - It is reusable. - Assembly is quick and the manufacturing period is short, and without foundations. - The structure is reinforced with steel and is resistant to wind and impact. - The external wall of the steel plate is corrosion resistant and acid resistant, and does not rust or crack, and its service life is over 20 years. - Good sound and heat insulation adopts air heat insulation design. - It can be designed in different shapes, with multiple colors on the outer wall. - Low cost and high quality.	 Figure (16): [20]
Standard insulation units made of tents by GUANGZHOU YOLLOY	It is easy to set up in a short time of five to ten minutes, and can be moved to a different location as required, and can stand after inflating it with an air blower or air pump. The size and design can also be customized	 Figure (17): [21]
NIXUS modular tent insulation units	NIXUS Emergency Medical Tents are suitable for all medical emergencies due to their rapid deployment, flexible configuration, sanitary linings, and robust construction making them suitable for sustainable use in all weather conditions. NIXUS Emergency Medical Tents have been provided to numerous military forces and foreign aid organizations and have proven their effectiveness in a wide range of conditions.	 Figure (18): [22]

2-2-6 Isolation at mobile hospitals.

The use of a temporary mobile hospital alleviates functional and locational constraints to create emergency isolation spaces. Mobile hospitals also improve mobility, scalability, and access to remote areas for rapid intervention.

Suitable materials for the mobile hospital:

There are two main types of materials in mobile hospitals:

1. High quality steel: As steel is durable, has high tensile strength, is flexible, and easy to use.
2. Double fiberglass: Fiber Glass Sandwich Panel Fiberglass insulation panels can be used with EPS or XPS insulation material. Fiberglass is lightweight, durable, flexible and has high tensile strength.

Is the mobile hospital customizable?

Yes, the layout and design are chosen by the client.

The standards that must be available in the mobile hospital:

Each country has its own standards. For example, in the United States, mobile hospitals must comply with the standards and codes of a fixed hospital, and they must also comply with ISO 9001 standards. However, manufacturers must comply with the following standards:

1. There must be a permanent power supply to help manage the hospital, as well as the necessary medical equipment for air conditioning and operating the intensive care unit.
2. There must be a flat floor design to help people move easily.
3. The mobile hospital must be properly ventilated to allow for free air circulation.

4. The units must have separate toilets for patients and staff.
5. A fire alarm system must be available with employees working 24 hours a day, 7 days a week.

Advantages of the mobile hospital:

Some of the advantages of a mobile hospital are[23]:

1. Convenience: as it can be integrated with existing facilities, the mobile hospital can also be deployed and moved to different locations, and it can be assembled and disassembled easily, so it is ready for use.
2. It is an additional means of convenience: as it is ideal for use in remote areas.
3. Quality and reliability: it is of high quality and can continue to operate for more than 40 years of continuous use, and it meets the approved quality standards in healthcare and ISO certification.
4. Functionality: it can be used instead of existing hospitals to provide most medical services.
5. Value: it is of high value that meets the needs of the client.
6. Time-effective: it can be designed, manufactured, and delivered within a short period of time.
7. It can be customized: it can be customized to meet the needs of the client.
8. There are no restrictions on shape and size.

Company	Mobile hospital	Figures
NAFFCO mobile medical unit	The mobile medical unit produced by Naffco is one of the best and most beneficial mobile hospitals in terms of technical, economic, and quality. This medical trailer, which is equipped with the best specifications, can withstand any harsh weather conditions. It is very important to ensure that the temperature inside the unit remains completely stable and safe wherever the unit stops or moves and under any conditions, in order to avoid expensive maintenance of equipment and ensure its accurate operation. The body of the vehicle was made of layers of high-quality materials that are also used in aircraft manufacturing. The expandable and extendable chambers are made of steel structures made of steel pipes. Bringing Vital Medical care to your Doorstep | NAFFCO Mobile Hospital – YouTube A video explaining how the company's mobile hospital works	 Figure (20): Source: [24]
Mobile polyclinic (emergency) of Optima Technic	Optima Technic designs and manufactures mobile clinical units according to the needs of the end user. A single mobile clinic can combine different and specific medical activities and thus offer diversified screening / examination services in the most remote areas in the fastest way. Mobile clinics can be a truck or trailer based platform. https://www.optimatechnic.com/storage/app/uploads/public /630/cae/9dc/630cae9dc f166457128076.mp4 A video explaining how the company's mobile hospital works	 Figure (21): Source: [25]
Mobile hospital for a company made-in-china	It was manufactured by made-in-china with dimensions of length 12192 * width 2438 * height 2896 mm, and it was made of a steel channel structure (galvanized) + insulated sandwich panels in white or green color, and the color can be customized as required, and the insulation was made of polyurethane, EPS, IEPS, rock wool, glass wool, and the floors are made of medical vinyl.	 Figure (22): Source: [26]
Vertisa's ambulatory care hospital	Vertisa equipped the mobile emergency hospital with smart technology with a team of R&D experts and engineers to update the hospital. Vertisa receives many requests from abroad for the mobile emergency care hospital, which it produces in the form of a trailer or truck based on the project.	 Figure (23): Source: [27]
ALURA TRAILER mobile hospital	ALURA TRAILER equipped the mobile emergency hospital with smart technology with a team of experts and it is a custom-made mobile hospital trailer. Mobile Hospital Trailer - YouTube A video explaining how the company's mobile hospital works	 Figure (24): Source: [28]

SUNNYDA mobile hospital	SUNNYDA is a China-based company that specializes in the manufacture of mobile hospitals. It can provide a comprehensive solution for general or infectious diseases hospital. The units are 6055 mm (length) * 2435 mm (width). The advantage of using a uniform size is to save material cost and installation time, which is the fastest. It can build a hospital in 12 days.	 Figure (25): Source: [29]

Table: (3) Summary of the most important examples of mobile hospital product

Isolation space creation measures (ISC)	**Effective insulation**	**Scalability**	**Environmental sustainability**	**Mobility**	**Waste disposal control**	**Controlled supplies**	**Access control**	**Flexibility**	**Meets functional requirements**	**Time required to create**	**Sufficient capacity**	**Easy to create and configure**	**cost**
Self-isolation at home.			✓							✓	✓	✓	✓
Isolation at **regular hospitals (public and** private)			✓		✓	✓	✓			✓		✓	
Isolation at existing epidemy hospitals	✓		✓		✓	✓	✓		✓	✓		✓	✓
Isolation at retrofitted temporary Covid-19 hospitals;(Shelter hospitals)	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Isolation at newbuild Covid-19 hospitals; (Field hospital)	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
Isolation at mobile hospitals.	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	

Table (4): shows the necessary standards for isolation measures to contain Covid

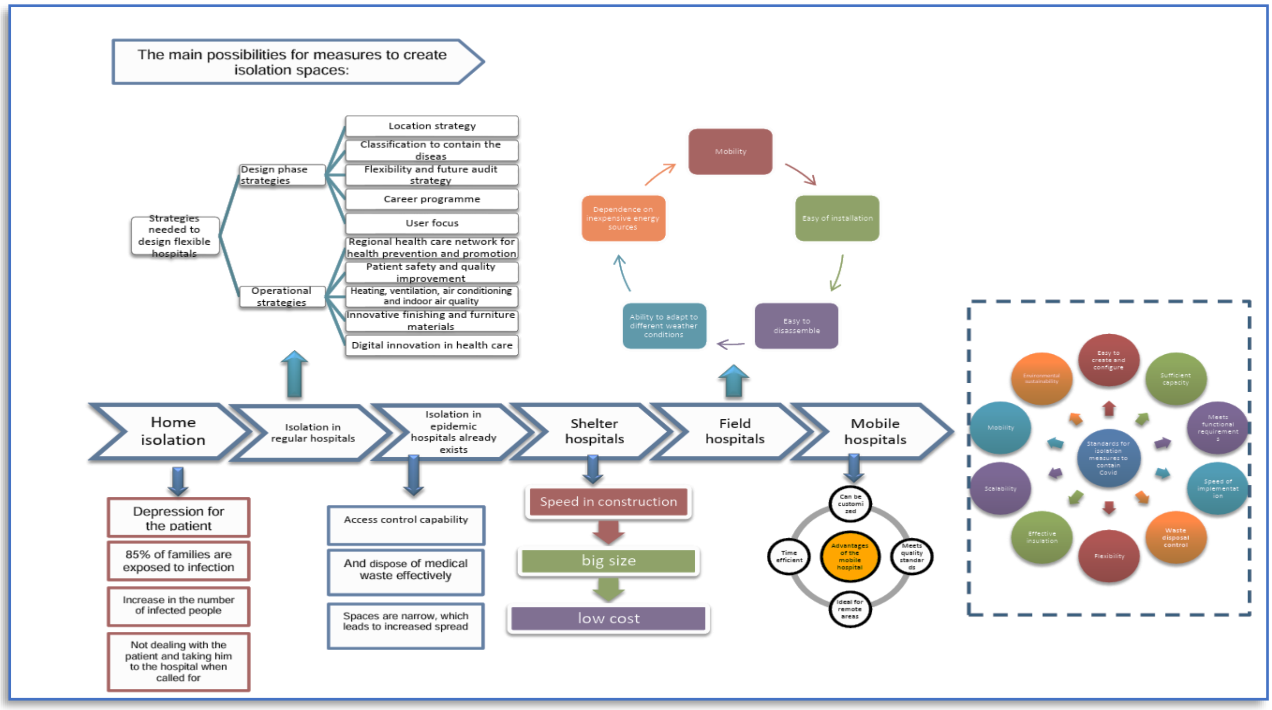


Figure (26): shows possible solutions for isolation area to contain Covid .

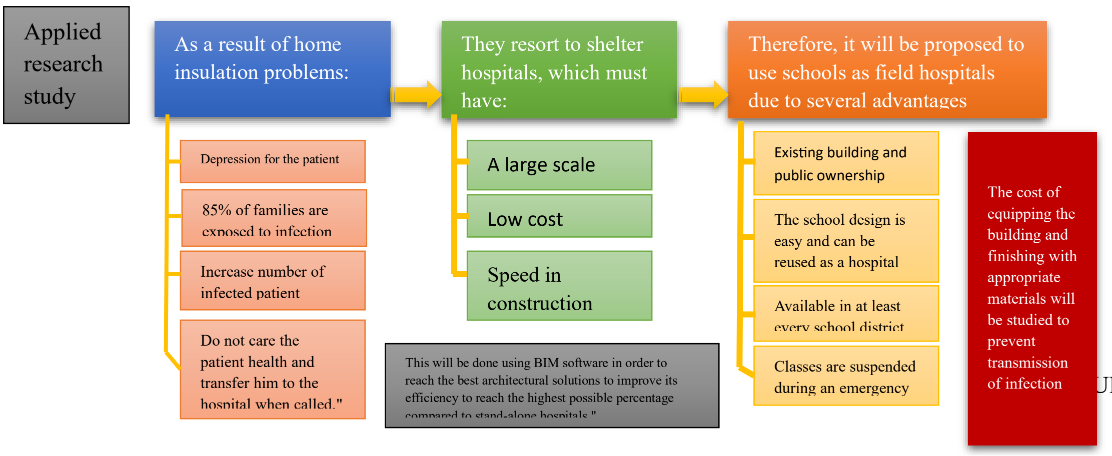


Figure (27): shows a diagram of the applied research study

Stage 2: Applied research study:

Content	Description
The sample of the study	Aschool in El Salam City, Cairo, El Salam First District, El Sharq District, has been selected. (El Bahr Elementary Model Institute). We will conduct a practical study on the building and apply modern technologies to it, and how to change its use in emergency cases as an existing building, and what are the variables that will be applied to it.
The project Location	The site of the model for the practical study is located in Cairo, El Sharq District, on Al-Azhar Institute Street. It is five minutes away from El Salam General Hospital, where emergency cases that need intensive care units are transferred.   Figure (28) shows the general location of the model under study. [30]. Figure (29) shows the general location of the model under study and its relationship to El Salam General Hospital. [30].

Table (5): case Study

The following table (6) shows what will be applied to the study case to reuse it as a field hospital in emergency situations.

Content	Description
Re-planning the general location of the school	**The site will be divided into three main zones:** • **Red zone**: This is a contaminated area where patients are admitted and only staff members wearing appropriate personal protective equipment (PPE) are allowed to enter. • **Yellow zone**: This is a semi-clean area where healthcare workers wear PPE. • **Green zone**: This is a clean area where individuals can work as usual, without PPE, and contains a clean warehouse for expensive materials that are safer to keep out of the Red zone, such as medications or spare equipment. Five beds will be divided into each ward after considering the design fundamentals. As a result, the hospital will have 125 beds. Ready-made bathroom units have been added to the playground, as well as four ready-made units for doctors away from the pollution area (as a doctor's residence). ICU units have also been added to the playground.

<table>
<tr><td></td><td>

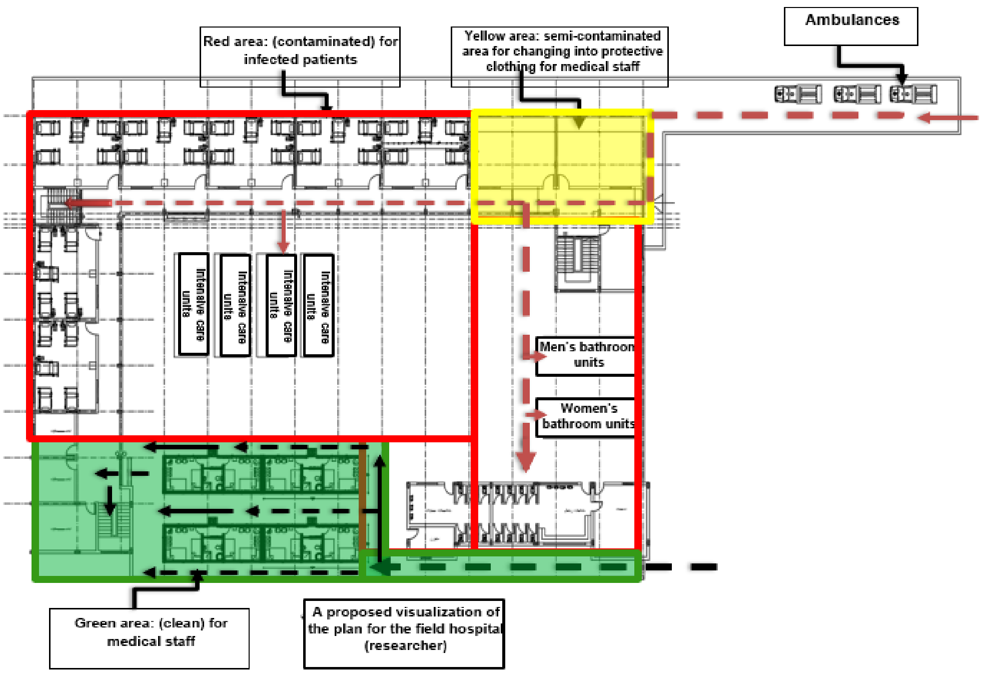
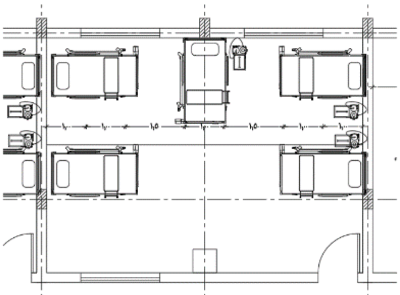
Figure (30) shows the Site of the model under study. Photo by: researcher</td></tr>
<tr><td>Re-planning the general location of the school</td><td>

Figure (31): Shows the proposal for the field hospital on the first floor by: researcher

Horizontal and vertical movement elements:

A dedicated movement path for medical staff was created to prevent them from being infected. A dedicated ladder was also allocated for medical staff.
A movement path for patients and suspected cases was also created.

Figure (32) shows layout of the room from the inside, showing the distribution of beds by: researcher</td></tr>
<tr><td>Finishes</td><td>Flooring: The floor will be made of a layer of polyvinyl chloride (PVC) flooring. This flooring is imported and will be glued to a layer of mosaic tile
Walls: The walls will be painted with a bacteria-resistant material.[i]CMB
Ceilings: Curtains will be installed between the beds, and lighting and ventilation equipment will be installed..
Windows and doors: UPVC windows and doors will be installed.</td></tr>
</table>

	 Figure (33) shows a visualization of the finishes inside the room and inside the bathrooms.[31],[32]
Electrical equipment	In terms of the electrical system, all 125 patient beds will be equipped in the same way to ensure flexibility and the ability to adapt in case of additional needs. In particular, each bed will be equipped with six general electrical sockets, one lamp, one service plug, and a patient alarm. A 600 kW backup generator will be placed outside the building for use in case of a primary power outage. From a safety perspective, it is allowed to install one ceiling video camera along the corridor. A wifi network will be created to allow the use of electronic patient clinical records within the temporary hospital.
Gas station equipment	Oxygen devices will be installed next to each bed. These devices will provide oxygen to patients who need it. The oxygen will be delivered through a nasal cannula or mask.
Bathroom fittings	A ready-made unit will be placed for men and another for women.
Health care equipment	Four ready-made units will be placed.
Equipment needed for the study case	**Furniture and supplies needed for the hospital:** 4 electric intensive care beds 125 folding beds with mattress 6 vital signs monitors 2 portable fans 2 ECG machines 4 monitor-defibrillators 2 automated external defibrillators 8 portable suction systems 50 injection pumps 6 portable ultrasound machine 4 video laryngoscopes 1 Mobile digital X-ray unit 4 refrigerators for medicines and pharmaceutical preparations 125Oxygen flow meter 2 balance 10 stretchers 5 anesthesia trolley 5 video camera * IT equipment (laptops, computers, printers, wifi routers, etc) *Furnishings (tables, chairs, shelves, folding sinks, etc.) *Medicines and consumables

The following table (7) shows the quantity survey for the model as of August 2023: by researcher

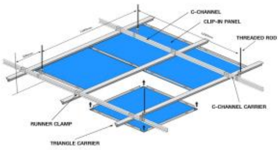
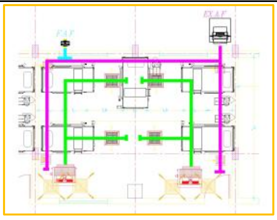
Finishing stage:

Item No	items of work	Unit	No	Size			total	reductio	addition	Total
				Length	width	height				
1	Flooring									
1-1	classrooms	M2	9	6	8		432			
1-2	Corridors	M2		50	2					
				25.30	2					
				7.75	2		166.1			
1-3	Affairs Offices	M2	2	3.75	3.75					
				4	5.75					
				6	3.88					
				2.5	3.88		83.98			
1-4	The stairs									
1-4-1	Stair1	M2	21	0.3	1.5					
			22	0.15	1.5					
			1	1.5	3.88					

			1	2	3.88		28			
1-4-2	Stair2	M2	21	0.3	1.2					
			22	0.3	1.2					
			2	0.2	3		31			
1-5	skirting	M2								
	classrooms		9	4.2	0.15					
	Corridors			144.2	0.15					
	Affairs Offices			80.82	0.15		73			
	Number of floors	M2	3						815	2445
1-6	Baths and mosque	M2		5	6.25					
				5	9.38					
				5	3.38					
				4.23	6.25		121.5			
	Total									2566.5
2	The walls									
1-2	classrooms	M2	9	28	3.30		832			
2-2	Corridors	M2		67.95	1.20		81.54			
				85.88	3.30		283.4			
2-3	Affairs Offices	M2		80.82	3.30		267			
2-4	The stairs	M2		12.88	3.30		42.5			
			2	11.4	3.30		75.24			
	Number of floors	M2	3				1582			4746
2-5	Mosque	M2		22.5	3.3		74.25			
	Total									
3	ceiling									
3-1	classrooms	M2	9	6	8		432			
3-2	Corridors	M2		83.05	2		166.1			
3-3	Affairs Offices	M2					83.89			
3-4	The stairs									
3-4-1	Stair1	M2	2	3	1.5				4821	
				1.5	3.88					
				2	3.88		22.58			
3-4-2	Stair2	M2	2*2	3	1.2					
			2	3	1.2		21.6			
	Number of floors		3				726.3			2179
3-5	Baths and mosque	M2					121.5			
	Total									2300.5
4	Windows	NO	31	2	1		62			
			2	2.5	1		5			
				1	1		1			
				2.25	1		2.25			
	Total		35							70.25
5	the doors	NO	9	1	2.20		19.8			
			9	0.80	2.20		15.84			
			14	0.70	2.20		21.56			
	Total		28							57.2
6	Electricity works	NO	27							
7	Air conditioning works	NO	27							
8	Curtain works									
	Total	M2	27	21.33	2		1152			1152

The following table (8) shows the bill of quantity as of August 2023: by researcher

Item No	items of work	Unit	Quantity	Item price	Total in EGP	Notes
1	**Flooring**					
	Supply and installation of flooring of type (anti static -ESD-pvc vinyl tile) **The flooring is anti-bacterial anti-static welding heat and the wazer with the cuff It is a roll of width 2 m * 20 m for a total of 40 square meters in the roll thickness 2 mm according to the principles of industry**[26]	M2	2566.5	1000	2566500	 Figure (34): Source: [33]
2	**The walls**					
	Painting and supply of walls with Bio-Chemathon **Painting plastic half-gloss resistant to bacteria and fungi for indoor and outdoor use.** **Based on concentrated vinyl and acrylic resin emulsions and high proportions of the finest types of titanium dioxide.** **Coverage 8:10 m2 per liter.** **A 9-liter can covers 90 m2.** **4821/90 = 53.6** [27]	M2	54	9 Liter 965	**52110**	 Figure (35): Source: [34]

			4821	50	241050	
	Total				293160	
3	**ceiling**					
	Supply and installation of 60*60mm anti-bacterial gypsum tiles including accessories, fire-resistant, sound-insulated ceiling, ordinary ceiling, integrated ceiling, heat-insulated ceiling, and smoke-resistant ceiling, in accordance with industry standards.[28]		2300.5	1000	2300500	 Figure (36): Source: [35]
4	**Windows**					
	Supply and installation of Tango aluminum with PS section, double glass 6mm, in accordance with industry standards. [29]	M2	70.25	2000	140500	 Figure (37): Source: [36]
5	**the doors**					
	Supply and installation of Tango aluminum with PS section, in accordance with industry standards. [29]	M2	57.2	2000	114400	
6	**Air conditioning works**					
	Supply and installation of concealed air conditioning works for insulation rooms, cooling capacity of 2 tons of cooling - Carrier brand. [30]	NO	9	290850	2617650	 Figure (38): Source: [37]
0	**Electricity works**					
	Supply and installation of a white, anti-bacterial headboard unit made of high-strength aluminum. [31] **300 US dollars** [32]	NO	135	9276	1252260	 Figure (39): Source: [38]
8	**Curtains work between the beds**					
	Supply and installation of PVC leather curtains of the antibacterial type, including the fabric in detail with accessories, with the aluminum sector and the hanging tie. [33]	M	1152	300	345600	 Figure (40): Source: [39]
9	Caravan works					
	Supply and installation of prefabricated caravans for bathrooms. [34]	NO	2	60000	120000	 Figure (41): Source: [40]
	Supply and installation of prefabricated intensive care units .[35]	NO	4	463500	18540000	 Figure (42): Source: [41]

	Supply and installation of prefabricated 3*9 doctors' housing units, including 2 rooms, a bathroom, and an office[34]	NO	4	63000	252000	 Figure (43): Source: [42]
	Total				**11855570**	
	Twelve million pounds, estimated					

Results :

1- when comparing to the item of prefabricated units only for the establishment of a field hospital:

No	items	No	Item price	Total in EGP
1	Supply and installation of prefabricated intensive care units.	**5**	**465350**	**2326750**
2	Supply and installation of prefabricated isolation units for	**50**	**300000**	**15000000**
3	Supply and installation of prefabricated housing units for	**4**	**63000**	**252000**
4	Supply and installation of prefabricated bathroom units.	**4**	**60000**	**240000**
	Total in EGP			**17818750**
	Approximately the total cost of constructing 100 beds for prefabricated units is only eighteen million pounds			

table (9): Cost of prefabricted units to establishment a field hospital.

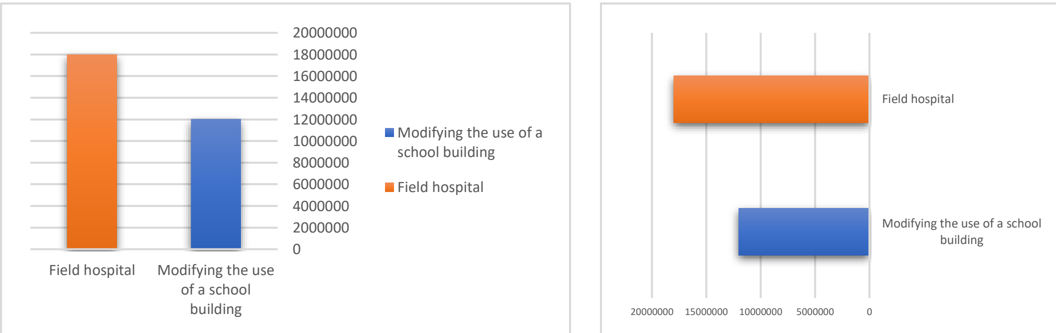


Figure: (44) A comparison between the cost of ready-made units for establishing a field hospital and modifying the use of the school building

- **From the results, we find that modifying the use of the school building takes a lower cost compared to operating a field hospital.**

2- When comparing the time factor between modifying the use of the school building and the field hospital:

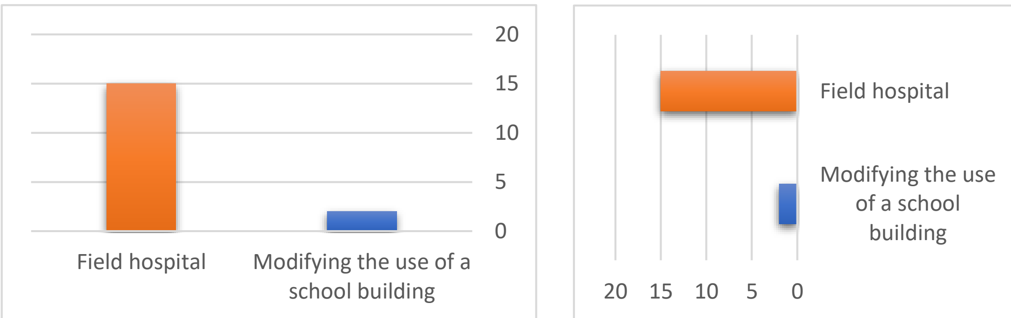


Figure: (45) :A comparison between the time of constructing prefabricated units to establish a field hospital and modifying the use of the school building

- **From the results, we find that: Modifying the use of the school building takes less time to prepare than making a field hospital**

Conclusions:

- Temporary units have been built around the world as an emergency measure to help victims of armed conflicts, natural disasters, epidemics, and pandemics. This was the case with the new coronavirus, which required the construction of field hospitals around the world. They were planned and built according to the characteristics of the situations they faced, and they can have variable physical structures as they must be easy to transport and assemble.
- Field hospitals are easy to disassemble, assemble, and transport, and they are considered one of the strongest solutions in emergency situations.
- Shelter hospitals can be one of the strong solutions for national responses to the COVID-19 pandemic and future epidemics and public emergencies.
- The proposal to modify the use of the school building is considered an effective solution as it takes less cost and less time to prepare compared to building a field hospital.
- This study presents one of the economic and effective solutions that can expand the capacity of isolation facilities, especially in developing countries, in terms of resource use, environmental, social, and cultural standards that must be taken into account in the design and implementation of health facilities in crises and emergencies.

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