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Contents

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As the official journal of the AIA Academy of Architecture for Health (AAH), this publication explores subjects of interest to AAH members and others involved in the fields of health care architecture, planning, design, and construction. The goal is to promote awareness, educational exchange, and advancement of the overall project delivery process, building products, and medical progress that affects all involved in those fields.

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Open Rooms for Future Health Care Environments

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ABSTRACT

In recent years, many studies have revealed an increasing rate of hospital obsolescence, which reflects the velocity at which contemporary society and medical knowledge evolve. Recognizing this challenge, the main goal of contemporary and future hospital planning is to create flexible facilities capable of modifying and updating their services over time.

Many scholars and practitioners have already developed prefabricated and flexible strategies. Working from Professor Kendall's Open Building theorization (Kendall, 1999) and current applications of hotel facilities plug-in rooms, a multidisciplinary research group from Alta Scuola Politecnica has developed the Open Room approach, an innovative design solution that is able to adapt to changing needs. The Open Room is an innovative design approach able to adapt to changing needs.

The design approach is structured into three parts:

- the primary system, which consists of a main structural framework that can host open room modules
- the secondary system, composed of the sub-structural skeleton with all the installations of the module
- the tertiary system, which features both the furniture and prefabricated finishing panels that allow changes to the room's inner configuration and function.

The final product is a prefabricated room, transportable in three parts and able to accommodate a variety of fit-out changes. The interior space is defined by a series of customizable wall panels with foldable furniture and integrated functions, while the tri-partition of the substructures creates the possibility to remove the room and repurpose the building over time.

The research work defined the conceptual and technological framework for different ongoing studies on economic feasibility and possible market application.

Introduction

One of the biggest challenges for health care architecture is creating resilience to social, economic, and medical changes and developing health care services and assets able to meet the constantly changing needs of health care systems and their organizational models (Capolongo et al., 2015). The rapid evolution of medical knowledge and technologies often makes health care facilities unsuitable or even obsolete just a few years after construction. Scholars and experts involved in hospital planning are increasingly investigating new strategies to respond to these current and future challenges.

The most consolidated approach to the resilience challenge is to provide flexibility in health facilities. Flexibility is a building's ability to respond to service change in the short, medium, or long term, based on costs and user needs (Capolongo, 2012). For health issues, flexibility in hospitals should include a multiscale vision that ensures real efficiency of services provided through continually changing systems. Flexibility is critical from the planning stage, to the network system of local services, to the health care buildings that deliver services, to the mono-functional environmental units. All these layers should be structured with respect to organizational and managerial levels in an adaptive and resilient way (Astley et al., 2015).

Knowledge about flexibility in adaptability to service change has been developed and analyzed by scholars and professionals from different fields. They've found that flexibility can only be ensured by a building defined in the pre-design phase, according to technological, structural, and plant engineering criteria.

As a consequence, building adaptability has become essential for all operative and future hospitals. Current research in health care design has focused on highly-adaptable systems, from the technological to the structural scale and from the engineering building plant to the functional level (Buffoli et al., 2012). Moreover, several scholars and companies are developing strategies to improve the flexibility of significant spaces, which is essential to ensure quality for the growing demands (Verderber, 2016).

Contemporary hospital projects, often unsuitable to the needs of management and organizational complexity, are subjected to changes over time. It is necessary to define technical and technological solutions that help guarantee future changes will have minimal impact on the building systems and building users.

Among many design approaches, some experts are exploring the Open Building (OB) approach. Building upon John Habraken's studies, Stephen Kendall defined that OB is a constant surface flexibility strategy that embeds the ability to change and adjust to new layouts without increasing the building area. OB encompasses spatial and functional redistributions as well as attempts to design interior spaces, promising a high level of adaptability. By reducing excessive and useless dependencies and entanglements among components of the project, it is possible to ensure their operation without interference or damage to the others (Habraken, 1972). A preliminary distinction between durable elements and those that can be easily changed allows quicker, more affordable, and greater customization. This approach may be useful in dealing with fast changing regulations and strict bureaucracies that don't suit the design and construction timeframes of complex structures like health care facilities. For the application of the OB approach to hospitals, it is necessary to understand three systems: primary (structure), secondary (components), and tertiary (equipment) (Kendall, 1999).

State of the art

Several hospitals have been built throughout the world with prefabricated technologies. In the health care field, companies manufacture prefabricated products in two main categories: Plug & Play and Industrial, Flexible, Demountable buildings (IDF). Plug & Play relies on prefabricated structures—operating theatres and sterilization units—that are placed inside or close to the hospital. Plug & Play is a strong concept that can provide considerable savings in construction time, with tradeoffs in huge dimensions and a lack of flexibility. IDF is less expensive in production and transportation but requires longer assembly time at the construction site (Pilosof, 2005). IDF provides good flexibility with longer installation times and on-site assembly.

Starting from an understanding of OB, Plug & Play, IDF, existing strategies in health care-facility flexibility, and international know-how on prefabrication, our multidisciplinary team of Alta Scuola Politecnica (ASP) from Politecnico di Milano (POLIMI) and Politecnico di Torino (POLITO) developed innovative research on adaptability and flexibility in health care design.

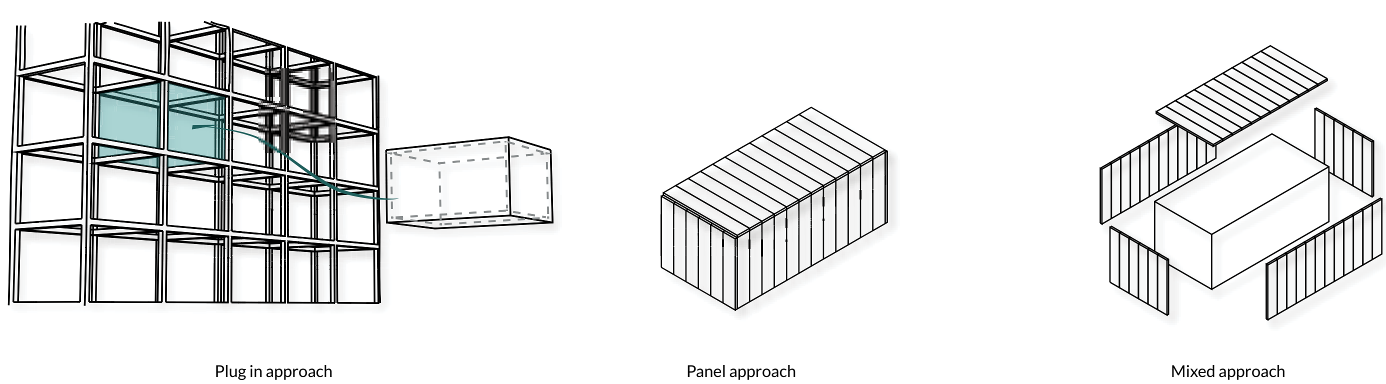
The Open Room (OR) guarantees maximum adaptability inside hospital wards with an original hospital planning approach and a prefabricated module system for healing environments.

Our research began with pop-up architecture; in particular, the prefabrication strategies for several hotel buildings. These facilities feature prefabricated rooms that were constructed in factories and plugged in during site construction (Di Pasquale, 2014). Although hotel rooms reflect specific organizational, logistic, and design needs, the layout of guest rooms is very similar to inpatient rooms. Therefore, the aim of this project is to define the conceptual and technological framework of a prefabricated healing setting application that can be plugged in and changed over time, always guaranteeing maximum efficiency of the health care facility.

Open Room approach

Starting from the OB concept, the research team focused on the small-scale room project, working to achieve a solution to address flexibility while enhancing the quality of care. To better understand the topic, the team attended lectures, international conferences, debates, and several site visits to international case studies in Groningen (Martini Hospital), Barcelona (Hospital del Mar and Hospital de Sant Joan Despí), Milan (Humanitas Clinical Institute), Bern (INO Hospital) and Chur (Kantonsspital Graubünden), each well-known for their flexibility.

FIGURE 1



Different approaches to flexibility.
Image credit: Open Building research group - Alta Scuola Politecnica

While new health care trends place greater emphasis on research and outpatient clinics, hospitals will continue to require inpatient wards, although residence time will continue to be reduced (Mauri, 2015). Beginning with the hospital room—like the hotel room—the research team began its early reflections on an inpatient room, classifying the differences. In some ways, hotel environments feature more advanced interior design and are focused on guest comfort and up-to-date technology and styles to meet contemporary market needs. The the critical feature of inpatient rooms is the space around the bed, used by users.

The Open Room concept development followed an iterative process, including input from scientific literature and interviews with health care experts. Collaboration with German-based international companies helped team members understand current and experimental technologies and techniques.

To facilitate installation, maintenance, and possible changes, we tested an approach that merged pre-built modules (Plug & Play) with the panels approach. The outer module became the container with the skeleton, connections, and installations (components), and interior finishing incorporated the panels, which become versatile, changeable, removable, and modifiable elements over time (equipment). In this scenario, the modules accommodate all possible technical needs and configurations of health care space while the finishing panels allow faster environmental transformation for the needs of the health care organization, both by a punctual modification and structural reconversion of a hospital ward (figure 1).

Driven by OB in health care, the Open Room approach can be described in three steps: Primary, secondary, and tertiary systems.

Primary system

The primary system, known as "base building," "core and shell," or "mother system," is the decision point with the longest utility value (Kendall et al., 2014). It includes the bearing structures, the main distribution, and the building plant system. The primary system can last more than 100 years and represents between 10–15% of the total investment. According to Kendall's studies, the main goal is to ensure the primary system can accommodate a variety of floor plans and equipment layouts over time. In other words, the structure should not be dependent on the secondary system.

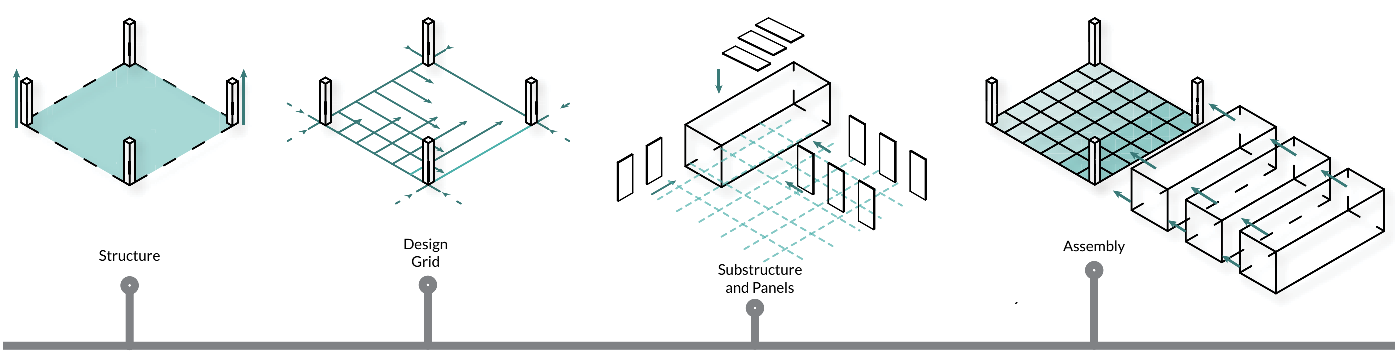
The structural grid must be regular and should guarantee maximum future flexibility for both predictable and unpredictable layouts. As OB theory states, it is crucial to understand and define maximum structure adaptability over time and, therefore, the dimensions that support several future scenarios, as the INO Hospital in Bern reflects in its layouts (Capolongo et al., 2016)

The analysis of several hospitals' furniture and spaces led to the choice of a 120 cm modular grid with exceptional submodules of 30 and 60 cm, as found in the Martini hospital. With this grid, each space can ideally accommodate an infinite variety of furniture and functions while maintaining a compact and non-fragmented feeling. The combination of these two basic elements helped define the structural frame as a rectangle of 6.90 x 8.40 m (interaxle), in which two single inpatient rooms of approximately 25–28 sq m can be hosted.

Secondary system

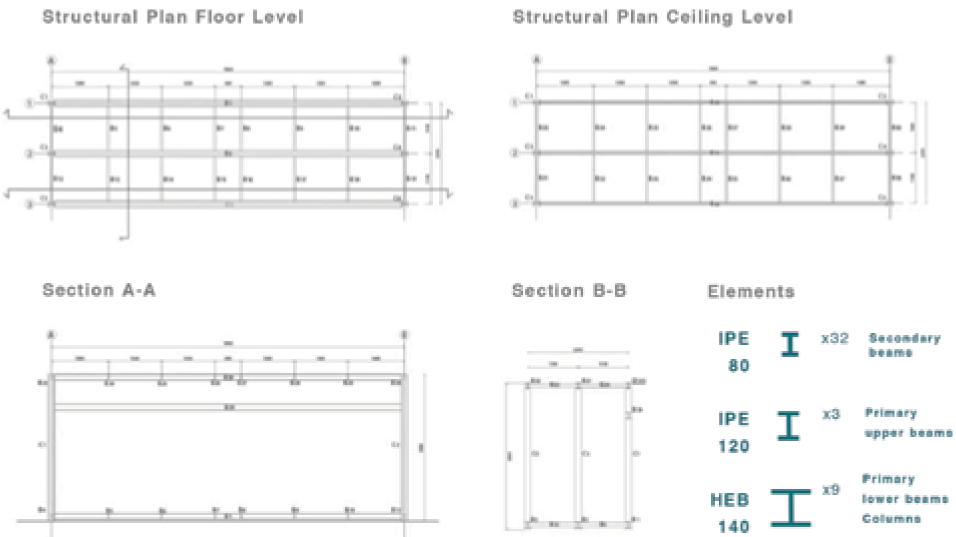
The lower level consists in the secondary system, known as "fit-out," which is fairly changeable without disrupting the base building or modifying the hospital ward dimensions or engineering plants. The secondary system generally includes partitioning, ceilings, and floor layers.

FIGURE 2



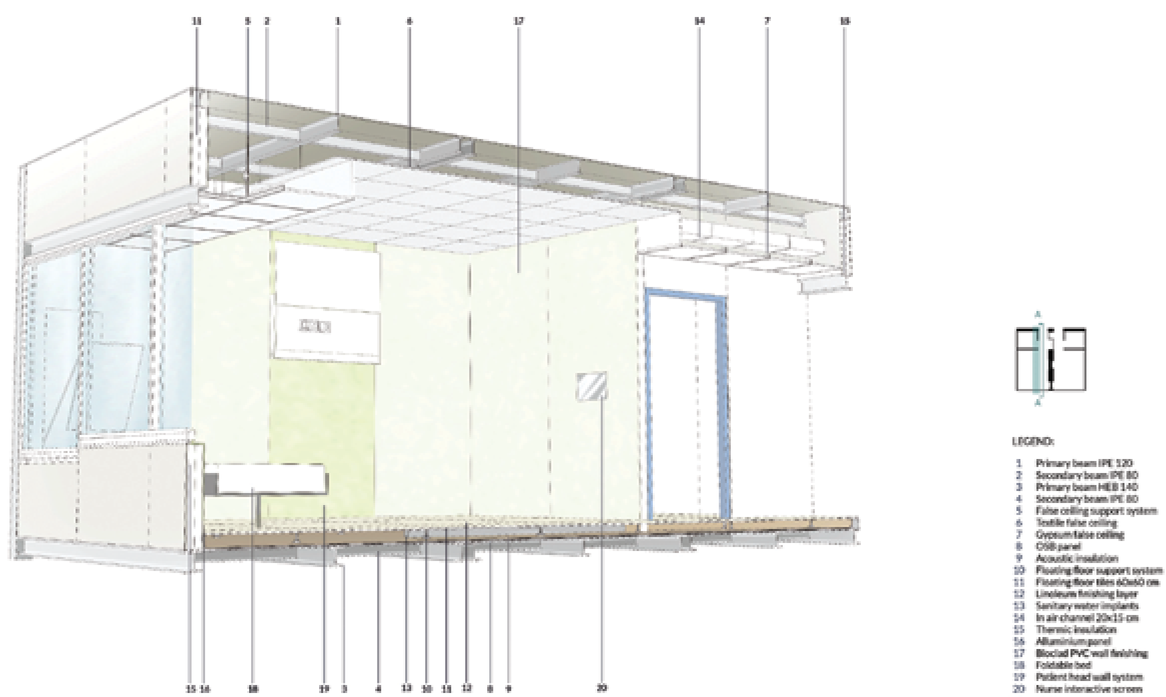
Open Room approach: Structure, design grid, substructure, and assembly.
Image credit: Open Building research group – Alta Scuola Politecnica

FIGURE 3



Module technical details
Image credit: Open Building research group – Alta Scuola Politecnica

FIGURE 4



Module technical details
Image credit: Open Building research group – Alta Scuola Politecnica

As Kendall et al. (2014) suggest in the OB approach, specific attention must be given to the provision of secondary-system components because it can be rapidly removed, repositioned, or replaced with minimal disruption to primary system. In the same way, changes made to the tertiary system, such as upgrades, replacements, or substitutions, should not excessively modify the fit-out level, which usually lasts for 20–40 years.

Although there are several hotel examples where guest rooms are already entirely plug-in, a plug-in hospital room is still far for from feasible. Unlike hotel rooms, hospital wards have several complexities that require attention to the implant design. Nevertheless, as shown in the primary system, the structural grid can accommodate two smaller rooms or one large room for each span. In fact, unlike hotels, hospital layouts have several functions and different room sizes, to guarantee maximum adaptability; the secondary system must host either one great space or two rooms.

For secondary systems, the main considerations are transportation, assembly technique, technologies, and engineering plants.

For transportation, current container approaches are limited by the fixed standard dimensions of a single unit, which are defined by European maximum allowable transportation dimensions (2.55 m x 12.00/16.50/18.75 m x 4.00 m). Starting from these dimensions, the design process led to the definition of three identical light substructural frames, equal to 2.40 m x 8.10 m x 3.30 m. The height of the frame was determined by transportation limits and truck dimension considerations, which allows the team to avoid exceptional transportation.

Each substructure is demountable and sustainable with a steel frame. In fact, the steel framing is a consolidated and common technology that allows for three substructures without any technical problem. Each frame is sustained by six columns bearing three principal beams of 7.96 m span on the top level and three on the floor level.

To distribute the load toward the primary structure and easily connect it to the substructure, the columns are welded to a steel plate in the factory. This connection should transfer the axial stress and the bendings. A fixed, bolted connection allows future disassembling of the substructure (figure 3). To support this connection, the primary structure should include ground anchors precisely positioned at the column base for connection to the steel plate with bolts fastened at the construction site. During the positioning, this technological choice keeps the substructure lifted from the slab of the primary structure through specific profiles that create a gap between the two systems to allow the removal of the wheels and the support. Through an integrated piston system, the movable support can be easily lowered and removed from the installation site.

This process—inspired by the growing tendency to place prefabricated bathrooms in health care facilities—can significantly reduce construction time. Moreover, it increases the safety of the work environment since the majority of building operations are performed in the controlled environment of an off-site industrial facility (Buffoli et al., 2012).

Additionally, the substructural frame is integrated with all the possible implants necessary for hospital rooms, including water, air, electricity, and gases. To guarantee maximum flexibility of space and functions, the secondary system designed considers all the functions that a hospital room may support due to future trends and modifications. For this reason, several focus groups were organized to investigate the different types of health care environments, analyzing all the needs and functions and defining the implant terminals positioning. In this perspective, the medical gas terminals, electrical, and data cables linked to the main implants distribution in the corridors, are well distributed in the room to allow reconversion without heavy implant modifications, if not for the finishing elements (tertiary system) (figures 5 and 6).

In addition, the substructures assume the role of secondary system for their complexity because they host the predisposition for all the possible implants. Even if this requires a higher initial investment, in a future perspective the solution allows maximum adaptability of the health care organization with time, cost, and organizational enhancements (figure 7).

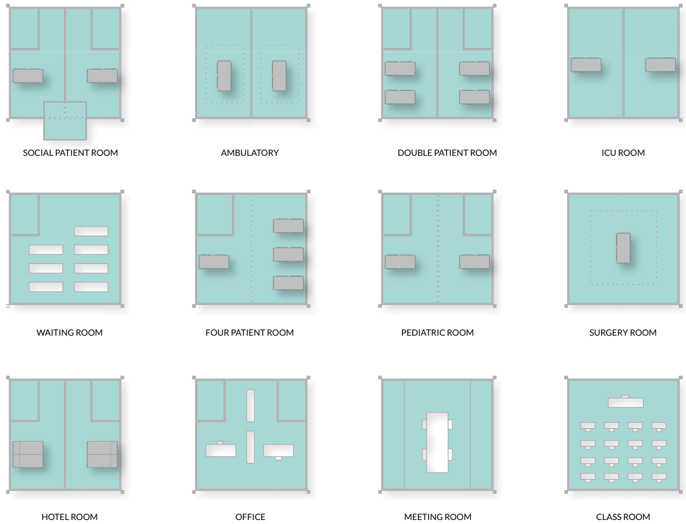
Tertiary system

According to the OB approach, the tertiary system—equipment—includes all the elements that are defined by IDF. Intensive use or rapid technological upgrades may require modifications within 5–10 years.

For the OR approach, the tertiary system is represented both by the furniture and, especially, by finishing panels. Working from focus group findings, the room's layout has been studied through an iterative process of design and verification from the conceptual to the detail scale to consider all the design parameters and user requirements affecting the design decisions. The dimensions of panels used are 30/60/120 x 240/270 cm, and they can create finishing elements that support several different functions based on requirements and general layouts (figure 7).

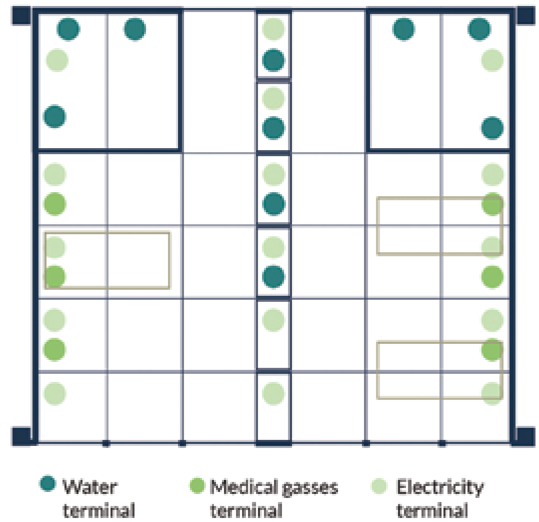
Current health care trends are toward increasingly shorter in-hospital recovery periods. Rather than foster an approach to transform hospital rooms into home environments (Scullica et al., 2012), it is better to adopt a series of small strategies to create a comfortable environment, while keeping a positive sense of temporality (Ulrich, 1992).

FIGURE 5



Open Room long-term reconversion scenarios
Image credit: Open Building research group - Alta Scuola Politecnica

FIGURE 6



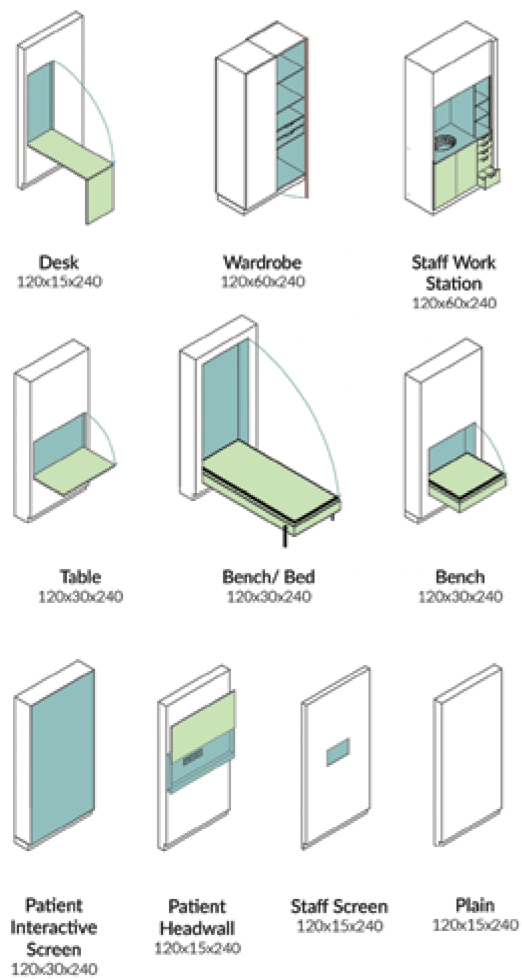
Superposition of implants terminals
Image credit: Open Building research group - Alta Scuola Politecnica

After considering several configurations, we detailed the singular and double inpatient room layouts (figure 8), structuring them into three main areas thatcorresponding to three substructures: The service zone, the inpatient's core, and the family space (figure 9). The first area includes the bathroom and a space specifically devoted to nursing activities; a lower false ceiling saves space for implants. The second area, the patient's core, contains furniture and the panels that host functions related to wellness and entertainment, including panels behind the bed that host medical gases, reading lights, and electrical plugs. Finally, the third area, the family space, hosts visitors through several configurations (Del Nord and Peretti, 2012).

The ceiling is high and constructed of textile panels with customizable integrated lighting systems. There is a wardrobe for personal items, an interactive screen, and a small screen embedded in the bathroom outer wall to let doctors access information and data. The interactive screen can serve several functions, including personal computer, images of the outside environment, and medical descriptions.

This study introduces Open Room methodological approach to flexibility, but the multidisciplinary background of the team members also helped detail hygienic, health care processes and organization, ICT, soft qualities, ergonomic, lighting, maintenance, and humanization aspects (Alfonsi et al., 2014).

FIGURE 7



Catalogue of all possible furniture units
Image credit: Open Building research group - Alta Scuola Politecnica

Perspectives

This research defines new perspectives in health care environment flexibility. By merging different fields, we achieved a multidisciplinary research outcome in which technology, layout and health care issues, social aspects, and soft qualities contributed to a final product easy to realize, fast to assemble, and well-integrated into the hospital life cycle. It also provides the opportunity to extend its lifespan by changing internal functions (Shepley et al., 2015).

The OR approach enhances operational sustainability, and it allows fast and safe changes in space and function in the short, medium, and long term. For short-term updates, flexibility is enhanced by the tertiary system's ease of panel replacement. For medium- and long-term changes in function, the module is composed of three substructures that can be unplugged from the primary system and quickly substituted and even recycled at their end of life. A similar approach was applied in Martini Hospital, Groningen (NL). In this way, it is possible to guarantee flexibility during the time. As Kendall states, a capacious container provides decision makers with good choices about what goes inside the health care facility (Kendall et al., 2014).

The layout configuration, soft qualities and materials, and the possibility of standard and/or premium customization all allow the OR approach to play a key role in enhancing users' wellness. Moreover, the adopted technologies allow the highest level of customization to support varying needs and constraints of different hospital facility managers. And, OR addresses flexibility as it enhances the quality of future health care environments.

Starting from this conceptual and technological basis, economic and market feasibility needs to be further investigated.

The Open Room is a technological definition of a prototype with a specific site approach to better understand the connection between the product and the whole hospital facility. At this stage, it is important to investigate the relationship that the OR has with different hospital ward layouts. In this direction, it is interesting to evaluate precautions and considerations while designing a hospital to host an OR system.

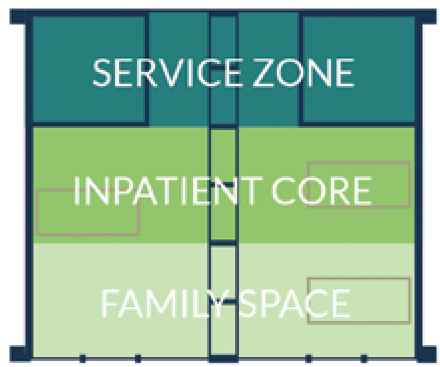
Moreover, an executive economic evaluation is crucial, one that includes close examination of the advantages and challenges in introducing a full OR production line into the current health care real estate market, taking production costs and selling margins into account.

It is also conceivable to apply this approach beyond the western context and verify the social, economic, and environmental feasibility of using prefabrication in developing countries with or without implementation know-how. Further, application in existing hospital structures requiring renovation should be studied to evaluate feasibility in international contexts.

FIGURE 8

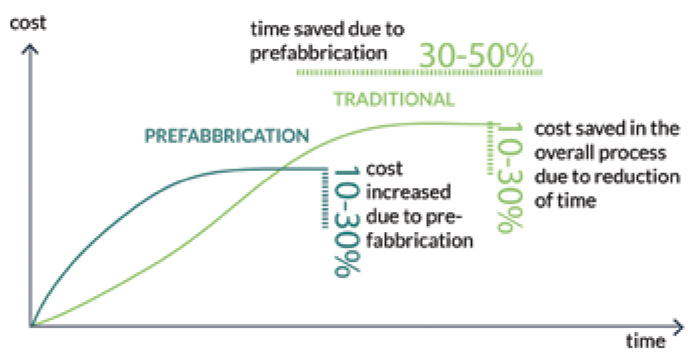
Module plan
Image credit: Open Building research group - Alta Scuola Politecnica

FIGURE 9



Room functional areas
Image credit: Open Building research group - Alta Scuola Politecnica

FIGURE 10



Comparison between prefabrication and traditional building technology
Image credit: Open Building research group - Alta Scuola Politecnica

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