Mobile Reserve Architecture: Designing the Post-Pandemic Solutions

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Abstract. The purpose of the article is to identify key solutions for pandemic architecture design. The research approach is based on the analysis of competition proposals and realized projects aimed at creating reserve hospitals during the pandemic. The historical role of epidemics in shaping architecture and cities was carried out. The precedents of mobile reserve hospitals that appeared during the pandemic were analyzed. Through the precedent’s analysis leading approaches to the new architectural environment have been distinguished (modularity and aggregation, inflatability, buoyancy, vertical expansion). The materials of this research can be used in further theoretical studies on post-pandemic architecture development scenarios and as a roadmap for practical solutions or proposals.

1. Emergence of pandemic architecture phenomena
The pandemic architecture phenomena were shaped in the shortest time possible as an inevitable reaction to the critical external conditions. The pandemic crisis provoked the mobilization of existing and the emergence of unique approaches to space organization in a rapidly changing world.

During the pandemic, architecture develops not only in line with contemporary technologies but also generates a futuristic vision that anticipates the current technological development of the society. At present, approaches to classifying developing forms of pandemic architecture have not yet been proposed, although many objects have already been constructed.

Recent research in the theoretical field show perspectives for creating innovative architectural habitat in response to the pandemic [1-5], changing cityscapes and urban fabric [6], the appearance of the new chapter of future-oriented architecture [7-10].

Several architectural competitions with open technical specifications were launched to share architectural solutions for the post-pandemic world: Pandemic Architecture International Ideas Competition (Greece), Rethink: 2025 - Design for life after Covid-19 (Great Britain), Design Class Coronavirus Design Competition (UK), Architecture Beyond Covid-19 (South Africa). The ideas of creating high-rise architecture against the pandemic healthcare crisis were reflected in proposals for the major annual international competitions as eVolo and Skyhive Competition.

2. Shaping the architecture throughout history
Throughout history, architectural forms have been shaped by the existing threat of contamination [11]. From interiors to urban planning, our built environment is shaped to some extent by disease. In the 14th century, the bubonic plague caused a fundamental urban transformation during the Renaissance.
Crowded living quarters in cities were expanded and cleared, the first quarantine zones were created, and broad public spaces were formed. During the Industrial Age, cholera and typhoid fever influenced the health reform movement. These epidemics fuelled the development of water and sanitation systems to fight pathogens, ultimately leading to innovations in sanitation and requiring straighter, smoother, and wider streets for underground pipelines. In addition, the third plague pandemic in 1855 changed the design of the smallest details of the urban environment: from drainpipes to door sills and building foundations [12].

In the 20th century, infectious diseases were one of the driving forces behind the renewal of the urban environment. Modernist architects saw design as a cure for the ills of overcrowded cities, where outbreaks of tuberculosis, typhoid, polio, and the Spanish flu contributed to urban planning, slum clearance, apartment building reform, and waste management. The aesthetics of modernism was partly influenced by the tuberculosis epidemic. The architecture of modernism was based on the purity of forms, the rigor of spatial geometry, the rejection of ornamentation. From both a materialistic and a metaphysical point of view, the architecture of modernism served as a symbol of purification. Modernist buildings had large windows, extended open balconies, and flat surfaces that did not collect dust. The predominant white paint in the decoration enhanced the feeling of cleanliness [13].

Currently, there are the first predictions about how the architecture will change after the pandemic. A. Kaicker, ex-project manager at Foster + Partners and current head of analytical research at Zaha Hadid Architects, predicts in an interview with The Guardian: “I think we will see wider corridors and doorways, more partitions between departments and much more stairs”. The old strategies for combining spaces will give way to division. The area of the lobbies is likely to be increased to prevent crowding at the entrance to the building. Elevators can be called from a smartphone without touching the button [14]. In addition to forecasts, essential projects: medical centers, are already being constructed.

3. Current pandemic solutions
The recent strategies developed throughout the pandemic were researched to classify the emerging architectural solutions.

3.1. Modular and growing
The modular building strategy has become widespread during the COVID-19 epidemic, as it allows to create cost-effective solutions and significantly reduce the time of construction. In addition, modular structures can be moved and erected in remote regions. Already at the current stage of technological development, the concept of cluster cities from modular elements is proposed [15]. These concepts can be implemented in a pandemic architecture as well. The studio 50 superreal designed a modular hospital “Adapta” that can be deployed to any site, regardless of size. The hospital design algorithm allows architects to generate hospitals of different sizes based on variable parameters. Key functional modules: hospital and intensive care wards, laboratories, and diagnostic rooms, were selected as the primary parameter. When the required number of main modules is specified, the accompanying rooms such as bathrooms, showers, dining rooms, storage, and corridor areas are calculated automatically and built into the model, optimizing the placement of modules on the site.

The organization of hospitals based on triangular prisms was proposed by the architectural bureau AGX Architects. Three modules of different areas were developed - 22.2 m², 29.7 m², 37.1 m² [16]. The inclined walls of the modular unit are made of sandwich panels 1 m wide, consisting of two profiled metal sheets with a polyurethane interlayer between them. The panels are connected by ridge fastening and do not require mastic treatment of the seam. The module includes a wardroom and an individual bathroom (figure 1). The cost of the module is $ 1500. Installation of a mobile hospital unit takes only two hours and does not require specialized training.
Figure 1. Modular hospital by AGX Architects.

3.2. Inflatable
Individual inflatable modules “Mobile PPS” (“Personal Protective Space”) create a protective space for doctors in the face of a shortage of masks and protective suits [17]. The module measuring 4 by 8 m is under constant overpressure: air only flows outward, preventing the virus from penetrating the envelope. The transparent part made of TPU has holes for the hands to ensure safe access for the doctor to the patient. The opaque compartment serves as an airlock and changing room. The supply of fresh air is provided by a fan with a pipe that goes outside or into a previously disinfected room. The cylindrical module can also be used by doctors as a mobile office or recreational space. Architects Y. Young and M. Canevacci propose a scheme that provides for the increment of modules and the formation of a sealed circuit along which mobile hospital beds can be located.

A compact deployable unit as an ancillary element for existing hospitals was proposed by Jupe. Modules with various configurations, equipped with ventilators, seats for patients with moderate severity, a relaxation area for doctors, a portable shower, and a toilet, can be rolled into flat packs and delivered using small trucks (figure 2). The module shell can be made of wood or awning material. Control of the module's automated systems that control climate, air conditioning, acoustic noise is provided [18].

Figure 2. “Jupe” – deployable and mobile medical unit.

3.3. Floating
Weston Williamson + Partners architects have developed a project for a modular hospital based on a cargo ship [19]. Due to the decrease in the international turnover of goods, many container sea vessels remain unclaimed. Floating "arks", equipped with the necessary medical equipment, can be sent to areas affected by the epidemic. Hospital ships are capable of accommodating up to 2000 places with mechanical ventilation, at the rate of 1 place per 1 container. The container modules will be arranged in vertical towers with a height equal to 6 modules. The cells are accessed through external decks served by freight lifts every 20 modules. Each module will receive electricity from the ship's engine and backup power supplies. Natural lighting and ventilation of a single room are provided by the transformation of
the container wall. The steel end panel was replaced with permeable plexiglass louvers and an integrated air conditioning system.

3.4. Vertical
To minimize the footprint of the building and place the hospital on a compact site in the structure of the urban fabric, it is possible to use a vertical organization scenario. The first place in the competition of skyscrapers of the future “eVolo-2020” was taken by the project of the vertical hospital “Epidemic Babel”, intended for deployment in Wuhan, where the first outbreak of the epidemic was recorded. The vertical hospital is built according to the principles of metabolic structures: replaceable functional modules are fixed on a rigid steel frame. The central support frame is a double helix in the form of a DNA molecule, on which functional blocks are fixed. The blocks contain 800 wards for 1600 patients. Additional rooms for medical personnel and laboratories are located inside the central frame. It is estimated that the hospital can be assembled on-site within five days, with the first 200 patients being placed in reserve wards on the third day of construction. Vertical construction will be carried out using guided drones [20].

Figure 3. Potential strategic solutions for pandemic architecture.

The idea of creating a vertical hospital in New York was reflected in the “Covision” competition proposal for the Skyhive-2020 Skyscraper Competition (figure 3). The high-altitude hospital is planned to be built on Roosevelt island, geographically isolated, but connected to all areas of the city by transport routes, allowing fast delivery of patients to the new hospital. The exoskeleton of the skyscraper is formed by a dispersed shell that allows for effective natural ventilation of hospital premises. The air flows between a porous outer structure and a glass inner layer that accumulates sunlight and protects the interior. The double façade system allows not only accumulating solar energy but also saving on building maintenance. The capsule belts contain well-lit resuscitation units. Research laboratories for vaccine development are located on the upper floors. The high-rise gardens and promenades are located on the southwest and southeast sides of the skyscraper and allow for more ventilation. The skyscraper has 2 underground parking levels for medical vehicles and 105 ground floors. The height of the skyscraper is 400 m.

The analysis of emerging solutions in the post-pandemic period revealed the following strategies (figure 4):
Figure 4. Potential strategic solutions for reserve pandemic architecture.

1. **Modularity and aggregation**: form development based on repeating units, manually or using a generative algorithm. The use of a modular and aggregation strategy can significantly reduce the time and cost of construction.
2. **Inflatability**: rapid form extension using fabric shell, which saves time during extreme situations. Inflatable structures provide for the multiple reuses of structures and materials with a possibility to change their functional purpose.
3. **Buoyancy**: the adaptability to water-level changes and mobility. Buoyant platforms isolate contaminated areas as well as move equipped hospitals to hard-to-reach areas;
4. **Vertical expansion**: saving territorial resources solution for dense cities. Revealed strategies shape the direction for future post-pandemic architectural solutions.

4. **Conclusion**
The identified strategies can be used in the design of architectural objects of various functions in the new environmental conditions of the post-pandemic world. Reserve pandemic architecture has the perspective of becoming a separate area in the mainstream of global eco-sustainable research. The general strategies for the post-pandemic architecture have already emerged and are characterized by such qualities as adaptability and rapid construction. The next-generation architecture will require fast responsive solutions. Similar strategies can be applied in future studies of architecture for other extreme conditions or alternative environments.

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