# A typological analysis of temporary medical structures before and during the Covid-19 pandemic.

How can design help us to deal with situations of crisis and emergency?

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# Content

# 1 Introduction: What is a situation of crisis and emergency? A historical consideration of the typology of the temporary medical structure.

### 1.1 Implementation of temporary medical structures during Covid-19

In situations of crisis, regular hospitals often do not longer suffice the high demand for medical care. In this case, temporary medical structures become indispensable. The Covid-19 pandemic has shown how quickly a situation can get out of hand for the health sector, even in countries with a supposedly stable health system. The rapid evolution from a local epidemic in China to a global pandemic in the course of March 2020 suddenly brought alarming problems such as the shortage of intensive care beds and pushed healthcare systems worldwide to their limits. Additionally, the safe interaction between staff and patients was often not possible anymore in existing structures due to the high risk of infection. The nature of the virus brought architectural challenges like the spatial re-organization of health institutions for high occupancy levels, the issue of infection control, the integration of new technologies, and the flexible and sustainable use of space to the forefront. As a result, designers were urged to think of effort-, material- and cost-efficient structures that could be built in a very short amount of time. This resulted in innovative solutions, from which we can learn for future situations of crisis and emergency.

### 1.2 Scientific approach

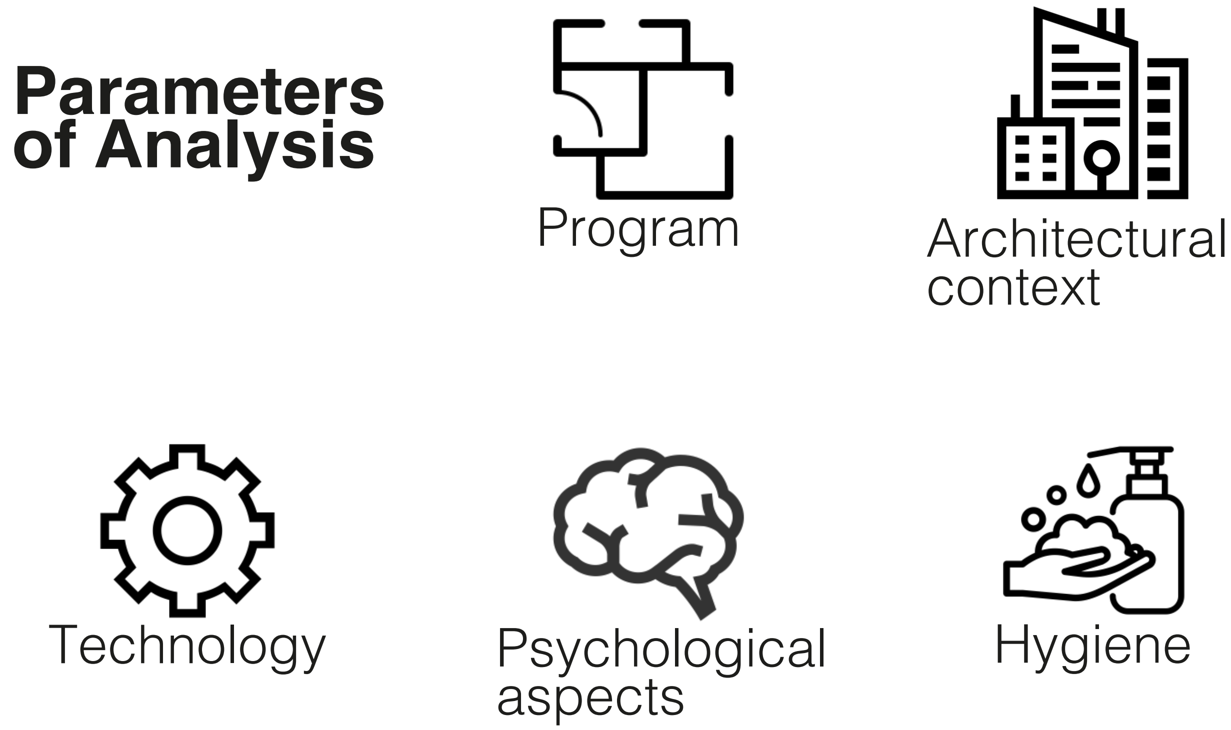
The aim of my thesis is to create a “catalogue“ of design strategies within the typology of the temporary medical structure that can be applied to future projects during the Covid-19 pandemic but also be transferred to different scenarios in which requirements overlap. Therefore, example projects will be embedded into their context and examined by means of certain parameters. These parameters revolve around the topics of hygiene, psychological aspects, program, technology, and the architectural context. In this way, the reader should be given an overview of how recurring or specific issues have been addressed in the case studies. The investigation in this thesis will be based on publications, articles, statements, and interviews with health professionals. Since the Covid-19 crisis is still ongoing, there are not yet many historical publications that engage with projects that were realized during the crisis in detail. This is why the thesis builds upon the academic context of historical publications which deal with medical crisis situations from the recent past. However, there is a large body of articles and guidelines referring to the Covid-19 crisis that provide information about current projects and show important factors to consider while designing temporary medical structures. The “Guidelines for Covid-19 Quarantine and Treatment Centers in the Ethiopian Context. Spatial and Engineering Requirements of the Physical Structure.”, produced by the Association of Ethiopian Architects (AEA) and published by the International Union of Architects (UIA), offers a clear summary of more fundamental publications like the WHO‘s standard for Severe Acute Respiratory Infection (SARI) Treatment Facility Design and narrows down the scope to the requirements for treatment facilities in relation to Covid-19. Furthermore, it textually and graphically presents design approaches that show how these requirements can be dealt with. This is why the publication will form the basis for the analysis of the example projects in my thesis.

### 1.3 Analytical approach

In order to frame the typology of the temporary medical structure and to examine the ways in which it is commonly implemented in disaster response, three designs for different emergency situations before the Covid-19 crisis are compared and common solutions for the most obvious design challenges are highlighted. In addition, I will explore what leads to the emergence of temporary medical structures. Thereafter follows an assessment of the specific arising challenges created by the ongoing Covid-19 pandemic that are posed to health-related architecture. Then a number of example projects of temporary medical structures that were built in direct response to the ongoing Covid-19 pandemic are analyzed and compared. In doing so, their different reactions to the consensus of the emerging challenges are highlighted.
In order to make the example projects comparable for my conclusion, I structured their analysis with the above-mentioned parameters. I decided to show very distinct design approaches, to capture a wide range of possibilities of tackling a certain problem. In this way, the thesis should serve as a source of inspiration for architects and whom it may concern in the medical field.

### 1.4 Implementation of temporary medical structures in disaster response

Sudden emergency situations can occur in the form of epidemics, pandemics, wars, large refugee movements, or natural disasters such as storms, earthquakes, tsunamis, or wildfires. Since some of these emergency situations have a similar kind of medical demand, they can be categorized into three main groups: illness-related crises, situations of danger and displacement, and natural disasters. To explore the requirements each of those situations imposes on the medical sector, specific examples of situations from the recent past in which temporary medical structures played an important role will be presented and analyzed. For each of those three situations, I will show a design of a temporary medical structure and discuss why there was a need for a temporary solution and what effects the specific situation had on the design. The chapters also aim to illustrate how crisis situations occur and what leads to them.



# 2 Illness related crisis – West African EVD epidemic 2014

### 2.1 The Ebola Virus Disease and its development into an epidemic

In March 2014, Guineas Ministry of Health reported an alert of an unidentified illness in its capital Conakry, which was shortly after confirmed as an Ebola Virus Disease (EVD). Due to the insufficient preparedness, EVD soon spread to the bordering countries Liberia and Sierra Leone and took hold in densely populated urban areas that facilitated its transmission. The epidemic was declared a Public Health Emergency of International Concern (PHEIC) by the WHO in August 2014. Soon after, the disease spread to several other African countries, Europe, and the U.S. The 2014 West African EVD epidemic was the most devastating since the discovery of the Ebola Virus Disease in 1976, claiming more lives than all previous outbreaks together.
In dependence of the availability and quality of medical care and the species of the virus, case-fatality rates in past EDV outbreaks have varied between 25% to 90%, with an average of 50%. Thereby it becomes apparent that the Ebola virus is transmitted differently and is more lethal than the SARS-CoV-2 virus.
The disease is transmitted from wild animals to humans and between humans through blood, secretions, organs, or other bodily fluids. The human-to-human transmission mainly takes place via direct contact or through contaminated surfaces and materials. Beliefs that are conflicting with contemporary medicine, burial practices that involve touching the deceased, and the long incubation period of up to 21 days, have made it difficult to contain the spread of the virus. (WHO, 2014)

**Fig.1** Medical assistants accompany an infected woman in Monrovia. | © AFP, https://ichef.bbci.co.uk/news/976/media/images/75589000/jpg/_75589471_afp.jpg

Fig.1

### 2.2 The Chinese Ebola Treatment Center in Monrovia

Liberia’s capital Monrovia was one of the hardest-hit regions and therefore received aid from international organizations, governments, and UN agencies. This involved the transformation of the existing Monrovia “Island Clinic” into an Ebola Clinic through the WHO, the setting up of eight Ebola Treatment Units (ETU’s) and several field hospitals through USAID and the US military, a tent hospital by MSF, and an Ebola Treatment Center (ETC) by the Chinese military.
Since the end of the Second Liberian Civil War in 2003, neutral China had been a peacekeeper and trading partner of Liberia and many Chinese firms won contracts for post-war reconstruction projects in the country. (Paye-Layleh, J. & Roy-Macaulay, C., 2014) According to the Chinese government, by December 2014, 122 million US$ and around 500 Chinese medical professionals were sent to Ebola-hit countries in West Africa, including Liberia. (Chinese Government, 2014) The Chinese Ebola Treatment Center (ETC), established on the parking lot of the SKD Stadium in Monrovia, was opened on the 25th of November 2014. The 5000m$^2$ structure was built within 28 days from prefabricated boards and the functional parts of the ETC included 16 buildings. Inpatient wards were constructed based on a hospital built and developed in Beijing, China during the Severe Acute Respiratory Syndrome (SARS) outbreak in 2003. The E-shaped main building included a division in “clear”, “potentially contaminated” and “contaminated” areas that forced staff to move through the structure in a one-way direction and to use the buffer zones for changing their personal protective equipment (PPE). In this way, fresh equipment could be transported through the clean pathway, and used equipment or waste could be safely transported out of the building through the contaminated pathway. This division took its inspiration from the simple tent-type structures set up in Monrovia earlier by MSF.

**Fig.2-5** The Chinese Ebola Treatment Center on the 25th of November 2014. Liberian President Ellen Johnson Sirleaf attended the opening ceremony. | © Xinhua, http://english.www.gov.cn/news/international_exchanges/2014/11/26/content_281475015514550.html

Fig.2


Fig.3


Fig.4

Fig.5

However, the comparably solid construction method that was used in the Chinese ETC had the advantage of being more resistant to harsh weather conditions such as direct sunlight or rain. A central monitoring system via video cameras and an intercom was used to communicate with patients and to give advice to healthcare workers, especially during the critical moment of taking off their protective gear in the buffer zones. The wards were equipped with in-room ultraviolet disinfection lamps and a bedside alert system that should reduce the anxiety of patients.
According to a report, an additional ventilation system had to be retrofitted because the chloride emissions from disinfectants irritated the eye and nasal mucosa of healthcare workers. This and the remarkably higher costs for the Chinese ETC can be seen as clear disadvantages in comparison to the open tent-like structures of MSF and USAID. (You & Mao, 2014)
There have been no large-scale violent clashes in Liberia since the signing of the final peace agreement in 2003. As a result, the safety precautions for the operation of hospitals were largely related to hygiene measures such as protective clothing, spatial separation of infected patients, and keeping the environment clean. (Herbert, 2014) The following example is intended to illustrate the difficulties involved in setting up hospitals in a war situation and how this affects the architecture of temporary medical structures.

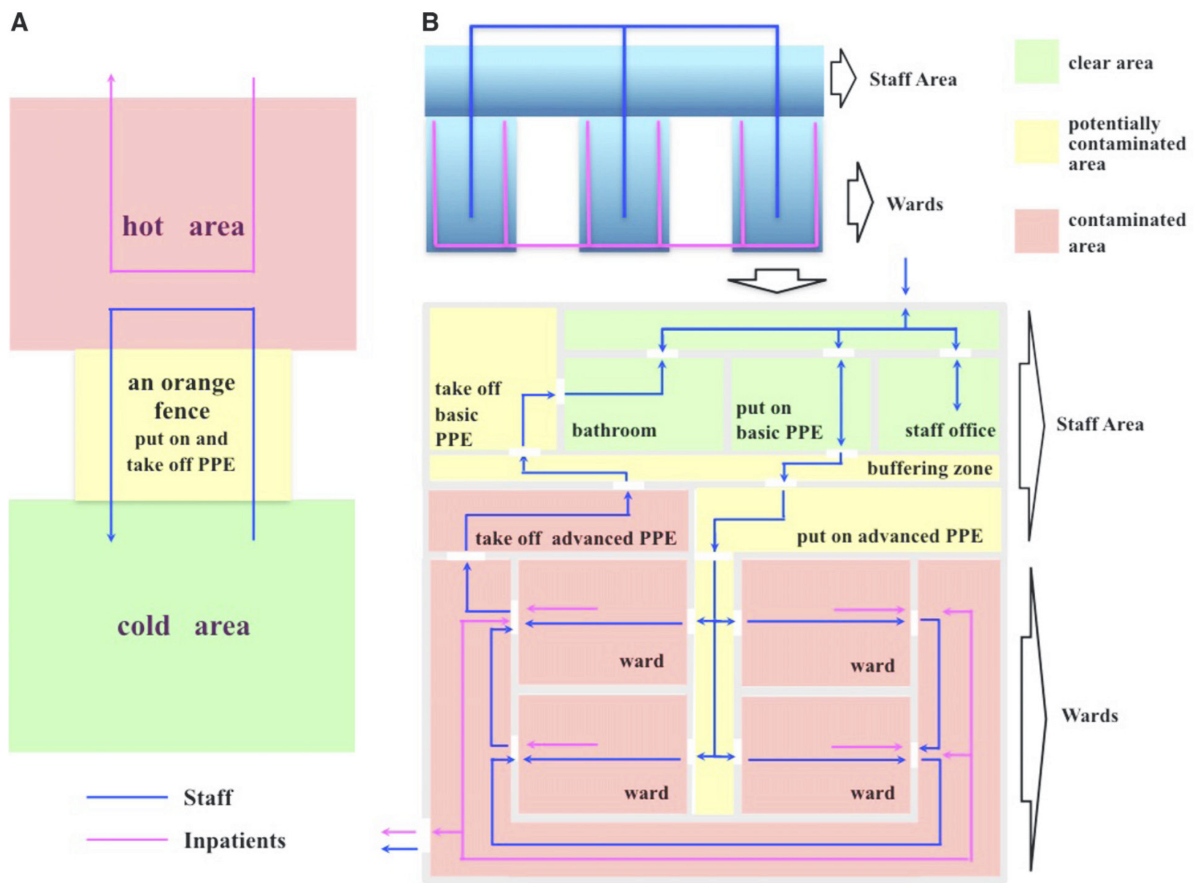



**Fig.1** Layout and zoning of the Chinese Ebola Treatment Center (B) compared with the layout and zoning of the simple tent-type structures in Monrovia such as the ones used by MSF (A). | © You & Mao, 2014

Fig.6



# 3 Situation of danger and displacement – Internally displaced people as a consequence of the South Sudan civil war

### 3.1 Historical background of the South Sudan civil war from 2013-2018

The East African country of South Sudan achieved its independence in 2011 after two brutal civil wars and decades of conflict between the north and the south, making it the youngest country in the world. A complex civil war between government forces and rebels erupted in December 2013, when President Salva Kiir Mayardit, an ethnic Dinca, accused the former vice president and opposition leader Riek Machar, an ethnic Nuer, of a coup attempt. (Abdallah, 2018) The control over oil fields in the states of Unity and Upper Nile played just as big of a role in the war as centuries of clashes between the Dinka and Nuer ethnic groups. (Titz, 2019) The escalation of these tribal conflicts led to targeted attacks on villages and mass killings of civilians by both parties which brought the country to the brink of genocide. Over the course of 2014, more than 1.3 million citizens had to flee their homes and by 2017, almost 2 million people were internally displaced and living in camps in their own country. (United Nations, 2016)

### 3.2 MSF tent hospitals in South Sudan's POC sites

Médecins Sans Frontières had already been in South Sudan for more than 30 years to provide medical care to remote regions and to maintain training hospitals for the education and training of local doctors. When war broke out in late 2013, one of the services provided was the emergency treatment of victims of violence.

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Fig.7

For this reason, several of the facilities were attacked in early 2014, including one of the oldest and strategically most important facilities in Leer. (MSF, 2014) From then on, MSF was active in the protection zones of the United Nations Mission in South Sudan (UNMISS), offering medical assistance to Internally Displaced People (IDP). These Protection of Civilians (POC) sites, although secured by UN soldiers, have been the target of attacks on several occasions. Therefore, the MSF tent hospitals include bunkers in addition to medical wards, infirmaries, surgical tents, a variety of treatment rooms, pharmaceutical and material storage, and staff housing.
The tent-type buildings used by MSF consist of a structural frame from either wood or metal which is covered in a skin from textile or plastic. The construction of those structures is executed by all-round logisticians who often have a background in the construction industry and work together with the local communities. (MSF, 2016) When materials cannot be sourced locally, MSF's logistics and supply departments organize their delivery. This can take up to several weeks in a non-emergency situation, while in emergency response, supply centers are able to deliver ready-to-use kits to the field within 48 hours. These kits can contain everything from surgical equipment to entire field hospitals. (MSF, 2016) According to MSF logistician Raque Kunz, who was working for MSF in Agok, materials for a 6-month period should be gathered on-site before the onset of the rainy season, as roads become hardly passable by then. (MSF, 2016) Since South Sudan can expect half a year of intense heat and half a year of intense rain, the structures must be able to withstand these extreme weather conditions, which is another major challenge in addition to the fragile security situation. In order to achieve a constant temperature, especially pharmaceutical storage facilities must have strong insulation in the roof, but also in the walls.

**Fig.8-10** Two different types of medical wards: Timber frame with corrugated sheet metal cladding (Fig.8) and aluminum frame with a skin from white fabric (Fig.9,10). | © Dr. Mühl-Benninghaus

**Fig. 11** MSF doctors in front of a surgery tent in South Sudan. | © Dr. Mühl-Benninghaus

Fig.8

Fig.9

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Fig.10

Fig.11



The insulation of the structures includes a multilayer, heavy, and reflective white outer skin made of textile or plastic. On top of this, reflective foils are applied or black cloths are placed at a certain distance to the roof to reinforce the natural cooling of the primary outer skin by back ventilation. Alternatively, hanging cloths can be used underneath the roof to provide a second shield for the intruding heat. (Willemsen, 2016) The bunkers consist of a somewhat more solid framework and are protected from gunfire and small detonations by heavy volumes, mainly sandbags, in the walls and ceilings. The electricity for lighting, air conditioning, and instruments is generated either by solar fields, fuel-driven generators, or both. MSF logisticians and local maintenance crews ensure the operability of these devices through daily checks. According to MSF surgeon Dr. Mühl-Benninghaus, air conditioning in surgical tents might be a pleasant feature for all involved but it is not mandatory to incorporate in field hospitals. Contrarily, every surgeon is obligated to have a headlamp within reach in case of a power failure.

Fig.12

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Fig.14

Fig.15

### 3.3 The MSF mass casualty plan

In the event of a mass casualty incident, the number of seriously injured patients can exceed the current capacity of the hospital. In this case, a mass casualty plan is immediately put into effect and sirens inform the hospital staff about the situation. Hereafter, the hospital is cleared of patients who are well enough to leave and all entrances except one are closed. The main entrance now serves as a filter where only one other person per patient is allowed to enter. The staff frequently trains the scenario and is assigned positions they take when the plan comes into effect. The hospital building is now divided into 4 zones: green, yellow, red, and black. In order to save as many lives as possible, a doctor has to perform triage, which means that those colors are assigned to each casualty. Since this has to happen quickly, the decision is based on simple criteria that evaluate the patient's condition. Thereafter, the casualties are dispatched to the 4 zones in the building. The green zone is meant for patients whose treatment can wait, the yellow zone acts as a buffer zone, and the red zone is for patients who must receive priority treatment. If it is decided that a patient's life cannot be saved with the available resources, they receive palliative care in the black zone. (MSF-USA, 2017) Mass casualty plans usually come to use in crisis situations such as wars, natural disasters, and infectious diseases. However, the WHO has issued templates for mass casualty plans and most hospitals worldwide have them incorporated into their program. (WHO & CBS&EI, N/A)

**Fig.16** Zoning of an MSF hospital during an activated Mass Casualty Plan.

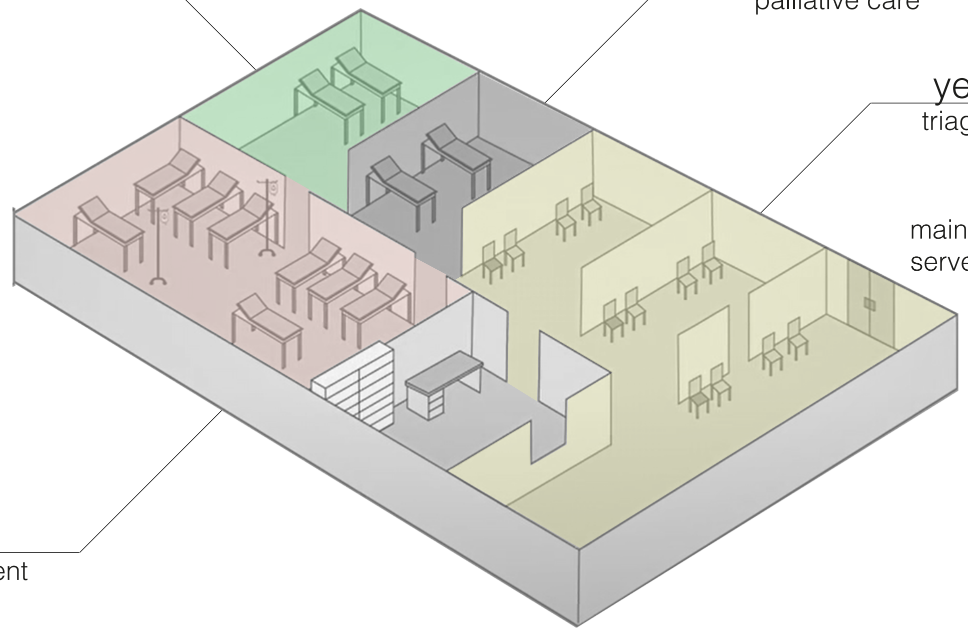


Fig.16



# 4 Natural disaster - The 2010 Haiti Earthquake

### 4.1 Social issues in Haiti and the impact of the 2010 earthquake

The island of Hispaniola was the victim of a devastating earthquake with a magnitude of 7.0 on the Richter Scale on January 12, 2010. Its epicenter was located in the town of Léogâne, 25 kilometers from Haiti's capital Port-au-Prince, and the primary quake lasted less than 30 seconds. According to various sources, between 220.000 and 300.000 people died as a result of the quake and its aftermath in Haiti. (MSF, 2020) USAID estimated the number of displaced people at 1.5 million one year after the disaster. Although the Dominican Republic was as well affected by the quake, the impact on Haiti was much greater due to its fragile economic and political situation, leading the country into a humanitarian crisis. As a result of the widespread destruction of infrastructure, large parts of the country were still in ruins months after the quake. In addition, the lack of hygiene in refugee camps led to a cholera endemic that killed 10.000 and lasted into 2019. (Mitchell, 2021)
The main reasons for the unequal impact of the earthquake on Haiti and the Dominican Republic were poor political relations and a resulting economic inequality between the countries. This can be traced directly to the colonial past and to a complex history of oppression through state debt and institutional racism. Although the Dominican Republic was one of the countries to send the largest contingents of disaster relief in the immediate aftermath of the 2010 quake, racism and ethnic violence against Haitians was fueled when many fled their country for better living conditions in the D.R.

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Fig.17

This led to the deportation of Haitians and the revocation of citizenship for Dominicans with Haitian roots who were born on Dominican soil after 1929. This political decision rendered 210.000 people stateless refugees, most of whom had lived normal lives in the Dominican Republic for generations.

### 4.2 Implementation of the Rapid Deployment Emergency Hospital by the IFRC

In response to the 2010 earthquake, national governments and NGOs undertook massive disaster relief efforts in the form of funding, the dispatch of humanitarian supplies, and the deployment of rescue workers, technicians for reconstruction, security personnel, and medical staff. (The Guardian, 2014) According to MSF, 60% of Haiti's already fragile health system was destroyed through the earthquake, and 10% of the medical staff were killed or left the country. (MSF, 2020) This meant that international aid was required to set up temporary medical facilities to support the remaining infrastructure and to cope with the enormous amount of patients.
Besides MSF, who already were in the country and started patient treatment minutes after the quake, the International Federation of Red Cross and Red Crescent Societies (IFRC) was one of the first international organizations to respond. Latter mobilized their largest single-country emergency response operation to date.
The global emergency response standby tools of the IFRC consist of Emergency Response Units (ERU's) which include specially trained IFRC staff and standardized, pre-positioned equipment that can be deployed to anywhere in the world in a matter of 24-72 hours. The unit that was mainly used in the Haiti earthquake response was the Rapid Deployment Emergency Hospital (RDEH), which is one of two health ERU types.

**Fig.18** IFRC ERU deployments worldwide from 1996 - 2011 | © IFRC, https://www.ifrc.org/Global/Statistics/Disasters/ERU-deployments-map.pdf

The standard version of the RDEH ERU consists of a tent structure with 20 beds that forms a medical and surgical facility. It is equipped with water purificators, sanitation and telecommunication systems, and generators that provide the hospital with electricity for lighting and electronic devices. Furthermore, it is delivered with vehicles and a base camp for the 12-14 specially trained personnel. By the end of January 2010, there were 20 ERU's deployed by the IFRC in Haiti. One of the RDEH ERU's was set up at the main university hospital in Port-au-Prince and later relocated to the southwest of Haiti. This particular RDEH was flown in from Oslo, Norway, and received the first patients on the 16th of January, 4 days after the primary earthquake happened. The expanded staff of 30 consisted of two surgical teams, one outpatient team, a midwife, nurses, technicians, administrators, community health specialists, psychosocial support specialists, and paramedics. The team arrived between the 15th and 19th of January. The IFRC Field Assessment Coordination Team (FACT) and an advance team of two arrived 24 hours prior to the ERU to identify the site and to evaluate the situation. Due to the lack of availability, the ERU could not be loaded to the Ilyushin 76 cargo plane, for which it was designed, but had to be split up to two smaller Antonovs and a Boeing 747. The specific Antonov cargo planes are self-offloading aircraft, which gives them an advantage in emergency situations, where off-loading equipment is often not available on site. In this way, they were able to land directly in Port-au-Prince, while the Boeing 747 landed in Santa Domingo, from where the equipment was trucked to its destination. During the four weeks in which the RDEH ERU was stationed at the university hospital, the outpatient department received an average of 70-80 patients per day, 300 surgeries were performed and the existing hospital received support in the form of advice and materials by the ex-pats. (Elsharkawi, Jaeger, Christensen, Rose, Giroux & Ystgaard, 2010)

**Fig.19** Systemic plan of one of the ERU's which were used in Haiti.| © John Alexander, https://docuri.com/queue/momtaz-red-cross_59c1e515f581710b286b88df_pdf?queue_id=5f2e5dda-560e9cbc758b458a

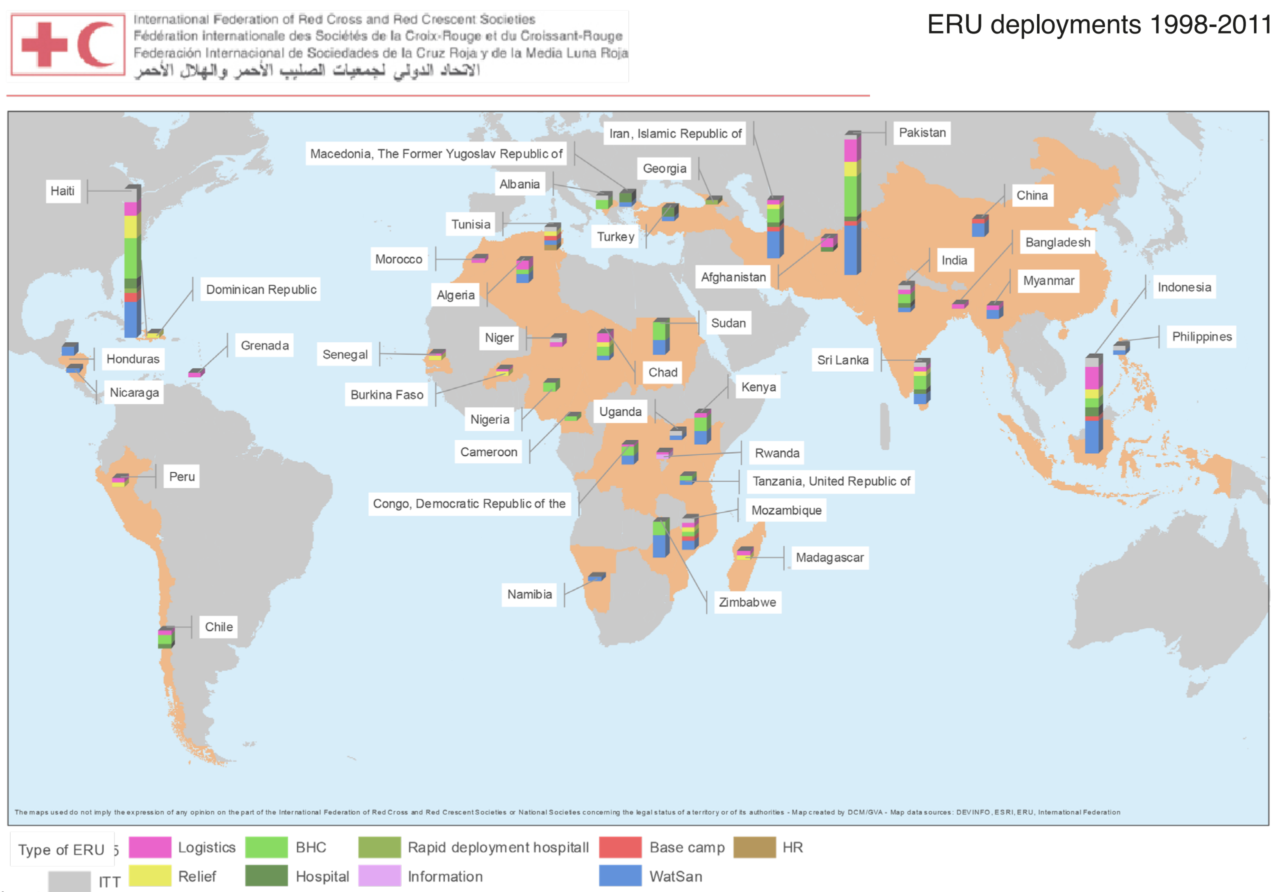


Fig.18

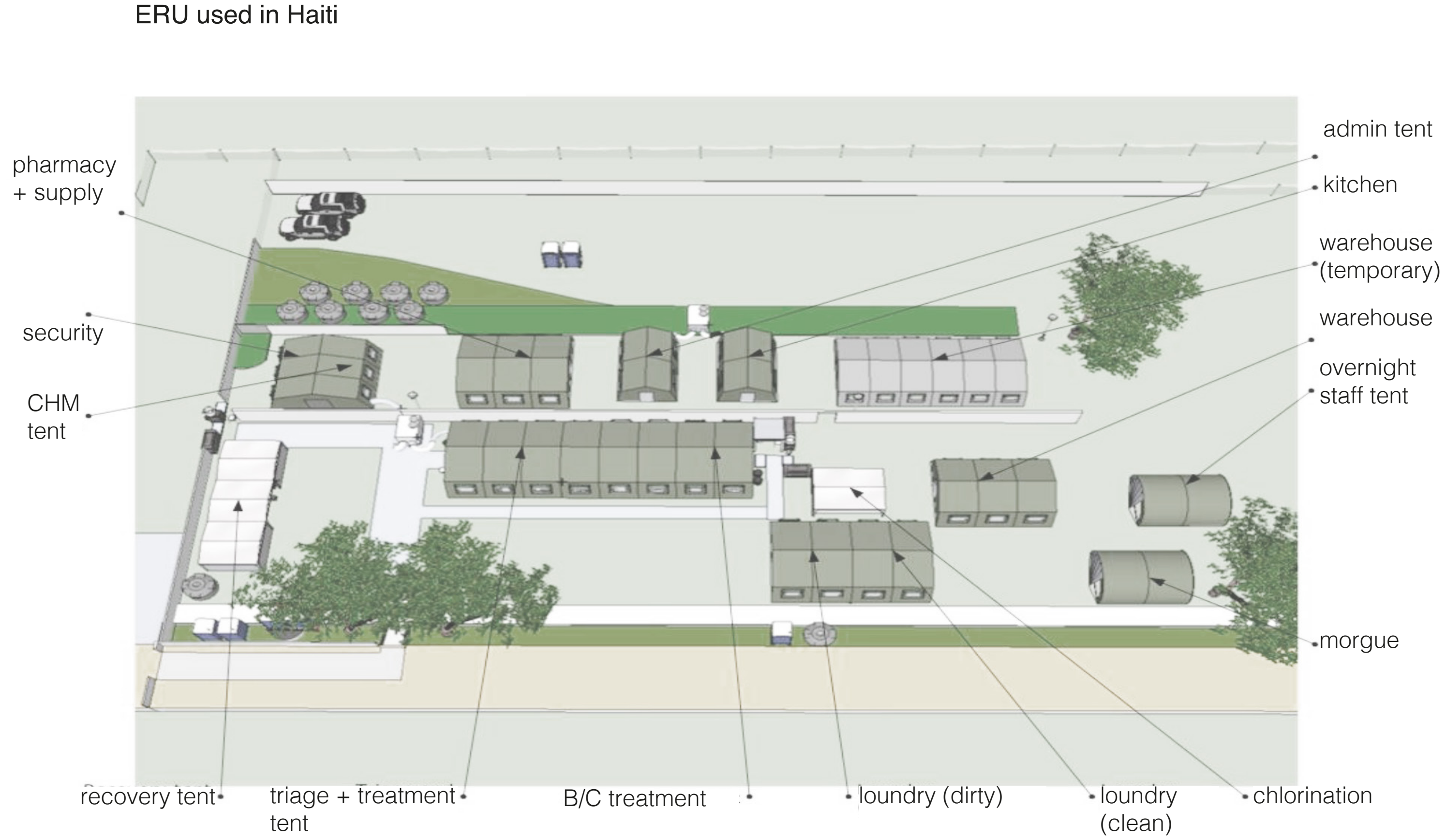


Fig.19

# 5 Implementation of temporary medical structures in past crisis situations

From the previous case studies, it became clear that temporary medical structures are usually implemented when the capacity of a regional health care system reaches its limits due to an unforeseen change in the situation, and when a permanent solution to the underlying problem appears to be too expensive, protracted or unfeasible. The reasons for this can be a lack of national economic power, political instability, or the extensive destruction of infrastructure. Aid then usually comes from governments of richer countries that maintain political relations with the affected countries, or from international NGOs with a humanitarian approach. For these kinds of crisis situations, flexible plans are put into place, which are capable of providing medical aid to a large number of people and of covering a wide range of scenarios. Professional personnel, pre-packed materials, and the necessary logistics are constantly kept on standby, and procedures are rehearsed to facilitate an intervention on a regional level in the event of a crisis. Usually, the types of temporary medical structures which are implemented in crisis situations can range from simple tent structures, partly built with regional materials and flown-in building system kits to individualized structures from prefabricated elements. The choice about the type of structure always depends on the timeframe of the mission, climate and terrain, availability of materials, political stability, and internal security of a region.

In the case of the EVD epidemic in Liberia, aid organizations were dealing with a situation that, albeit being tragic, took place in a peaceful environment with a functioning infrastructure. This meant that even more complex projects with larger building components could be transported to the site without having to fear the loss of building parts through attacks. This reduced the risk of delayed finalization of the building or the cancelation of the entire project. Although EVD case numbers started to diminish shortly after the arrival of the organizations, it was initially expected that the battle with the illness required a long-term solution. In this way, the decision for a pre-tested full-scale hospital using pre-fabricated components that were flown in from abroad presented the fastest way of providing quality medical care to a large number of patients.

In contrast to the EVD epidemic in Liberia, providing aid in the UN POC sites during the South Sudan civil war from 2013-2018, presented a chaotic situation that required simple solutions. With basically no infrastructure and extreme levels of violence, reaching the UN-protected camps with all materials intact, was crucial for the success of the mission. A hybrid tent-type solution from different frame and cladding materials that could be sourced either locally, or be delivered as ready-to-use kits, presented the best way of dealing with this issue. By not relying on a sophisticated and complex building system, enough flexibility was gained to adapt to numerous scenarios. Through the separation of the functions - such as patient wards, surgery, or bunker - to different tents, it became possible to expand on certain functions over time, or to reduce others, simply by adding or subtracting tents.

This flexible logic of functional division is also included in the RDEH ERU‘s that came to use in the aftermath of the 2010 Haiti earthquake. The main difference between providing aid to the internally displaced people in South Sudan‘s POC sites and the treatment of victims of a natural disaster, like the Haiti earthquake, are the intensified requirements towards time management. While in war zones punctual mass casualty incidents can lead to a high amount of severe injuries, many of them gunshot wounds that require specially trained surgeons, an earthquake produces an unexpected mass casualty incident that can affect large parts of the population of an area. Therefore, in such situations, action must be taken extremely quick in order to be able to help the wounded survivors. This demands a compact and pre-packed building system with medical staff and vehicles on standby, through which the arrival of all components to the site can be ensured despite the destruction of infrastructure. The RDEH ERU presents an elaborated solution, that can be deployed to any part of the world within a matter of days.



# 6 Design challenges created by the Covid-19 crisis

On January 30, 2020, the WHO classified the spread of Covid-19 as a „Public Health Emergency of International Concern.“ The initially location-bound spread subsequently developed into a conflagration, which was declared a pandemic by the 11th of March. Healthcare systems worldwide have been pushed beyond capacity by the ever-growing number of COVID-19 patients ever since, and the need for hospital beds, ventilators, PPE, Intensive Care Units (ICUs) and isolation rooms vastly outstripped the available supplies in many places. The Covid 19 pandemic represented a novel crisis situation that the world had never seen before on this scale. The main challenge was, and still is, to deal with a highly contagious virus that can be hardly brought under control due to a globalized world.

As case numbers continued to rise in the first months of 2020, governments were doing their best to contain the virus by enforcing “lockdowns“ and curfews. In many countries, this resulted in the succumbing of large parts of public life. In desperate attempts to save the national economies from being ruined, many countries loosened measures, which resulted in a stagnation of case numbers and the recurrence of “waves“. For hospitals, this meant that they always had to calculate with an unexpected rise of case numbers, resulting in a scarcity of isolation wards, respiratory equipment, and intensive care beds.

To increase the capacity and spatial efficiency, the layout of many existing hospitals was re-arranged to create safe environments for the interaction between healthcare workers and patients. This required a spatial division and zoning that guaranteed a low risk of cross-contamination. Especially patients without symptoms, who came to the hospitals for other reasons, had to be prevented from catching and spreading the virus. Besides spatial delimination, solutions were found in the implementation of materials with cleanable surface properties, biocontainment ventilation systems that met infection control requirements, and IoT-ready solutions that facilitated the monitoring and management of large amounts of patients. The isolation of patients in critical condition also raised questions about what architecture could do to ensure their mental health besides the physical health, and how family members could still make visits.

These new aspirations which were posed to hospital architecture, some of which are only valid for the duration of the pandemic, could not always be incorporated within the boundaries of the existing hospital infrastructure, and therefore often required elaborated supportive temporary structures. In searching for these medium-term solutions, innovative architectural works have emerged within the typology of temporary medical structures, which can be classified into four categories: Lightweight construction, container architecture, pneumatic architecture, and the adaptation of existing structures. While the lightweight construction method is quick to erect, mobile, and cost-effective, containers can be well insulated, selectively ventilated to meet biocontainment requirements, and are able to withstand harsh weather conditions. Pneumatic architecture is quick to set up and highly portable, while adaptation of existing structure presents a good interim solution for unused spaces that can generate large-scale hospitals with minimal effort. The following chapters will address at least one representative project from each of these categories, and discuss the advantages and disadvantages, as well as how we can learn from the concepts for future crisis situations.

# 7 Lightweight construction

## Series of mobile health units - JUPE Health

The U.S. was one of the countries that were most affected by the pandemic. As of the mid of April 2020, the number of Covid-related deaths peaked with a mediocre value of more than 2000 new deaths per day and the U.S. became the country with the most reported corona deaths worldwide before Italy and Spain. (Shumaker, 2021)
This development was driven by inconsequent countermeasures against the spread of the virus sides the Trump administration. Federal leadership of the country failed, and most decisions about the handling of the situation were conceded to the individual states, which led to inconsistent regulations. The social-distancing measures were only slowly introduced to the population, tests were delayed and the wearing of masks was only advised and not made mandatory. (Paz, 2021)
Hospitals were clearly not prepared for this new type of situation and soon faced shortages of PPE, respiratory equipment, and personnel, alongside massive over-occupation. For this reason, temporary medical structures started to pop up across the country with the U.S. military, national guard, and civilian companies involved in their construction. Large indoor event spaces such as stadiums and fairgrounds were repurposed, and outdoor spaces such as parks and parking lots were covered with tent structures. (Singelis, 2021) Even though proven mobile hospital solutions and care tents by healthcare and military organizations were used as much as possible, large parts of the structures were rather provisional and set up by companies that had little to no experience in the health sector. (Brown, 2021) Due to the fact that many of the existing solutions were transported in shipping containers and were not exactly designed to be very efficient in quantitative terms, the U.S. start-up Jupe Inc. came up with

**Fig.20-23** The three types of mobile JUPE Health Units: Jupe Care (Fig.20), Jupe Rest (Fig.21), and the mobile Intensive Care Unit (ICU) Jupe Plus (Fig.22). Jupe Care and Plus units are also available with a wooden hard shell (Fig.23). | © JUPE, https://www.archdaily.com/936378/jupe-health-designs-mobile-units-to-address-hospital-bed-shortage-from-covid-19

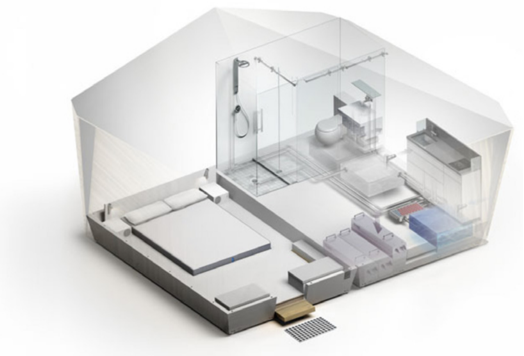


Fig.20

Fig.21

Fig.22

Fig.23

a solution, that was tailored to the specific situation and could be easily and cost-efficiently produced. The company which previously developed affordable tent-type housing solutions, teamed up with a multidisciplinary team of experts to create a set of affordable and highly deployable mobile units that were based on a housing concept they had developed for displaced people. The team surrounding the company's co-founders Jeff Wilson and Cameron Blizzard consisted of Chief Medical Advisor Dr. Esther Choo, Chief Humanitarian Advisor Cameron Sinclair, along with former employees of Space-X and Tesla, and multiple medical experts who were experienced in crisis situations. (Price, 2021) The manufacturing techniques of the units were inspired by common practices from the automotive, space, and software industries. The flat-packed health units were developed, so 24 of them could fit in a 40-foot shipping container or onto a standardized "40-foot flatbed" trailer pulled by a pick-up truck. In theory, 500.000 units could therefore fit on a single cargo ship. This allowed for highly efficient transport of the units to rural as well as urban areas across America. While the main production site is still located in the El Paso region at the moment, the company is striving for partnerships with both national and international manufacturers. (Gibson, 2021)
In order to be able to cover a wide range of requirements posed by the pandemic, three standalone units were developed: JUPE Rest, JUPE Care, and JUPE Plus. Medical professionals who are exposed to the virus in their work, have widely stated that they are afraid to travel back home to their families in between shifts because they do not want to take the risk of a spread. With overcrowded hospitals and a general lack of space, this raised the question of where they could recover.
JUPE Rest was developed to serve as a sleeping unit and "micro self-isolation room" for this purpose. Included are either two single beds, or one "queen size" bed, storage spaces, waste containers, and batteries for temporary off-grid use. Wi-Fi and climate control are offered as optional features. It became clear very soon,

**Fig.24-26** 24 Jupe Health units fit into one standardized 40-foot shipping container (Fig.24).The Units are flat-packed (Fig.25) and therefore highly deployable. Moreover, they are very easy to assembe (Fig.26).. © JUPE, https://www.archdaily.com/936378/jupe-health-designs-mobile-units-to-address-hospital-bed-shortage-from-covid-19

Fig.24

Fig.25

Fig.26

that the course of the illness could vary in severeness from person to person. Also, different states of the illness require different levels of care and the spatial separation of infected persons is crucial in the limitation of a further spread. JUPE Care provides a unit for Covid-19 patients who are non-critical, to quarantine and recover. It includes all features of the JUPE Rest unit in addition to a full bathroom and kitchen. (Berting, 2021) The most elaborated of the units is JUPE Plus, a stand-alone isolation and intensive care unit (ICU) for Covid-19 patients who are in need of critical care. (Guimapang, 2021) This unit was designed to directly relieve hospitals, predominantly in North America's rural regions. The compact package includes everything from a bed to respiratory and monitoring equipment, a wet cell, and PPE for healthcare workers. It is highly deployable, relatively affordable, and capable of forming a micro-network that takes into account air monitoring, climate control, and noise-reducing technologies. JUPE Care and Plus units are both available with a soft fabric outer skin and a wooden hard shell, which are modular, interchangeable upon need and both fit into the flat-packed chassis format for transportation. (De51gn, 2021)

**Fig.27** Technical infrastructure of the standalone ICU JUPE Plus | © JUPE, https://www.archdaily.com/936378/jupe-health-designs-mobile-units-to-address-hospital-bed-shortage-from-covid-19

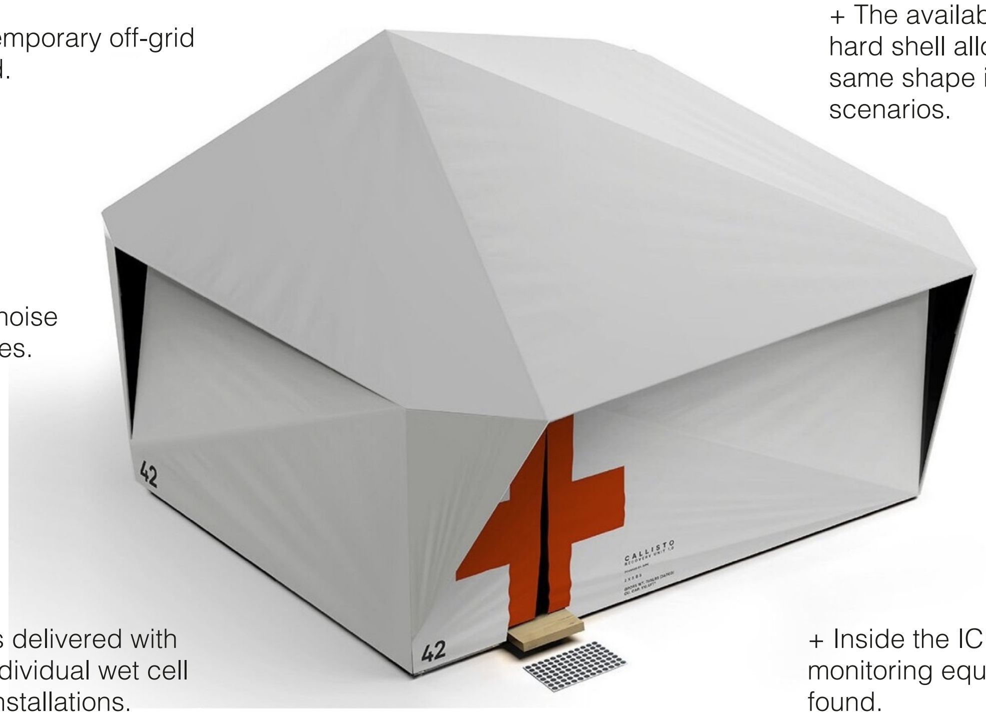



Fig.27



# 8 Container architecture

## 8.1 CURA Pods - Carlo Ratti Associati (CRA)

Italy was the first western country to be affected by the worldwide spread of the SARS-Cov-2 Virus originating from China's Wuhan region. In mid-April of 2020, Italy developed towards being the hardest hit country by the pandemic in Europe. Despite the nationwide quarantine that was enforced on the 9th of March, 205.463 infections were recorded between the 24th of February and the 30th of April, from which many cases developed the Severe Acute Respiratory Syndrome and 27.967 died. The majority of cases were concentrated in the northern regions of Lombardy, Emilia-Romagna, Veneto, and Piedmont. One major reason for the high death toll was the shortage of ICU space in hospitals. (Mirella Aliberti, De Caro, Boccia and Capunzo, 2021) As a response to the issue, Italian architecture firm Carlo Ratti Associati teamed up with an international task force to design a module that could add a fully functioning and mobile ICU to temporary and permanent hospitals. The outer shell of CURA (Connected Units for Respiratory Ailments) is based on a repurposed and modified, 20-foot shipping container.
The prior response to the shortage of treatment spaces in Italy was the setting up of either tent hospitals or prefabricated wards with biocontainment systems. While tents pose a higher risk of contamination and limit the possibilities of treatment, prefabricated wards are resource-, cost- and time-intensive. In this sense, the idea of modifying a shipping container as ICU incorporates "the best of both worlds".

**Fig.28** Illustration of one possible composition of CURA Intensive Care Pods from the human perspective.| © CRA

**Fig.29** A CURA Intensive Care Pod installed in a hospital in Turin, Italy.| © CRA

**Fig.30** Illustration of one possible composition of CURA Intensive Care Pods from above.| © CRA

**Fig.31** Illustration of the interior of a CURA Intensive Care Pod.| © CRA, https://www.globalconstructionreview.com/news/carlo-ratti-and-jacobs-team-design-shipping-contai/

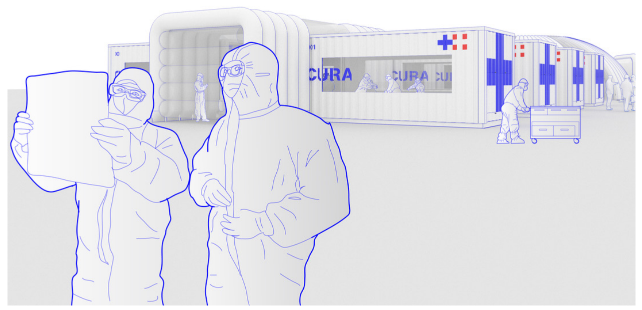
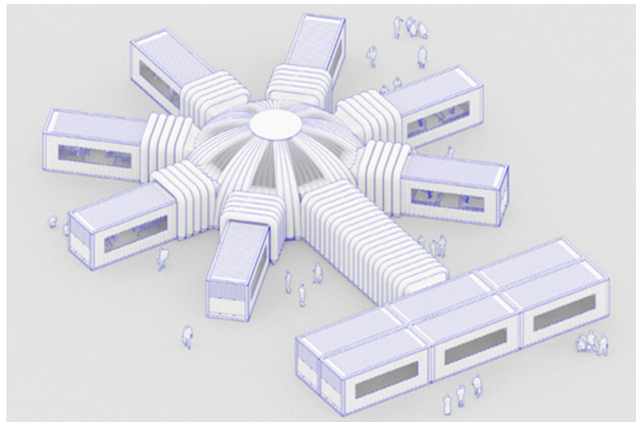



Fig.28


Fig.29



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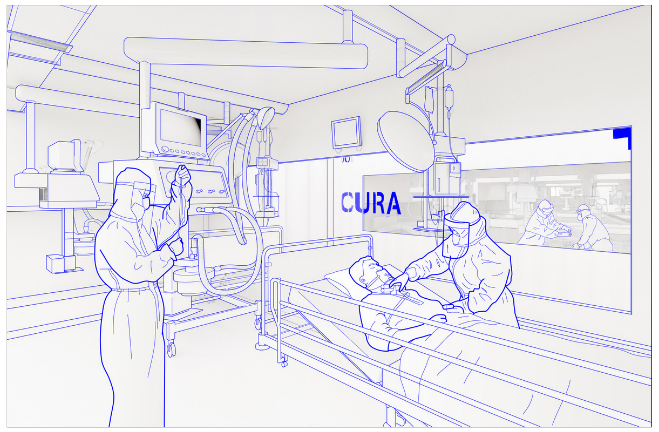



Fig.31

CURA can be set up in a very short amount of time with little effort. Through the use of an extractor, negative interior pressure for biocontainment is generated, which makes it comply with the standards of Airborne Infection Isolation Rooms (AIIR's) and therefore creates an environment that has the same safety properties as a hospital isolation ward. Two glass windows implemented in the long sides of the containers are meant for doctors to always get a sense of the status of patients. It also allows friends and family of patients to get as close as possible to their beloved ones, without risking an infection. The pods work autonomously and can be promptly shipped to any location around the world. Each of the intensive care pods is delivered with medical equipment for two ICU patients, including ventilators, monitors, intravenous fluid stands, and syringe drivers. The individual modules can be interconnected by inflatable structures and are capable of forming either an extension of the existing structure or an entirely self-sufficient field hospital. The project was designed in a matter of four weeks and configured as an open-source project, which means that everyone can download detailed technical specifications, reproduce the concept, and even take part in its further development via the website https://curapods.org/open-source-files. (De51gn, 2021)
On the 6th of April 2020, the construction of an 8900 m² field hospital with 92 beds started on the soil of the former industrial complex Officine Grandi Riparazioni (OGR) in Turin. Here, the first CURA Pods were installed. The construction was managed by the Italian Air Force and Protezione Civile and coordinated by the Crisis Unit of Italy's northern region of Piedmont, which had been one of the regions that were hardest hit by the crisis at that time. The practical test was a success and the project was internationally recognized and reproduced in several countries such as the UAE and Canada. (CRA, 2021)

**Fig.32** Technical infrastructure of the CURA Intensive Care Pod | © CRA, https://www.archdaily.com/936247/carlo-ratti-converts-shipping-containers-into-intensive-care-pods-for-the-covid-19-pandemic

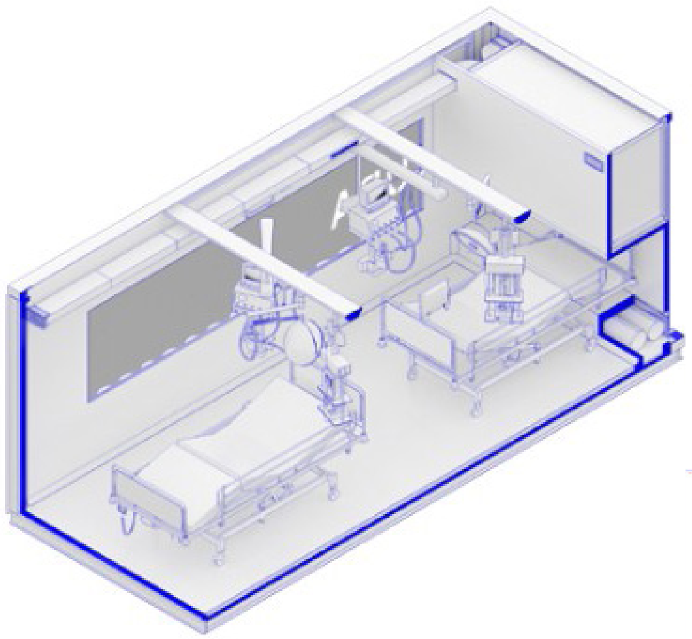


Fig.32


Fig.33

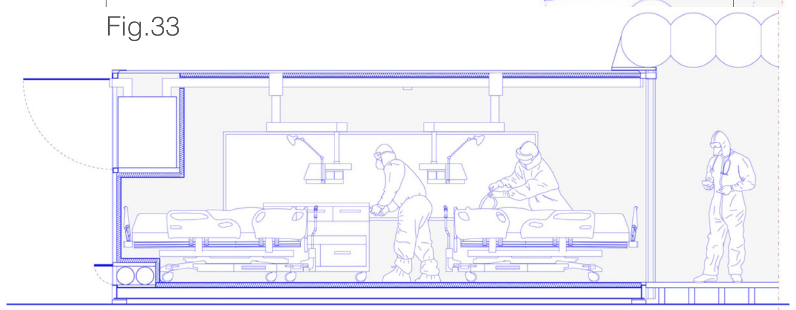


Fig.34



## 8.2 RESUS Medical Facility - Spacecube

Although in comparison to other countries, Australia witnessed low case numbers over the entire course of the Covid-19 crisis, there was a steep rise in cases beginning from the 10th of March 2020. Until this first wave peaked with 348 new cases per day on the 29th of March, the widespread belief was that case numbers would continue to rise steadily, as seen in Italy and other countries. As a result, the Australian government enforced a long list of preventive measures, which were in large parts responsible for the successful containment of the virus in the country. This included travel bans, the shutdown of infrastructure to absolutely indispensable functions, and strict lockdowns. (Attanasio, 2021) In a statement from the Australian Health Protection Principal Committee (AHPPC), published on the 22nd of March 2020, it was confirmed that the occurrence of infections mainly took place in the eastern seaboard cities of Sydney, Melbourne, and Brisbane. In contrast to previous discussions, the trigger for further interventions, such as the construction of supportive medical structures, was now "a substantial growth in locally transmitted cases, which could be predicted to exceed the future capacity of the region's health services." This meant that far-reaching measures were introduced in the above-mentioned cities with immediate effect. These preventive countermeasures, which were not refined at this date, were based on the principle of "getting ahead of the curve". (Australian Government Department of Health, 2020) As part of this government initiative, it was decided to set up a semi-permanent structure at the Monash Medical Centre in Melbourne. Since the hospital's Emergency Department underwent construction works at the time, the supportive facility was supposed to help the Hospital with the suspected overflow of patients in need of resuscitation beds.

**Fig.35** Picture of the RESUS Medical Facility in Melbourne, Australia, shortly after its opening. | © Spacecube, https://spacecube.com/wp-content/uploads/2020/11/SC_ProjectOverview_Monash-Health.pdf


Fig.35

The commission for the "Covid-19 RESUS Medical Facility" went to the Melbourne-based company Spacecube. The company had developed a portable modular building system for events, commercial use, and disaster relief, which they optimized since their founding in 2012. Spacecube teamed up with Aurecon, a local engineering, design, and advisory company, and Monash Health, to finalize the project within the given timeframe of 3 weeks. The design phase was concluded after one week and the project had received all necessary approvals shortly after. The assembly of the main structure took 15 hours and was handed over to Erilyan Commercial Construction in the following, to complete the internal fit-out together with the commissioning of medical equipment. The rapid construction time was achieved through the off-site pre-assembly of modules in a controlled environment. This also reduced the time during which the ambulance bay, on which the facility was built, could not be used by the hospital's vehicles. (Archello, 2020) Other than CRA's autonomous CURA Pods, the RESUS Facility forms a compact 360m² supportive hospital structure spreading over two levels, which was based on 25 cubical modules and a prefabricated stair module. The necessary HVAC systems were placed in two central positions on the roof and the conditions in the rooms could be operated individually. The layout includes six negative pressure resuscitation rooms, a nurse's station, a medication room, utilities, and a staff break room. Cubical modules form the base of the Spacecube building system. The particular modules that were used in the RESUS Facility, had already been in operation at the Formula 1 Australian Grand Prix and Melbourne Cup Carnival before, and were reused for the construction of the facility. (Spacecube, 2021) The sub-framing of the modules is engineered with a high strength aluminum alloy which, through its positive material properties such as low weight, non-magnetism, and high corrosion resistance, presents the perfect material to be reused over and over again.

**Fig.36** Aerial view of the RESUS Medical Facility. | © Spacecube

**Fig.37,38** Interior fit-out by Erilyan Commercial Construction. | © Spacecube, https://spacecube.com/wp-content/uploads/2020/11/SC_ProjectOverview_Monash-Health.pdf

**Fig.39** Assembly of the prefabricated modules. | © Spacecube, https://www.archdaily.com/943908/monash-health-resus-facility-spacecube -photo?next_project=no

Fig.36


Fig.37


Fig.38

Fig.39

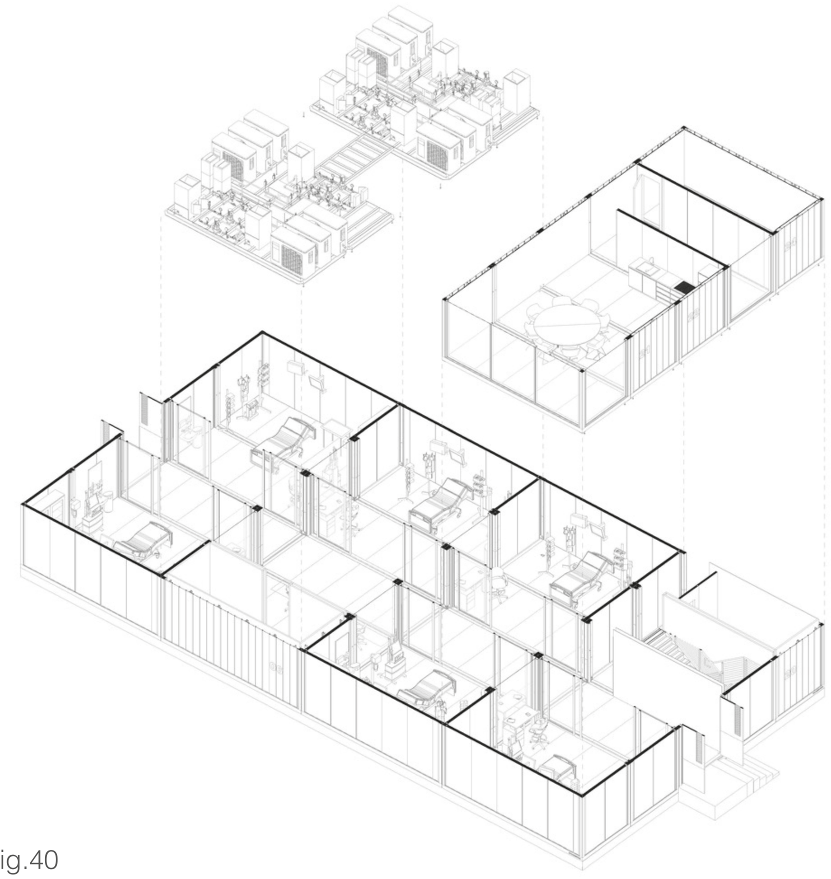


Systemical solutions for the aluminum façade, vinyl flooring, and glass doors, windows, and partitions including frames, were provided by multiple local companies and tailored to the Spacecube system in advance. (Luco, 2020, Spacecube, 2020) Great advantages of the modules are that they are prefabricated and that they can be flat-packed for transportation and set up rapidly on site. Paired with high design flexibility within the system, this enables the Spacecube to quickly find a solution for many combinations of challenges and to deploy their modular structures to rural, as

**Fig.40** Exploded axonometry and floor plans of the RESUS Medical Facility, showing the layout and technical infrastructure on the roof. | © Spacecube

**Fig.41** Section through the stair and three of the negative pressure resuscitation rooms. | © Spacecube

**Fig.42-44** Elevations showing the structure from all sides. | © Spacecube, https://www.archdaily.com/943908/monash-health-resus-facility-spacecube?ad_medium=gallery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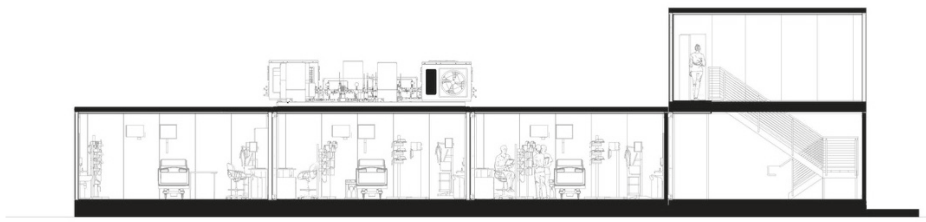
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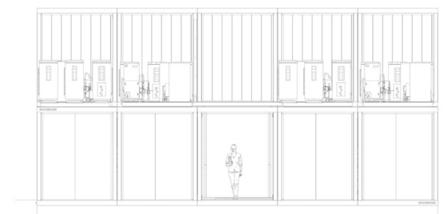
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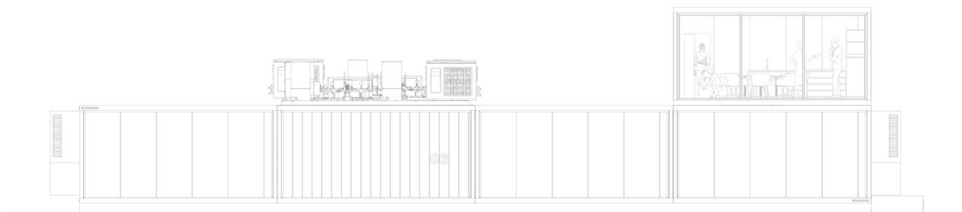
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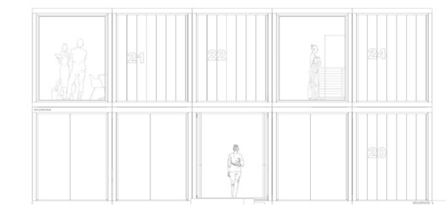
Fig.44

# 9 Pneumatic architecture

## Inflatable emergency hospital in Pachuca de Soto - Tecnodimensión

In Mexico, the first case of Covid-19 was recorded on the 28th of February 2020. Since then, case numbers have been continuously rising up until well over 2 million. In the first week of April 2020, the death toll exceeded 100 and increased twentyfold in the following month. (Radtke, 2021, Johns Hopkins University, 2021) When Mexico declared a "national state of sanitary emergency" on April 30th, an agreement was issued that revealed tax and employment-related measures, along with an economic stimulus plan and a set of regulations regarding the import of health-related goods to the country. It was decided that a simplified procedure for imports carried out by the Ministry of Health and Health Sector through decentralized agencies should be established. The Health Department and decentralized agencies that were authorized by the Health Sector were allowed from now on to import goods for medical treatment by foreign entities that sought to provide help in the health emergency, without having to go through administrative formalities or having to pay custom duties. (KPMG, 2020) In response to this, Spanish company Tecnodimensión deployed one of their specially designed inflatable hospitals to the city of Pachuca de Soto which is located in the critical region of Hidalgo, and in close distance to Mexico City. The small company, which is based in Girona and exists since 2001, focuses on the design and development of numerous types of inflatable and tension structures, that can be implemented in a wide range of applications.

**Fig.45** Aerial view on the inlatable emergency hospital in Pachuca de Soto, Mexico, by Spanish company Tecnodimensión. | © Idoia Sota, https://elpais.com/elpais/2020/03/20/icon_design/1584698437_069896.html

Fig.45

The 25 co-workers are manufacturing most parts of the structures in-house and have started to work on their emergency hospitals in full speed since the beginning of the pandemic. The 1000 m² hospital structure was placed in the center of Pachuca de Soto, at one of the main squares "Plaza Bicentenario", and next to the "Monumento la Victoria del Viento", which has an integral significance for the city in commemorating two hundred years of Mexican Independence. The emergency hospital, installed in the capital of Hidalgo, has two visiting rooms, 20 individual rooms, and four operating theatres that are perfectly insulated and prepared for any type of operation. Once the lighting, heating, ventilation, water, gas, and oxygen ducts have been installed and the medical equipment and beds have been brought in, this type of hospital is ready for use. Through its inflatability, the hospital was made fully functional within 20 hours upon arrival by the means of electric air pressure motors. Compared to the record-breaking construction time of 10 days for the Huoshenshan hospital in Wuhan, or the 18 hours that were needed to retrofit a pavillon on the fairgrounds of Ifema in Madrid, the hospital in Pachuca de Soto sits among the fastest construction times of fully autonomous emergency hospitals ever to be recorded, while also being highly deployable. (Xiaowai, 2020) The company's CEO Jesús Pallarès pointed out, that the textile structure does not require beams or any types of metal construction. In this way, their emergency hospitals can be shipped to virtually any country in the world, are easy to install, and can provide medical infrastructure for patients in a 50-kilometer radius. This is especially useful in the rural regions of big countries like Mexico, where this kind of infrastructure does hardly exist. (Cuevas Vidal, 2020)

**Fig.46,47** Exterior views on the inflatable emergency hospital in Pachuca de Soto, Mexico, by Spanish company Tecnodimensión. | © Tecnodimensión

**Fig.48,49** Patient wards with standardized interior fit-out (Fig.48). Corridor connecting the patient wards and serving as waiting area for friends and family (Fig.49). | © Tecnodimensión, https://www.tecnodimension.com/en/producto/emergency-hospital/

Fig.46

Fig.47

Fig.48

Fig.49

By the use of a specially developed 100% recyclable high resistance fabric based on polyvinyl chloride (PVC), the structures comply with a long list of specialized building code requirements for inflatable structures, one of them being fire retardance. The clear advantage of the material is the low cost, making the price of 300€ per m² in the emergency hospital possible. Through the merging of dome geometries and stiffening seams, the building is resistant to strong winds and ultimately becomes more durable and reusable. The membranes of the operating rooms are separated from the rest of the structure and their air conditioning system differs from the rest of the rooms. HEPA14 filters are used to guarantee optimized biocontainment properties and to reduce the risk of cross-contamination. (Nguyen, 2020)

**Fig.50** Operating theatre with a separate air conditioning system using HEPA 14 filters. | © Tecnodimensión, https://www.tecnodimension.com/en/producto/emergency-hospital/

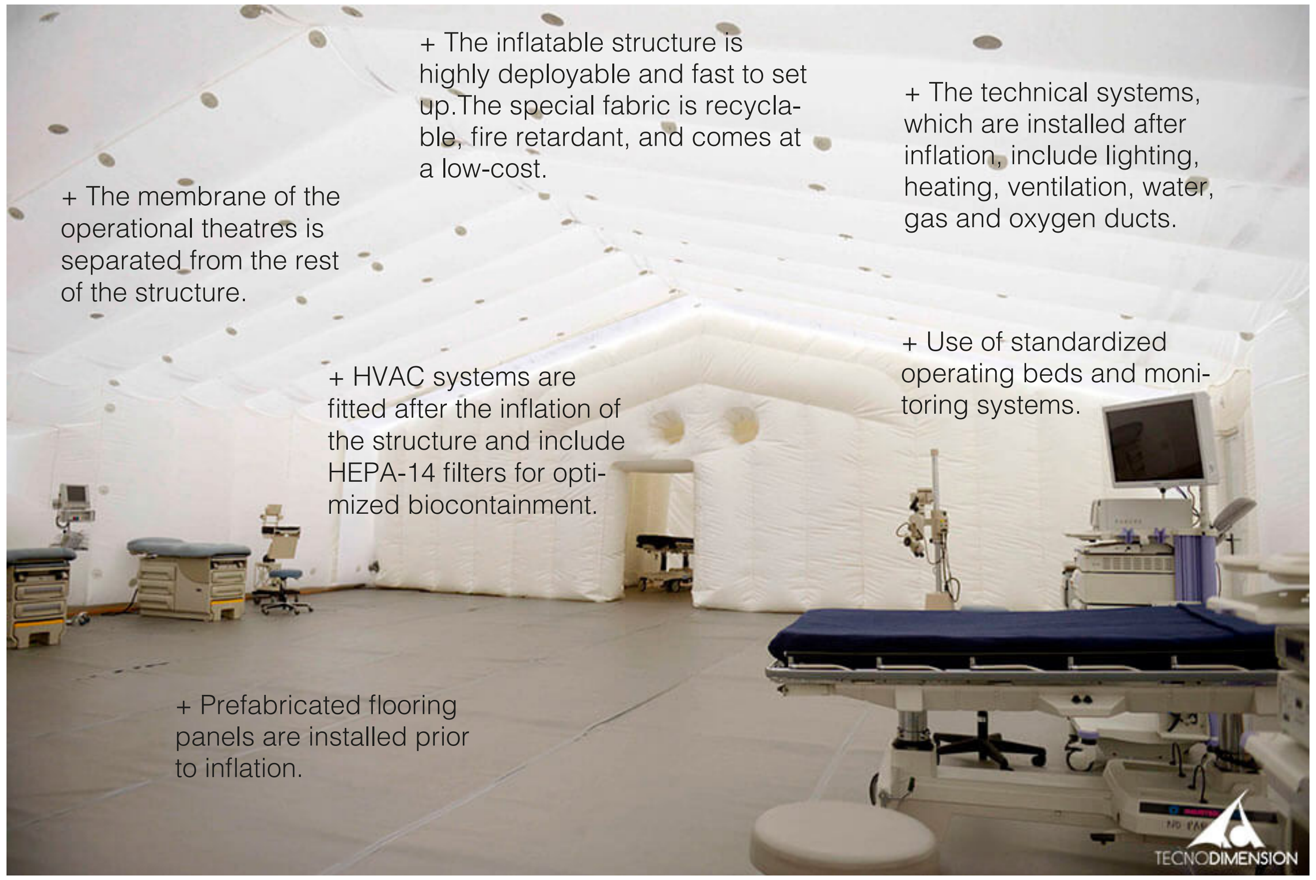


Fig.50



# 10 Adaptation of existing structure

### Corona Treatment Centre Berlin - Heinle, Wischer und Partner

Like many other European countries, Germany was hit by the crisis from the start. With a mediocre value of daily new Covid 19 cases rising from 103 on 7 March to 1.114 on 17 March, assessments of the coming crisis development painted a bleak picture. An exponential increase in case numbers was expected, which is why contingency plans were drawn up nationwide for the possible event of bottlenecks in hospital capacity. On 17 March, the Senate of the City of Berlin decided to build a stand-by facility with up to 1000 beds on the grounds of Messe Berlin. The responsible working group „Team Jaffé“, named after the address of the Berlin Trade Fair, decided who should carry out the project. The decision was made in favor of the Berlin architectural firm Heinle, Wischer und Partner, which already had many years of experience in hospital construction. The architectural firm was then commissioned to develop a concept within two days. (Pintos, 2020) Edzard Schultz, a shareholder of the company, explained that planning continued during construction and procurement. Due to the enormous time pressure, an analysis of the existing structure could hardly be carried out in advance, so the office had to resort to new means to avoid complex solutions. The decision was made in favor of a modular solution, that allowed for a high grade of transformability.

**Fig.51** Spatial zoning and layout of the retrofitted interior, and novel container exterior infrastructure at the Corona Treatment Centre Berlin Jaféstraße by Heinle, Wischer und Partner. | © Heinle, Wischer und Partner, https://www.archdaily.com/940802/corona-treatment-centre-berlin-heinle-wischer-und-partner?ad_medium=gallery

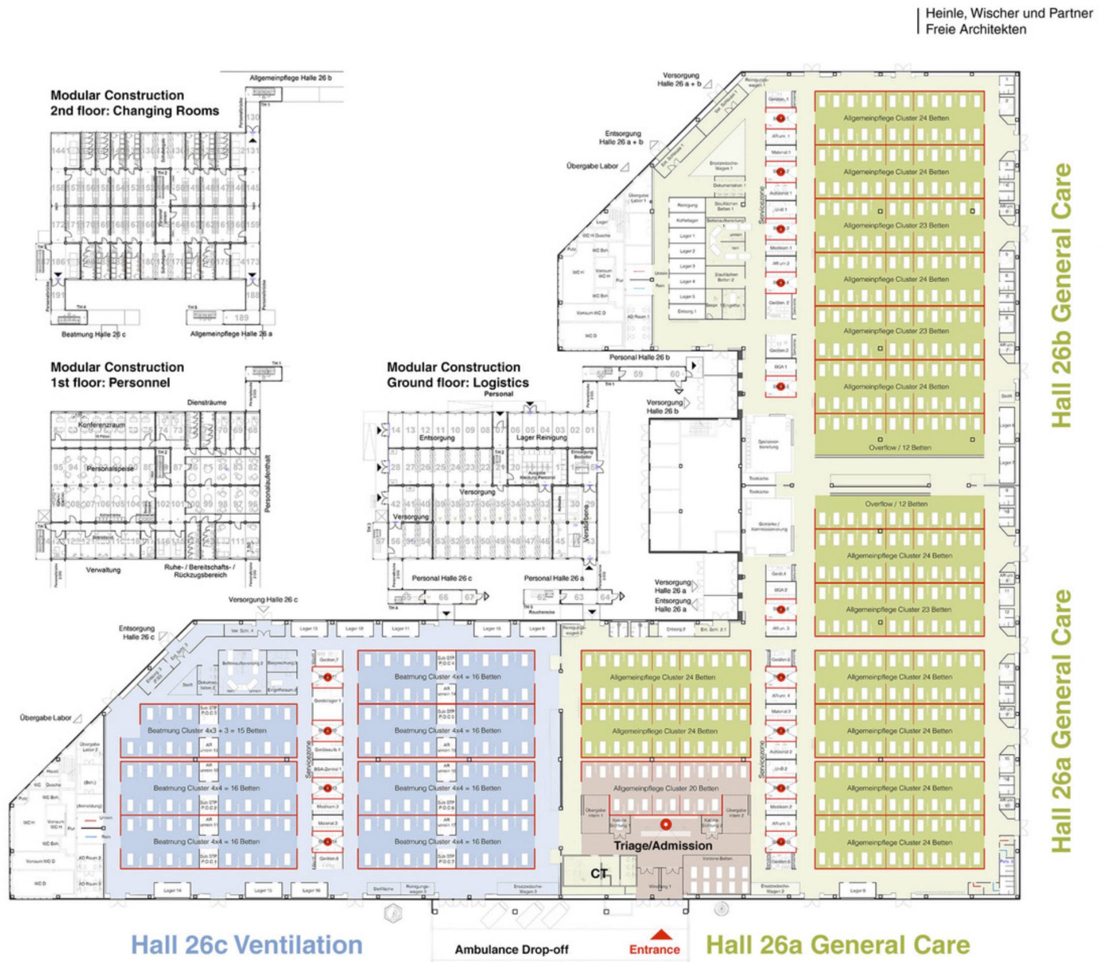


Fig.51

Fig.52 Interior view of one of the general care clusters marked by a green flooring material and numbering with a closer stance of bed spaces than in the ventilation clusters. | © Nordsonne Identity

Fig.53 View on the supportive exterior container structure in the north-western forecourt, | © Nordsonne Identity

Fig.54 Close-up photograph of the retrofitted traverses at the ceiling.| © Nordsonne Identity

Fig.55 One of the ventilation clusters for Covid-19 cases with Severe Acute Respiratory Syndrom..| © Nordsonne Identity, https://www.archdaily.com/940802/corona-treatment-centre-berlin-heinle-wischer-und-partner?ad_medium=gallery

It involves a central service zone and a cluster that consists of general care modules with 24 beds and modules for artificial respiration with 16 beds. The modules can be adjusted and re-organized easily upon need by the means of mobile beds, equipment, storage boxes, and disinfectant-resistant folding partitions. To lower the felt height of the spaces, two-third of the space above each bed is covered with a translucent fabric. Electrical and data technology supply, as well as 6 kilometers of oxygen lines, are guided via 3 kilometers of newly mounted traverses at the ceiling and can be accessed from above the modules. This technique is normally used in events and has the advantages of being time-efficient during assembly and offering great amounts of flexibility. It took roughly a week to assemble all of the traverses and installations in the ceiling, whereas the fitting of the 11.000 m² of flooring took only a few days. The municipal hospital group Vivantes was designated as the operator and provider of the medical concept for the facility and set the proportion of beds with respirators at 20 %. In this way, 111 of the 488 beds were equipped with respiratory devices. The hospital is accessed via the southeast, from where one reaches the interior main entrance. The triage, admission, and CT are located there. The south-western hall section 26 c is designated for artificial respiration, while the remaining hall sections 26 a and b are designated for general care. Hall 25 could be equipped with 320 beds if necessary. A temporary container structure was erected on the north-western forecourt of hall 26. On the one hand, it was not integrated into the hall because no further space was available in addition to the 500 beds required for the time being.


Fig.52


Fig.53

Fig.54


Fig.55



On the other hand, it was possible to ensure the clear spatial separation of patients and staff, as well as separated supply and disposal flows. In addition to changing rooms and a dining room, the containers also contain recreation rooms where the staff can recover from their hard work. The entire hall is designated as an infectious area and the three entrances in the northwest take over the necessary sluice function here. Although the hospital was handed over on 11 May 2020 after a record construction period and was not cheap with a price tag of 55 million euros including medical equipment, almost no patients have been received yet. Berlin had managed to cushion the shortage of intensive care places with the existing capacities and the „Corona Treatment Centre Jafféstraße" together with the Corona Treatment Centre at Prenzlauer Berg served as mere backup emergency hospitals. At the moment, around 90 hospital beds are acutely available but if necessary, this number could be quickly increased. However, the senate of Berlin has set the end of use for May and the dismantling for June due to the expected low infection numbers in summer. Luckily, the circular construction concept allows for 90% of the materials to be directly reused. (Redecke, 2020)

Fig.56 Conceptual exploded axonometry of the retrofitted ceiling traverses for lines and cables and the cluster system. | © Heinle, Wischer und Partner, https://www.archdaily.com/940802/corona-treatment-centre-berlin-heinle-wischer-und-partner?ad_medium=gallery

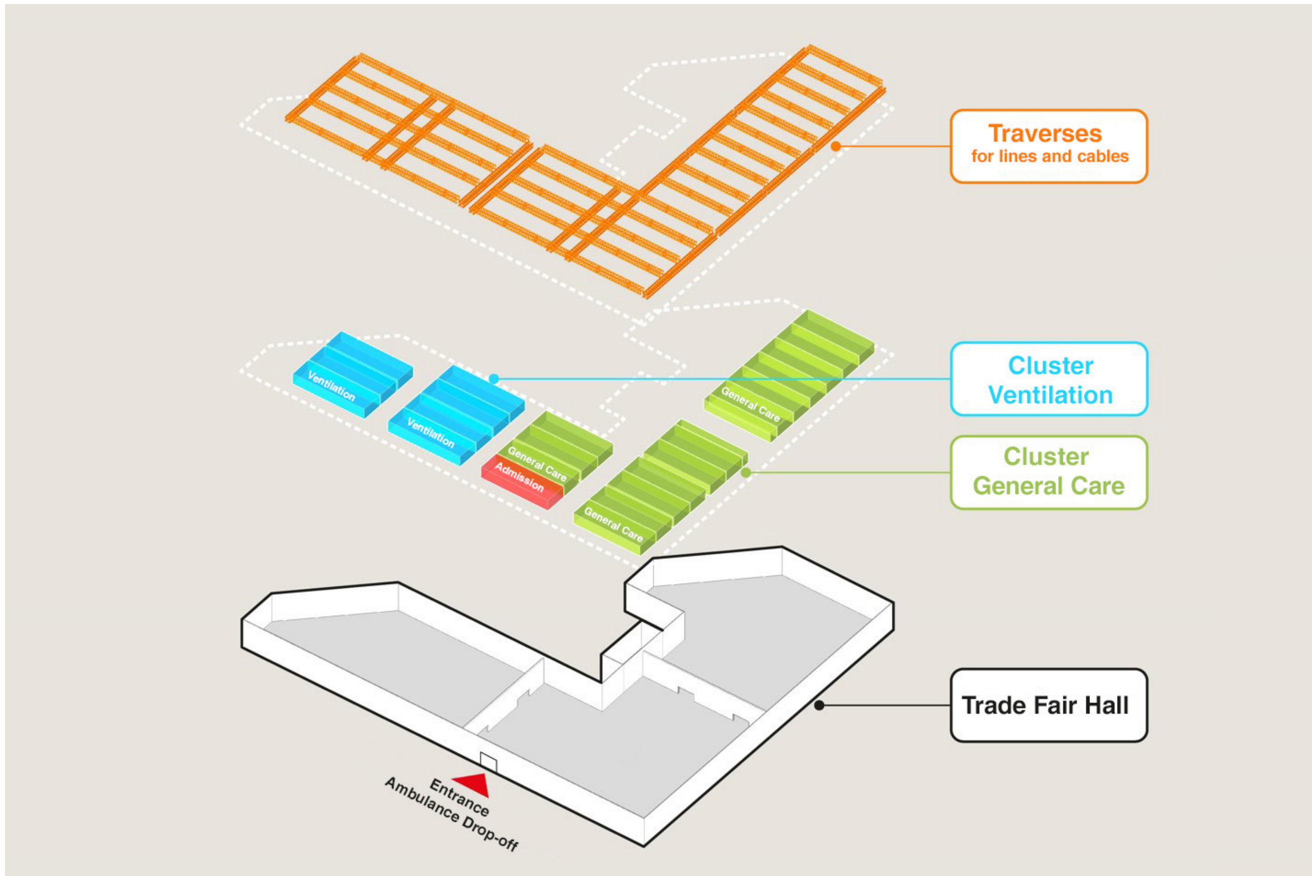


Fig.56

# 11 Conclusion: How can design help us to deal with situations of crisis and emergency?

## 11.1 Actuality of temporary and mobile structures

In a constantly changing world, flexibility and adaptability are becoming increasingly important in architecture. These terms had a firm place in the architectural discourse since the modern era and experienced a hype in the 1960s and 70s under the collective term of “mobile building.“ Architectural groups such as Archigram, Groupe d‘Études d‘Architecture Mobile (GEAM), and Superstudio, imagined a world in which nothing was forever and everything was in motion. The theoretical utopias of these groups found their way into building practice with the typologies of transportable and convertible buildings for temporary or permanent use, as well as industrially pre-manufactured housing solutions. Nevertheless, reinforced concrete still remains the material of choice for many architects to this day.
However, in recent years “mobile building“ has experienced a comeback. With a growing interest in the discourse on circularity in construction, the concept of the mobile, flexible and temporary structure is now more relevant than ever - provided that the used materials can be given another function in their afterlife.
By not viewing this new generation of temporary structures as disposable, and by making structures easier to configure than ever before through 3D programs, highly developed building systems, new manufacturing methods, and advancing materials research, temporary structures will steadily gain in importance in the architecture of the future.

## 11.2 How can design help us to deal with situations of crisis and emergency?

Over the course of the Covid-19 crisis, it became apparent that especially common practices in hospital architecture were in need of reform, towards greater flexibility and adaptability. Until then, architectural innovations have been blocked by outdated regulations and a reluctance to experiments on the part of the medical industry and the market. This was due to the fear of losing investments in projects that would not pass their practical test. Therefore, at the beginning of the pandemic, many hospitals turned out to be unprepared for the underlying situation and were suddenly unable to safely treat the high number of infectious patients. The main reason were rigid floor plans that left no room for the rearrangement of spaces to meet requirements regarding infection control. In addition, many buildings could not accommodate the necessary technical infrastructure, interior spaces were hard to reconfigure, and outdated data networks made it difficult to keep track of patients‘ conditions. The result were bottlenecks in hospital capacity which often had to be compensated for with supporting temporary medical structures. These structures functioned either as a flexible extension of a hospital or as completely independent hospitals to cushion the effect of overcrowded patient wards. The case studies from this thesis have shown that the use of temporary medical structures was an effective way of dealing with the situation of the Covid-19 crisis, but also with other types of crisis situations. As the number of people being vaccinated continues to grow, the curve of Covid-19 case numbers will flatten out in the foreseeable future and at some point, the pandemic will be over. However, this does not mean that the Covid-19 pandemic was the last crisis the international community ever had to face.



As a result of the globalized world and the way we run our businesses, new viruses can be transmitted from nature to humans at any time, and even known viruses can spread worldwide at breakneck speeds. Especially in the constantly changing and growing urban centers, action must then be taken quickly, flexibly, and in an organized manner.
At the same time, the strong geopolitical power shifts of our time will create new trouble spots and old trouble spots will generate new wars and war-related crises. Furthermore, man-made climate change is already presenting us with major challenges that will become impossible to ignore in the future. In addition to extreme heatwaves, which can lead to forest fires that devastate entire regions, cold spells are a much-underestimated problem. The latter can lead to widespread power outages, and homeless people, in particular, are in need of emergency shelters during these periods. Rising sea levels and the sinking of entire groups of islands will also be a problem that we will have to deal with.
These future crisis situations, many of which we can not predict yet, can only be overcome by flexible approaches. The architecture that we envision today, can make a contribution in solving many of the arising problems.

The Covid-19 crisis presented a wake-up call for architects of health facilities and the entire medical world to reformulate current practices in hospital architecture and temporary medical structures. The solutions that were developed in the field of temporary medical structures during the pandemic can be valuable precedents from which we can learn for the future of health architecture.

## 11.3 Architectural context

With the steep rise of Covid-19 case numbers in countries around the globe, preventive measures had to be taken by their respective governments. Possible bottlenecks in the capacity of intensive care beds in regular hospitals and many other issues created by the pandemic were prevented by the means of temporary medical structures. The high demand had to be met with deployable solutions that could be implemented in urban as well as rural areas, and potentially shipped to locations around the globe or be reproduced easily by local companies.
While architectural firms like Jupe and Spacecube came up with flat-packed solutions that could be shipped in high quantity and at a low cost, CRA developed an open-source concept using standardized shipping containers, where the idea could be adapted and optimized by multiple parties. In contrast, Tecnodimensión took advantage of the properties of inflatable structures such as low costs, the absence of load-bearing frames, the lightweight, and the adaptability to ground properties. The structures from the case studies can serve as an extension of existing hospital infrastructure and some of them can even form entirely self-sufficient field hospitals. Therefore, they present feasible solutions to provide critical medical infrastructure for the population of remote regions and are flexible enough to deal with the ever-changing requirements of today‘s metropolis.

## 11.4 Program

Like all of the presented projects, Heinle, Wischer und Partner‘s Corona Treatment Centre as well follows a modular logic, which adds much flexibility and adaptability to the internal organization of the structure. Here, the modules can form clusters, which provide clear zoning and hierarchy of spaces that everyone can understand at first glance. By separating different functions into clusters or single modules, as

could also be seen in the projects of CRA and Jupe, different climate scenarios and levels of biocontainment can be applied to them. This allows for controlled and punctual configuration of the modules to meet specific requirements. In this way, another level of security is added by the resulting spatial separation of staff and patients.
Spacecube, Jupe and Heinle, Wischer und Partner also created separated spaces for medical staff to extract activities like management, personnel break activities, and resting spaces from the functional areas that are dealing with the patients. While Spacecube achieved this, by separating spaces within their structure, Jupe created special tents that were designated only as spaces for medical staff to rest, whereas Heinle, Wischer und Partner built a separate container structure to house all staff-related functions.
In an increasingly computer-driven world, new ways of hospital management, telemedicine, and improving monitoring software have changed the ways medical professionals work. Jupe created units that are interconnected through an elaborated Internet of Things (IoT) they developed in cooperation with software engineers. This virtual organization of the physical architecture, although still in its infancy, will become more and more important in the future.

## 11.5 Technology

In the physical structure, closed objects that can be well insulated have the clear advantage that contaminated air can be extracted by the use of negative pressure. In this way, containers and frame systems with solid cladding materials, like in the projects of CRA and Spacecube, have superior properties to pneumatic architecture, tent-like structures, or open clusters. However, biocontainment can also be improved for partly open structures. Therefore, Jupe offers a hard shell next to the fabric outer skin of their isolation- and intensive care units and, to optimize the biocontainment properties, Tecnodimensión and Heinle Wischer und Partner include ambitious air extraction- and filter systems in their hospitals.
The hospital in Berlin incorporates centralized HVAC systems, which can be controlled individually for certain spaces. The HVAC infrastructure was installed at the ceiling to provide constant airflow and climate control. In the case of the inflatable hospital, systems are fitted in between membranes, and the air is led into the rooms through openings in the walls. The RESUS Facility presents a hybrid solution, in which two central HVAC systems are placed on the roof of the building. In contrast, the CURA pods and JUPE Health units come with individual HVAC systems, which makes the modules self-sufficient and easier to re-arrange in an ensemble.
The modular construction system with pre-fabricated parts, which underlies all of the projects, has the advantages of low construction times on-site and high deployability. In combination with building systems from selected manufacturers, as could be seen in the RESUS Facility, or by using off-the-shelf products, like in the Corona Treatment Centre, powerful building solutions for rapid response missions can emerge.

## 11.6 Psychological aspects

It is common knowledge that the pandemic not only affects our physical but also our mental health. Especially patients who are in critical condition and stuck in quarantine wards are affected by this problem. Therefore, it is important to generate a relationship between the patient and the outside world to prevent the patients from the effects of loneliness and isolation. This issue was addressed in the CURA pods by integrating windows in the long sides of the container. In this way, families and friends could visit their beloved ones without having to risk an infection.
The concept of a visual connection to the outside was also incorporated in the RESUS Facility by using mainly glass walls for the resuscitation rooms.



This was also beneficial for doctors since they could keep track of the patients' condition more easily.
Jupe and Tecnodimensión followed a different principle, by giving the patients more privacy and providing individual sanitary facilities and, in the case of JUPE Care, even a fully equipped kitchen. Also, the medical staff was affected by the working conditions in Covid-19 hospitals. Some of the case study projects acknowledged this problem by creating special areas where healthcare workers could rest or have social interaction to recover from their work.
Except for the hospital in Berlin, where the low, open clusters led to a good lighting situation within the existing structure, and the hospital in Pachuca de Soto, where artificial lighting was used, the case studies stand out by the extensive use of glassed surfaces or translucent materials. In this way, natural sunlight was guided into the interior spaces, which had a positive effect on the users' mental health.
The hospital in Pachuca de Soto, however, had the advantage of high ceilings and curved forms in the shape, which prevented the patients from feeling incarcerated.
Another important factor for the mental well-being of patients are clearly organized spaces that make a professional impression.
Through the use of light colors, the labeling of spaces by colored flooring materials, textual descriptions, and the use of large symbols on the separating walls, especially the Corona Treatment Centre in Berlin achieved to communicate a feeling of „being in good hands“.

## 11.7 Hygiene

The zoning of a healthcare facility largely contributes to the containment of the spread of viruses. Most importantly, infectious patients and medical staff have to be spatially separated. In the project by Heinle, Wischer und Partner, this separation was accomplished with a system of pathways between the clusters, while the inflatable building system of Tecnodimensión allowed for large spaces to be created at a low cost, which prevented people from getting too close to each other. In the CURA and JUPE units, only the individual modules were designated as infectious zones, and buffer zones could be found outside.
These buffer zones and sluices are important because the medical staff takes off their PPE there and material flows are controlled by them. It must be ensured, that the flows of clean and contaminated materials do not interfere, to prevent cross-contamination. The management of these flows needs special attention in temporary medical structures. As stated before, yet another important factor to prevent cross-contamination are biocontainment measures such as selective ventilation systems and the extraction of contaminated air from the isolation wards by the means of negative pressure. Hygiene requirements also have to be met in the interior configuration of hospitals. Here, the choice falls on robust materials with cleanable surfaces, that meet hospital standards for infection control.

In the following, the findings from the conclusion are compared according to the parameters of analysis and presented in a clear table.

| 11.8 Comparison of the case studies according to the parameters of analysis | Series of mobile health units - JUPE Health | CURA Intensive Care Pods - CRA | RESUS Medical Facility - Spacecube | Inflatable hospital in Pachuca de Soto - Tecnodimensión | Corona Treatment Centre Berlin - Heinle, Wischer und Partner |
|---|---|---|---|---|---|
| Architectural context | + The project responded to a lack of beds in U.S. hospitals and the increasing demand for supportive temporary medical structures with a flat-packed solution.<br>+ As the units can be produced in high volume at a low cost, and deployed easily to anywhere in the world, they present a solution for any type of hospital in rural as well as urban areas. | + The CURA Intensive Care Pods were a response to the shortage of ICU spaces in Italian hospitals.<br>+ Through the repurposing of shipping containers, they are easy to manufacture and can be deployed to anywhere in the world, or reproduced.<br>+ The clusters can be set up on parking lots in proximity to existing hospitals, or on the open field. | + The Covid-19 RESUS Medical Facility was set up in response to "ahead of the curve" preventive measures by the Australian government at the ambulance bay of the Monash Hospital in Melbourne.<br>+ It was set up as a supportive structure for the hospital's Emergency Department, which underwent construction works at the time.<br>+ The solution is highly deployable and easy to reconfigure. | + The structure was set up on a square in Pachuta de Soto, Mexico, due to the high infection rates in the area.<br>+ An economic stimulus plan, issued by the Mexican government, had previously facilitated the import of foreign health-related products and services in the country.<br>+ The type of structure can help the population in rural regions of big countries to get access to medical care. | + The Corona Treatment Centre has been built in the halls of the Berlin Trade Fair in response to preventive measures by the German government.<br>+ Due to the small timeframe of the project, the existing structure could hardly be analyzed and therefore it was decided for a flexible modular building system using off-the-shelf materials. |
| Program | + Standalone modules create IoT-ready solutions.<br>+ Different tent types are serving different functions, such as rest spaces for health professionals, isolation and recovery of patients, and a fully self-sufficient ICU.<br>+ The modules are used as an extension of existing hospitals.<br>+ They can be set up in parking lots, as well as on the open field. | + The modules are fully self-sufficient and can be clustered together by the means of an inflatable structure.<br>+ In this way, the units can form supportive structures for existing hospitals or entire field hospitals.<br>+ Every unit provides space for two patient beds, both being equipped with respiratory devices. | + The facility forms a compact 360m$^2$ supportive hospital structure spreading over two levels.<br>+ The layout includes six negative pressure resuscitation rooms, a nurse's station, a medication room, utilities, and a staff break room. | + The inflatable emergency hospital by Tecnodimensión includes 20 individual patient wards, four operating theatres, and two visiting rooms.<br>+ Separate inflatable modules add a certain amount of flexibility to the layout of the hospital and make it reconfigurable.<br>+ The structure can serve multiple purposes, besides being an emergency hospital. | + The spaces in the existing structure are separated by two types of clusters: Ventilation clusters with 16 beds, and general care clusters with 24 beds each.<br>+ Since the Berlin Trade Fair halls are designated as infectious zones, a supportive container structure for medical staff has been built in the forecourt of the building.<br>+ The modular system allows for a great amount of flexibility. |
| Technology | + Manufacturing techniques are inspired by common practices from the automotive, space, and software industries.<br>+ The availability of a soft and hard shell allows use in different climate scenarios.<br>+ Batteries for temporary off-grid use are included.<br>+ Wi-Fi is offered as optional features and allows for well-ventilated and IoT-ready spaces. | + The units use negative pressure to meet biocontainment requirements.<br>+ Air is filtered by the means of HEPA-14 filters.<br>+ Intensive care technology is mounted on rails over the patient beds. This allows for the flexible use of space.<br>+ Insulation of the units allows for the implementation of exact climate control. | + HVAC systems were placed in two central positions on the roof and the climate could be controlled individually for each room.<br>+ Negative air pressure is used to meet biocontainment requirements.<br>+ The 6 resuscitation rooms are fitted with all of the necessary technical infrastructures.<br>+ The Spacecube building system, paired with other systemical solutions, is highly reconfigurable and deployable. | + Due to the omission of any load-bearing structures other than the inflatable membranes, the structure is highly deployable and fast to set up.<br>+ The technical systems, which are installed after inflation, include lighting, heating, ventilation, water, gas, and oxygen ducts.<br>+ The special fabric is recyclable, fire retardant, and comes at a low cost. | + 3 kilometers of traverses at the ceiling guide the technical infrastructure, namely electrical and data technology supply and 6 kilometers of oxygen lines, to the clusters.<br>+ 20% of the beds are equipped with respiratory devices.<br>+ supply and disposal flows are spatially separated and controlled via sluices in the north. |
| Psychological aspects | + Jupe mobile health units offer a high amount of privacy for the users, be it a recovery space for health professionals in JUPE Rest, a fully equipped quarantine and isolation space for patients in JUPE Care and Plus. | + Through long windows on the sides of the unit, the patients do not lose the reference to the outside world.<br>+ Friends and family can visit patients and be very near to the under the protection of the windows. | + The interior is highly organized with colors pointing out functions and a clear spatial division.<br>+ The extensive use of glass creates views from and into the resuscitation rooms.<br>+ Separate areas for staff create private spaces for rest and social interaction to recover from the work. | + The individual patient wards provide a high level of privacy and the visiting rooms provide space for friends and family to be near their beloved ones.<br>+ High ceilings and the curved forms of the shape prevent the feeling of being incarcerated in the hospital. | + The spatial division of the structure is organized clearly. This is communicated to the users by the use of colors in the flooring material and the numbering and textual description of the zones on the separation walls.<br>+ Fabrics over the beds prevent the patients from looking at the building technology at the ceiling. |
| Hygiene | + Every Unit is delivered with the necessary PPE.<br>+ JUPE Care and Plus offer an individual wet cell with the unit so that no cross-contamination can happen through bad hygienic conditions of public bathrooms. | + Buffer zones are created in the corridors formed by the pneumatic structure. In this way, health professionals can take off their PPE there.<br>+ The negative pressure in the modules facilitates biocontainment. | + The RESUS Facility meets all of the hygiene requirements for hospitals.<br>+ The interior fit-out uses cleanable surfaces, and the spatial order guarantees a low infection risk.<br>+ Biocontainment of the resuscitation rooms lowers the risk of cross-contamination. | + HEPA-14 filters provide optimized biocontainment conditions in the separated areas.<br>+ The polyvinyl chloride fabric is a cleanable material.<br>+ With the building system, large spaces can be created at a low cost that prevent people from getting too close to each other. | + The spatial separation of staff and patients prevents cross-contamination and the spread of the virus.<br>+ Used materials meet hospital standards for infection control and will be reused in actual hospitals after the pandemic. |

# 12 Annotated bibliography


A

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Retrieved from: https://www.bpb.de/internationales/weltweit/innerstaatliche-konflikte/228561/suedsudan

This article published by the german Federal Agency for Civic Education manages to provide an overview of the complex political and economical relations in the youngest member of the international community of states, South Sudan. The country reached its independence in 2011 after a decade lasting conflict between north and south. Nevertheless, a civil war erupted in 2013 and was ended in 2018 due to international pressure. Eversince the peace in the state remains fragile.

**AEA' (Association of Ethiopian Architects)**, (2020). Guidelines for Covid-19 Quarantine and Treatment Centers in the Ethiopian Context. Spatial and Engineering Requirements of the Physical Structure. UIA (International Union of Architects), Paris, France.
Retrieved from: https://www.uia-architectes.org/webApi/uploads/ressourcefile/663/aea_guideline_for_covid_19_facility_layout.pdf

The Guidelines for Covid-19 Quarantine and Treatment Centers in the Ethiopian Context were produced by a team of AEA members, one of whom is a PhD candidate at TU Delft. They are adressed to the Ethiopian Federal Ministry of Health and were accepted, which means that they are currently in use. It is described in detail how a quarantine or treatment center for Covid-19 has to be constructed to meet international standards set by the WHO. Besides the establishment of new structures, the guidelines as well propose ways to retrofit existing structures.
The paper starts with general important information and categorization of international standards before diving into different relevant aspects of what to consider when constructing quarantine and treatment centers for the context of the covid-19 pandemic. The graphic representation of specific building parts and entire layouts make the subject very easy to understand and provide great insight into the workings of the structures.

**Archdaily**, (2020). St. Carolus Screening Facility/ AT-LARS. Archdaily (online).
Retrieved from: https://www.archdaily.com/947140/st-carolus-hospital-screening-facility-at-lars

In this article, AT-LARS describe their St. Carolus Screening Facility, focusing mainly on the spatial arrangement and materiality of the structure. Furthermore, AT-LARS underline the sustainable value by proposing the re-purposing as an emergency shelter for victims of floods, which are a common sight in Jakarta, Indonesia. Besides the textual description, pictures and drawings give a good insight into the nature of the project.

**Archello**, (2020). Modular RESUS Facility: SPACECUBE. Archello. Retrieved from: https://archello.com/project/modular-resus-facility.

This article provides detailed project information about the Covid-19 RESUS Medical Facility at the Monash Health Hospital by Spacecube.

**Attanasio, J.**, (2021). Coronavirus Australia: A look back at March 2020. 9News Breaking News. Retrieved from: https://www.9news.com.au/national/coronavirus-australia-one-year-on-pandemic/718557a9-b779-474e-a644-9393104763b2.

This article shows the impact of the Covid-19 crisis on Australia over the course of March 2020 by means of chronologically ordered relevant events that took place.

**Australian Government Department of Health**, (2020). Australian Health Protection Principal Committee (AHPPC) coronavirus (COVID-19) statement on 22 March 2020. Australian Government Department of Health. Retrieved from: https://www.health.gov.au/news/australian-health-protection-principal-committee-ahppc-coronavirus-covid-19-statement-on-22-march-2020-0.

In this statement by the AHPPC from the 22th of March 2020, the spread-containing measures which came into effect shortly before in Australia are discussed. Also, further measures are proposed to come into effect immediately, which include the expansion of hospital infrastructure, by the means of projects like the RESUS Facility by Spacecube.

B

**Berting, N.**, (2021). New flat-pack recovery units for doctors and patients. [online] What Design Can Do. Retrieved from: https://www.whatdesigncando.com/stories/new-flat-pack-recovery-units-for-doctors-and-patients/.

This article provides detailed project information about the Jupe Health ICU's.

**Bitterman, N., and Zimmer., Y.**, (2018). Portable Health Care Facilities in Disaster and Rescue Zones: Characteristics and Future Suggestions. Industrial Design, Faculty of Architectureand Town Planning, Technion, Haifa, Israel.
Retrieved from: https://www.researchgate.net/publication/326380013_Portable_Health_Care_Facilities_in_Disaster_and_Rescue_Zones_Characteristics_and_Future_Suggestions

This paper analyzes the way in which temporary medical structures are commonly used in the present and discusses recurrent problems and potentials. Furthermore, the authors make suggestions for future designs and deployment plans. The paper provides a great overview over the topic of portable health care facilities and their application, while there is also a wealth of detailed description of specific points.

**Brown, A.**, (2021). They were supposed to build stages for Coachella. Now they're building coronavirus triage tents. [online] Los Angeles Times. Retrieved from: https://www.latimes.com/entertainment-arts/music/story/2020-03-30/coronavirus-event-companies-coachella-pivot-covid-19-testing.

This article covers the story of the young company Choura Events, which had to rethink their business model when the pandemic started and ended up building triage and other types of health related tent structures to help the country deal with the lack of hospital beds.

C

**Carlo Ratti Associati**, (2020). CURA (online).
Retrieved from: https://carloratti.com/project/cura/

CURA (Connected Units for Respiratory Ailments) is an open source project developed by Carlo Ratti Associati and Italo Rota. Through the website https://curapods.org/ everyone can take part in the further development of the unit and download detailed technical specifications. The project was designed in a matter of four weeks and set up for the first time in a temporary hospital in Turin, Italy.

**Chen, X., Lu, L., Shi, J., Zhang, X., Fan, H., Fan, B., Qu, B., Lv, Q., & Hou, S**. (2020). Application and Prospect of a Mobile Hospital in Disaster Response. Disaster medicine and public health preparedness, issue 14(3), p. 377–383.
Retrieved from: https://doi.org/10.1017/dmp.2020.113

The article highlights the importance of and aims for the optimization of the a rapid disaster response through mobile hospitals. The authors argue that since disasters are usually accompanied by disruption of the functioning of local medical institutions, mobile structures play a crucial role in saving casualties and alleviating the shortage of medical resources. Types and characteristics of mobile hospitals used by medical teams in disaster rescue are analyzed and problems and needs of mobile hospitals are shown.

**Chinese Government**, (2014). China finishes construction of Ebola treatment center in Liberia. (online). Retrieved from: http://english.www.gov.cn/news/international_exchanges/2014/11/26/content_281475015514550.htm

This is a press release from the Chinese government, which provides information about the Monrovia Ebola Treatment center such as the construction process, layout and technical details about the project.

**CRA**, (2021). Cura Pods. [online] Cura Pods. Retrieved from: https://curapods.org/.

This is the official website of the CURA Intensive Care Pods by CRA.

**CRA**, (2021). COVID-19: Open-source design helps turn shipping containers into Intensive-Care Units at record speed. [online] Retrieved from: https://docs.google.com/document/d/1dTLiOj5gP7I7xG-b6UrJTFyZ04TGFGMG/edit.

This is the official press release for the CURA Intensive Care Pods by CRA. Most of the information which is spread across articles that cover the project, can be found here in a bundled form.

**Cuevas Vidal, A.**, (2020). Los hospitales hinchables: una iniciativa española para combatir el coronavirus en México. Sputnik Mundo. Retrieved from: https://mundo.sputniknews.com/20200331/los-hospitales-hinchables-una-iniciativa-espanola-para-combatir-el-coronavirus-en-mexico-1090965793.html.

This article provides detailed project information about the inflatable Covid-19 emergency hospital by Tecnodimensión.

D

**De51gn**, (2021). Carlo Ratti Associati proposes modified shipping container ICU units to boost hospital capacity to deal with Covid-19 pandemic - De51gn. [online] De51gn. Retrieved from: https://de51gn.com/carlo-ratti-associati-proposes-modified-shipping-container-icu-units-to-boost-hospital-capacity-to-deal-with-covid-19-pandemic/.

This article provides detailed project information about the CURA Intensive Care Pods by CRA.

**De51gn**, (2021). Jupe Health designs world's first mobile off-grid ICU unit to act as Covid-19 isolation rooms - De51gn. [online] De51gn. Retrieved from: https://de51gn.com/jupe-health-designs-worlds-first-mobile-off-grid-icu-unit-to-act-as-covid-19-isolation-rooms/.

This article provides detailed project information about the Jupe Health ICU's.

E

**Elsharkawi, H., Jaeger, T., Christensen, L., Rose, E., Giroux, K., & Ystgaard, B.**, (2010). Mobile field hospitals in the Haiti earthquake response: a Red Cross model. Humanitarian Practice Network HPN, London, UK.
Retrieved from: https://odihpn.org/magazine/mobile-field-hospitals-in-the-haiti-earthquake-response-a-red-cross-model/

The Rapid Deployment Emergency Hospital Emergency Response Unit (RDEH ERU) is one of the IFRC's global emergency response standby tools. The article describes how specially designed versions of this ERU were brought from Oslo to Haiti in response to the 2010 earthquake. In addition to a lot of specific information about transport and assembly, there is a lot of information about working methods and the specific equipment of the RDEH ERU.

G

**Gibson, E.**, (2021). Jupe flat-packed care units could bolster hospitals in coronavirus pandemic. [online] Dezeen. Retrieved from: https://www.dezeen.com/2020/03/27/jupe-health-flat-packed-coronavirus-care-units/.

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**Guimapang, K.**, (2021). Jupe creates rapid response deployable shelter units for healthcare workers and patient recovery. [online] Archinect. Retrieved from: https://archinect.com/news/article/150191943/jupe-creates-rapid-response-deployable-shelter-units-for-healthcare-workers-and-patient-recovery.

This article provides detailed project information about the Jupe Health ICU's.

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**Harrouk, C.**, (2021). Alternative Healthcare Facilities: Architects Mobilize their Creativity in Fight against COVID-19. Archdaily (online).

Retrieved from: https://www.archdaily.com/937840/alternative-healthcare-facilities-architects-mobilizetheir-creativity-in-fight-against-covid-19

The article from the 28th of may 2020 presents a wide range of alternate healthcare facilities, that respond to the Covid-19 pandemic. The partly realized projects range from hospital ships over pneumatic designs to modular and often mobile hospital structures. The article was published at the peak of the first wave in most european countries and performs pioneering work in ordering the topic and bringing together very different approaches that respond to the scarcity of hospital beds.

**Herbert, S.**, (2014). Conflict analysis of Liberia. Birmingham, UK: GSDRC, University of Birmingham. Retrieved from: https://gsdrc.org/publications/conflict-analysis-of-liberia/#:~:text=Liberia%20is%20vulnerable%20to%20cross,Ivoire%20%E2%80%93%20share%20common%20conflict%20dynamics.

This publication by the University of Birmingham, provides an overview over the political relations in Liberia and examines how the conflicts came about, which haunted the country in the past decades.

I

**IDMC Internal Displacement Monitoring Centre**, (N/A). South Sudan. Annual conflict and disaster displacement figures (online). Retrieved from: https://www.internal-displacement.org/countries/south-sudan?type=All&items_per_page=8&page=1

The IDMC publishes up-to-date information about the internal displacement situation worldwide.

**IFRC (International Federation of Red Cross and Red Crescent Societies)**, (N/A). Emergency Response Units (ERUs): Types (online).

Retrieved from: https://www.ifrc.org/en/what-we-do/disaster-management/responding/disaster-response-system/dr-tools-and-systems/eru/types-of-eru/

The IFRC is the largest humanitarian network worldwide. It has a global Disaster Response System that is mobilized when a national society cannot respond alone. "An Emergency Response Unit (ERU) is a standardised package of trained personnel and modules of equipment, ready to be deployed at short notice. The units are fully self-sufficient for one month and can be deployed for up to four months." In the article, the IFRC explains the workings of the ERUs and provides technical, spatial and logistic information on each one of them. I am interested in the Rapid Deployment Hospital ERU because it was mainly used in the Haiti earthquake response from 2010. Further information about this ERU type can be found in the items catalogue: https://itemscatalogue.redcross.int/emergency-preparedness--7/health-eru--6.aspx

J

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K

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This information website provides a summary of all the measures that came into effect in Mexico in response to the Covid-19 crisis.

L

**Luco, A.**, (2020). Monash Health RESUS Facility / SPACECUBE. ArchDaily. Retrieved from: https://www.archdaily.com/943908/monash-health-resus-facility-spacecube.

This article provides detailed project information about the Covid-19 RESUS Medical Facility at the Monash Health Hospital by Spacecube.

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**Maiztegui, B.**, (2020). The World's Answer to the Lack of Medical Facilities: Temporary and Convertible Hospitals. Archdaily (online).

Retrieved from: https://www.archdaily.com/936244/the-worlds-answer-to-the-lack-of-medical-facilities-temporary-and-convertible-hospitals?ad_source=search&ad_medium=search_result_all

The Article, which was published on the 31th of march 2020 in the beginning of the pandemic, presents different projects from around the world that respond to the lack of hospital capacity in their country.

**Médecins sans Frontières.** (2018) Ebola – vielversprechender Impfstoff für eine unheilbare Krankheit. Médecins sans Frontières (online).
Retrieved from: https://www.msf.ch/de/unsere-arbeit/krankheiten/ebola

This article combines and compresses the most important information about the Ebola virus. It covers the history of Ebola epidemics and later focuses on the 2014 West-African epidemic in specific. Moreover, symptoms and transmission routes are listed. In the end, Médecins sans Frontières present their remedies and challenges in the fight against the virus.

**Mirella Aliberti, S., De Caro, F., Boccia, G. and Capunzo, M.**, (2021). Is the Coronavirus crisis a teacher for the future? Italian experiences in the frame of worldwide discourses. [online] Science Direct. Retrieved from: https://www.sciencedirect.com/science/article/pii/S1865921720301768.

This paper discusses the lessons that can be learned from the experiences that Italy made with the Covid-19 crisis. In the conclusion, an action plan for future crisis situations.of the same nature is proposed.

**Mitchell, C.**, (2021). PAHO/WHO | Haiti reaches one-year free of Cholera. [online] Pan American Health Organization / World Health Organization. Retrieved from: https://www.paho.org/hq/index.php?option=com_content&view=article&id=15684:haiti-reaches-one-year-free-of-cholera&Itemid=1926&lang=en.

This PAHO/WHO press release covers the Cholera Epidemic, which was triggered by bad living conditions in the slums of Haiti after the 2010 Earthquake.

**MSF**, (2014). Medical care under fire in South Sudan (online). Retrieved from: https://www.msf.org/medical-care-under-fire-south-sudan

This article by MSF adresses the growing problem of attacks on their medical facilities in South Sudan.

**MSF**, (2014). South Sudan - Medical Care Under Fire | MSF (video) Retrieved from: https://www.youtube.com/watch?v=VsK2WDgCeD8&ab_channel=M%C3%A9decinsSansFronti%C3%A8res%2FDoctorsWithoutBorders

This video provides information abou the attacks on medical facilities in South Sudan, especially the hospitals in Malakal and Leer.

**MSF**, (2016). Are you MSF? | Daniel - All-round Logistician (video). Retrieved from: https://www.youtube.com/watch?v=4twlcPXT2RY&ab_channel=M%C3%A9decinsSansFronti%C3%A8res%2FDoctorsWithoutBorders

This is an interview with an all-round MSF logistician, who worked in South Sudan and explains about his daily routines and how the medical structures are set up and maintained.

**MSF** (2016) The humanitarian supply chain in MSF (online). Retrieved from: https://www.msf-azg.be/en/supply

This article and embedded videos provide information about the supply chain management in MSF. It is depicted, how the products that are used in the temporary medical structures find their way to the site.

**MSF**, (2016). HUMANITARIAN SNAPSHOT | Logistician in South Sudan. (video) Retrieved from: https://www.youtube.com/watch?v=n7Lym8ykz2g&ab_channel=M%C3%A9decinsSansFronti%C3%A8res%2FDoctorsWithoutBorders

This is an interview with an MSF logistician, who worked in South Sudan and explains about his daily routines and about the supply chain at MSF.

**MSF-USA**, (2017). How MSF Activates a Mass Casualty Plan. (video) Retrieved from: https://www.youtube.com/watch?v=1fL1WQW05pM&ab_channel=DoctorsWithoutBorders%2FMSF-USA

This video provides information about the activation and implementation of the Mass Casualty plan in case of a severe incident.

**MSF**, (2020). Retrieved from: https://www.doctorswithoutborders.org/haiti-ten-years-after-earthquake

This MSF article covers the situation in Haiti, ten years after the 2010 Earthquake. It includes personal stories of victims and a description of the precess that was being made in the reconstruction of infrastructure.

N

**Nguyen, M.**, (2020). Inflatable Emergency Hospitals / TecnoDimension. ArchEyes. Retrieved from: https://archeyes.com/inflatable-emergency-hospitals-tecnodimension/.

This article provides detailed project information about the inflatable Covid-19 emergency hospital by Tecnodimensión.

P

**Paye-Layleh, J. & Roy-Macaulay, C.,** (2014). Chinese-built Ebola center dedicated in Liberia. AP News, New York, US. Retrieved from: https://apnews.com/article/63cbaab6748142d7aad47d07f887262c

This is an American Article providing background information about the situation in Monrovia regarding the 2014 EDV outbreak and the coming coming about of the Chinese-built temporary Ebola hospital.

**Paz, C.**, (2021). All the President’s Lies About the Coronavirus. [online] The Atlantic. Retrieved from: https://www.theatlantic.com/politics/archive/2020/11/trumps-lies-about-coronavirus/608647/.

This article critically discusses the Trump administration‘s approach in the first months of the pandemic.

**Petit, Q.**, (2020). Entramos en el hospital de campaña de Ifema: “Esto parece un campamento militar”. El País Semanal, Madrid, Spain. (31.03.2020).
Retrieved from: https://elpais.com/elpais/2020/03/30/eps/1585580618_413163.html

The article that was published in “El País“ documents the re-purposing of the fairgrounds of IFEMA (Institución Ferial de Madrid) to an emergency hospital for Covid-19 patients. Besides photographs that show the establishment of the hospital beds in the existing structure, professionals talk about their experiences and share personal stories.

**Pintos, P.**, (2020). Corona Treatment Centre Berlin / Heinle, Wischer und Partner. [online] ArchDaily. Retrieved from: https://www.archdaily.com/940802/corona-treatment-centre-berlin-heinle-wischer-und-partner?ad_medium=gallery

**Price, A.**, (2021). Jupe Health Launches Mobile ICU Units - Impakter. [online] Impakter. Retrieved from: https://impakter.com/jupe-health-launches-mobile-icu-units/ .

This article provides detailed project information about the Jupe Health ICU‘s.

R

**Radtke, R.**, (2021). Coronavirus - Infektionen und Todesfälle in Mexiko | Statista. [online] Statista. Retrieved from: https://de.statista.com/statistik/daten/studie/1139974/umfrage/erkrankungs-und-todesfaelle-aufgrund-des-coronavirus-in-mexiko/.

This article provides an overview over the development of the Covid-19 crisis in Mexico.

**Redecke, S**., (2020). Wir brauchen einen modularen Krankenhausbau. Bauwelt, (15.2020), pp.42-47.

The interview with shareholder Edzard Schultz revolves around the temporary Corona Treatment Centre on the fairgrounds of Messe Berlin from Heinle, Wischer und Partner. The project hosts 500 beds on a surface of 11.000 $m^2$ and was developed and realized with the concept of a modular cluster withing a few days. Redecke and Schultz are talking about the background of the project. A shorter article about the project can be found on Archdaily: https://www.archdaily.com/940802/corona-treatment-centre-berlin-heinle-wischer-und-partner

S

**Shumaker, L.**, (2021). U.S. coronavirus deaths top 20,000, highest in world exceeding Italy: Reuters tally. [online] U.S. Retrieved from: https://www.reuters.com/article/us-health-coronavirus-usa-casualties-idUSKCN21T0NA.

This article shows a snapshot of the situation in the U.S. in mid april 2020, when the Covid-19 infection numbers in the country surpassed the ones of Italy and Spain.

**Singelis, P.**, (2021). Photos: Field hospitals built around the globe as coronavirus pandemic spreads. [online] ABC News. Retrieved from: https://abcnews.go.com/International/photos-field-hospitals-built-globe-coronavirus-pandemic-spreads/story?id=69962474.

This article provides an overview over field hospitals that were set up around the globe in reaction to the Covid-19 pandemic.

**Spacecube**, (2021). Monash Health. Spacecube. Retrieved from: https://spacecube.com/project/monash-health/ .

This article provides detailed project information about the Covid-19 RESUS Medical Facility at the Monash Health Hospital by Spacecube.

**Spacecube**, (2020). Modular RESUS Facility: SPACECUBE. Archello. Retrieved from: https://archello.com/project/modular-resus-facility.

This article provides detailed project information about the Covid-19 RESUS Medical Facility at the Monash Health Hospital by Spacecube.

T

**Tecnodimensión**, (2020). Emergency Hospital (online).
Retrieved from: https://www.tecnodimension.com/en/producto/emergency-hospital/

The spanish company Tecnodimensión built an inflatable hospital of 1200$m^2$ for a parking lot in Pachuca de Soto, Mexico due to the rising cases of Covid-19. The webpage includes only little text but many images that show the exterior and interior of the building. In this way, it is possible to analyze the equipment and spatial configuration that was used. https://www.youtube.com/watch?v=3I1CXBM13jI&ab_channel=NoticierosTelevisa

**The Guardian**, (2014). Haiti earthquake aid pledged by country. Retrieved from: https://www.theguardian.com/news/datablog/2010/jan/14/haiti-quake-aid-pledges-country-donations

This article by The Guardian reveals all of the monetary donations that were pledged to Haiti after the 2010 earthquake. It also provides a information about the sectors in which the donated money was utilized.

**Titz, C.**, (2019). Krieg im Südsudan - ein Bombengeschäft. Hamburg, Germany: DER SPIEGEL. Retrieved from: https://www.spiegel.de/politik/ausland/suedsudan-im-krieg-ein-bombengeschaeft-a-1287219.html

This article reveals the “wire-pullers“ behind the conflict in South Sudan. Interestingly, this shows the conflict a very different light than to what is the common perception and unveils the subliminal reasons behind the war: greed and money.

U

**United Nations**, (2016). Risk of ‘outright ethnic war’ and genocide in South Sudan, UN envoy warns. Retrieved from: https://news.un.org/en/story/2016/11/545172-risk-outright-ethnic-war-and-genocide-south-sudan-un-envoy-warns

This is a press release by the UN, stating that South Sudan is getting close to genocide. It also shows that much of the conflct is based on long lasting ethnic disputes.

W

**WHO**, (2014). Ebola virus disease. Fact sheet N°103 (online). Retrieved from: https://web.archive.org/web/20141214011751/https://www.who.int/mediacentre/factsheets/fs103/en/

This is a factsheet with the most important details about the Ebola Virus Disease. It covers everything from symptoms, possible countermeasures to the history of the disease.

**WHO & CBS&EI**, (N/A). Mass Casualty Disaster Plan Checklist: A Template for Healthcare Facilities (online). Retrieved from: https://www.who.int/hac/techguidance/tools/5.8%20Mass%20Casualty%20disasterplan.pdf

This is a blueprint of a Mass Casualty Plan, issued by the WHO & CBS&EI for implementation in hospitals worldwide.

**Willemsen, T.**, (2016). 2016 MSF Tent insulation. (video) Retrieved from: https://www.youtube.com/watch?v=fOfYN6WhZog&ab_channel=TonWillemsen

In this video, a supplier of MSF explains the different types of insulation techniques of tent hospitals. It is also meant as educational video for MSF logisticians.

X

**Xiaowai, X.**, (2020). Demystifying the hospital built in 10 days. CGTN. Retrieved from: https://news.cgtn.com/news/2020-04-24/Demystifying-the-hospital-built-in-10-days--PWDKNw6nC0/index.html.

Y

**You, J. & Mao, Q.**, (2014). An Improved Ward Architecture for Treatment of Patients with Ebola Virus Disease in Liberia. The American Society of Tropical Medicine and Hygiene. Department of Infectious Diseases, Southwest Hospital, Third Military Medical University, Chongqing, China. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4824206/pdf/tropmed-94-701.pdf

This is a report by two Chinese researchers who were involved in the Monrovia Ebola Treatment Center project. It provides a detailed description of the building, explaining novel methods that were used and the development of the design. Additionally, it includes a list of what was learned in the process and future suggestions.