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PATIENT-CENTRED AND TECHNOLOGICAL-CENTRED APPROACHES
Patient room adaptability solutions

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ABSTRACT
Starting from the study of the spatial/technological organization models of the hospital room (Intensive Care Patient Room, Acuity Adaptable Rooms, Universal Bed Care Delivery) and the main trends regarding the modernization of the architectures of the Italian National Health Service, increasingly attentive to the human dimension and the digital/technological dimension, the paper aims to define design alternatives for the hospital room, trying to combine spatial/technological flexibility with organizational flexibility to optimize workflow in care processes and the appropriateness of spaces to the psycho-physical-social well-being of all the users involved.

KEYWORDS
patient-centred vision, bio-technology-centred vision, intensive care patient room, acuity adaptable rooms, universal bed care delivery

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The current setup of Italian PNRR[1] (National Recovery and Resilience Plan) identifies a series of reforms and investments that will have to lead our National Health Service (NHS) towards a change, starting from the criticalities that emerged during the Covid-19 pandemic. If on the one hand the emergency situation following it confirmed the quality of our NHS hospitals, on the other hand it highlighted the fragility and weaknesses of a rigid system from a spatial, functional, technological and organizational point of view, though it was able to cope with the emergency by resorting to extraordinary initiatives (closure of departments, home treatment through Usca, allocation of Covid patients to homes for the elderly or temporary structures in buffer zones).

However, the attempt to counter the pandemic phenomenon led to awareness of the potential that certain innovations can have in terms of resilience of hospital structures, such as: 1) user-centred solutions for flexibility of environments through the adaptability of some departments to accommodate Covid patients through temporary solutions (separation/division of patients/spaces), showing the potential that a flexible design attentive to the relationships/integrations between spaces-equipment-systems and dividing elements can have in terms of optimizing activities, improving productivity, 'centrality of the patient' (user-centred approach) and in terms of response to a condition of uncertainty/emergency; 2) technology-centred solutions – such as e-health, telemedicine, imaging, digitalization of functions, robotic systems of service/assistance to personnel – showing the potential that the new technological frontiers can have both in terms of organizational complexity (miniaturized intra-body technologies, interventional robotics, Interactive Systems, sensors and monitoring actuators) and management (Big Data, AI, digitalization), in the dense network of relationships between spaces, equipment and users (Figg. 1, 2).

The same PNRR, on the one hand, underlines the need for a holistic vision of health as psycho-physical and social well-being by expanding it – in the concept of One Health[2] – to the interconnections between health, environmental and climatic fields and in the even more up-to-date approach of Planetary Health, to well-being and social equity throughout the world, through balanced governance of the political, economic and social systems that are decisive for the future of humanity and the natural systems of the Earth (Whitmee et alii, 2015). On the other hand (in component 2 of Mission 6 of the PNRR, 2021) it highlights the urgency of digital modernization of the hospital technology park, focusing precisely on the organization of healthcare on 'technology-centred' solutions with implications/changes in terms of both organizational and managerial complexity.

It emerges that the main challenge that all of us – technicians, health professionals and scholars – are called on to face is to overcome or rather combine the dualism of Technical Progress and Humanization. Dualism is increasingly characterised by the conflict between the hyper-accelerated dynamics of health technological innovations – whose positive effects on health must not be forsaken – and progressive awareness on the part of every citizen of their dignity, their rights and their conscious and uncon-

Keywords search string	acute care, intensive care, acuity adaptable rooms, universal bed care delivery model, health and environment, hospital design, healthcare facility design, hospital planning, hospital management, ward design, isolation and infection control, fall incidence and prevention, patient occupancy rates, patient transfer, design and well-being, patient-centred care, cooperative care, patient room, private rooms, single occupancy rooms, semi-private rooms, multiple occupancy rooms, patient rooms, double occupancy rooms, social interaction, privacy, nursing efficiency in hospitals
Eligibility criteria	**Architecture and Design** Healthcare Design, Hospital Design, Healthcare Interior Design
Nature of the topic	**Hospital and healthcare** Health Facilities Management, Infection Control, Hospital Infection, Critical Care Nursing, Services Management
	Social, Psychological and Behavioural Environmental Psychology, Environment and Behaviour, Behaviour, Health Psychology, Social Psychology

Tab. 1 | Keyword identification and eligibility criteria used (credit: C. Cellucci, 2022).

scious willingness to participate in the healing process on which architecture in its component of an emotional, perceptive and sensorial nature can play an important role (Del Nord, 2006; de la Fuente-Martos et alii, 2018).

The prospect of convergence between the two approaches, within hospitals, can be expressed in the hospital room, which represents the place the patient interacts with most and the one in which activities related to personal and private life are conducted; at the same time it constitutes the space in which patients are given treatment and their state of health is monitored. The design approach may be oriented towards providing spaces with standards and technological equipment that can be implemented at a later time, to be conceived as 'software' that is updated with a level of flexibility not linked to the contingent moment but projected into the future. In particular, the field of biomedical technologies allows us to configure the Patient Room as a real Bedside Point of Care, that is a care model that reduces the patient's movements so as to reach interventional and imaging technologies, making each room the hospital's spatial and clinical 'centre of gravity'.

Through an analysis of the recent scientific literature, the objective of the paper is to identify the main trends in the design of the functional area of the hospital. Several strategies were used to identify potential studies/articles. Firstly, a keyword search was conducted in relevant databases, such as ABI/Inform, EBSCO Host, EMBASE, JSTOR, Medline, Pubmed, Science Direct, World Cat, and further information was gathered from secondary sources such as research centre archives (Health and Care Infrastructure Research and Innovation Center, International Academy for Design &

Health, Center of Health Design). Secondly, the ‘potential studies’ were compared in relation to the eligibility criteria referring to three macro-areas – Architecture and design, Hospital and healthcare, Social, Psychological and Behavioural – in order to separate the results included in the sphere of application from those outside this sphere and avoid distortions generated by selection through keywords (Tab.1).

Bibliographic research (120 selected papers) has shown that patient room models that adapt to the complexity level of the disease – known as Intensive Care Patient Rooms, Acuity Adaptable Rooms, and Universal Bed Care Delivery Models – are the main trends in patient room design and involve considerations on the layout of the entire functional area of the hospital. Starting from an analysis of the main critical issues concerning the traditional spatial/organizational solutions of hospitalization from which the first reflections on people-centred models (patient-centred, family-centred, medical-staff-centred) have been derived, the paper identifies three main thematic axes with respect to which different organizational/spatial/technological solutions are analysed to optimize the ‘flexible room’ model: 1) adapting the hospital room to the level of complexity of the pathology; 2) balancing the technological complexity with the human dimension; 3) improving the organization of staff work through decentralized nursing stations.

For each strategic axis, case studies have been identified, representative of the design trends, analysed in their criticalities and peculiarities with respect to the possible users (patient, visitors and medical/assistance staff), summarized in a matrix that illustrates and relates spatial/technological flexibility to organizational flexibility in order to optimize the ‘workflow’ in care processes and the appropriateness of spaces to the psycho-physical-social well-being of all the users involved (Fig. 3). Evaluation/verification of the solutions of the three thematic axes with respect to the points of view of the different users constitutes the element of originality of the contribution, which does not aim to define the characteristics of an absolute spatial/organizational model but, through the definition of a complex framework research not yet consolidated, to provide a framework of design alternatives that can be selected based on the priorities and specificities of the hospital’s economic, social and environmental contexts.

Problematic environment: Intra-Hospital Transport | A recent survey by the Ministry of Health of the health facilities present on the national territory and their technological apparatus highlighted a widespread structural, spatial and technological obsolescence[3] and the consequent need to activate a process of modernization of the NHS – as demonstrated by the substantial investments in healthcare construction allocated by the PNRR (1,450,000,000) – in terms of effectiveness of interventions (from the urban scale, to the building, the hospital room) in production of health.

On the scale of the hospitalization room, various studies (Ferenc, 2014; Murphy, 2020; Sunder et alii, 2021; Eilers et alii, 2021) have shown that the hospital of the future will be designed with single rooms designed to accommodate various care and

Figg. 1, 2 | Pierangeli Nursing Home, Pescara, Italy (credits: S. Camplone, 2019).

health activities in which not only infection control but a more efficient care service will be better guaranteed. These are solutions related to Acuity-Adaptable care/Universal care models, already tested in some hospitals (e.g. in some hospitals in America such as Cathedral Hill Hospital, MultiCare Good Samaritan e il Memorial Sloan-Kettering Center), which go beyond the traditional approach to assistance in which patients are transferred (intra-hospital transport, IHT) from one unit to another in search of the correct level of care, towards a 'patient-centred' model of hospital rooms adaptable to the level of complexity of the pathology (low/medium intensity), eliminating patient transfers from ordinary to sub-intensive and intensive settings. The evidence shows that transporting patients has repercussions on managerial and clinical assistance aspects (Prandini and Zettele, 2013).

Several studies show significant correlations between transport and 1) increase in infection rates Eveillar et alii (2001); 2) increased medication errors, e.g. complications during transport related to airway equipment, infusion and drug equipment, monitoring equipment, etc. (Hendrich, Fay and Sorrells, 2004); 3) medical or clinical alterations, e.g. respiratory, cardiovascular, neurological, stress and anxiety problems for the patient (Zhang et alii, 2022); 4) risk of back injury or more generally of musculoskeletal disorders for staff due to manual handling of patients, considering that the average age of the typical nurse has increased to 47 years (Brown, 2007); 5) higher service costs and lower productivity (Hendrich and Lee, 2005). The vast majority of the time spent on intra-hospital transport is wasted on delays caused by communication problems, and delays in recording transfers or managing information about the availability of beds, equipment or staff (Ulrich and Zhu, 2007).

Intra-hospital transport of patients, therefore, represents an area of fundamental importance in quantifying the quality and efficiency of the care process, if we consider that transfers from one room to another – due to the need for additional technologies (imaging, surgery, other diagnostic or therapeutic purposes), the need for more qualified personnel (ICUs, are the most common origin of IHT) – are quantified in a measure of 2/3 times for short-term stays (Hendrich and Lee, 2005). Although some research argues that risk can be reduced with increased monitoring and support (Murata et alii, 2021), strong evidence indicates that in-hospital transport triggers complications and suggests the need to rethink the organizational model and architectural environment to minimize transfers through organizational solutions and spatial/technological models that adapt the staff and spatial/technological models to the level of intensity of care (Garg and Dewan, 2022).

Flexibility of the hospital room: literature review | The Acuity-Adaptable and Universal Room models, which have been experimented with in the United States since the 1970s, and became highly popular in the late 1990s, especially in highly complex specialist hospitals, have provided valuable lessons in long-term flexibility in spatial organization, technology of hospitalization rooms and organization of assistance centred precisely on the patient and the area he or she stays in. As these models have matured, their application and purpose have evolved and, in some cases, have become interconnected (Brown, 2007; Ferenc, 2014; Sunder et alii, 2021).

The patient's room adaptable to the acuity of the pathology is based on the single hospital room model in which the patient is treated/assisted during the entire hospitalization period and at any level of acuity of the pathology. The inpatient room model called Universal Care Room (UCR) is organized around the possibility of providing various technological plant and electro-medical equipment such as to be able to accommodate and manage any type of patient, regardless of the level of clinical complexity (e.g. intensive, med/surg). In most cases, the room set up for universal assistance is a hybrid of different types of rooms with the facilities provided for an intensive care room. Both models share the goal of flexibility to adapt space/technologies/personnel to the level of intensity of care but differ in purpose. In the Acuity-Adaptable model, the focus is on eliminating patient transfers by providing complete care directly at the patient's bed. By contrast, the goal of the Universal Room model is to provide a room with an adaptable design that can meet the changing needs of clinical acuity, without specifically altering the current care practice and patient transfer (Gallant and Lanning, 2001).

Although innovative, both solutions have the weakness of associating the flexibility of the room with an organizational model that is often difficult to implement, as certain services (cardiovascular surgery, neurology and trauma management) require different nursing skills and therefore a different staff based on the level of care (basic or acute nursing care), leading to staff organization problems (Ulrich and Zhu, 2007). As a result of these problems, a third model of care has emerged that divides Intensive Care Units (ICUs) from acute care rooms. It is a room model with beds adaptable to the required intensity of care and intended for patients who need intermediate care and possibly intensive care.

Adaptability of the space/equipment/technological system to the intensity of care | Adaptability of the hospital room to emergency conditions, through the analysed models, in order to manage the patient at the different levels of intensity of care directly from the bed, involves the integration of technological, electro-medical and functional equipment with respect to the different levels of care, within interstitial spaces present in attics, equipped floors or technical nuclei between the rooms (Brown, 2007; Ferenc, 2014).

Hamilton and Ulrich (2014) have identified three possible solutions for the integration of technological devices in the patient room, tested in different hospitals: 1) the 'headwall' configuration, in which the monitors and equipment sockets are positioned on the wall behind the head of the patient's bed, designed to be a flexible/customizable system to adapt to staff preferences; 2) configuration of the 'power column', in which the system of sockets/equipment is contained in a vertical device (from floor to ceiling) and generally placed sideways to the head of the bed, a solution that eliminates the need to move the bed but can cause interference with the flows/movements of staff during procedures or emergencies; 3) the configuration of 'suspension' systems, in which the life support components are suspended from the ceiling or the wall with the possibility of rotation of the system and adaptation to different bed positions (Pati, 2008). Although the latter is the most flexible and does not generate interference between electrical connections and movements of nurses/patients (reducing the potential risk of falling), the 'headwall' configuration is the most common choice among life support systems (Needham et alii, 2005). A concrete and innovative example is the headwall of the Jacobs Medical Center in San Diego in which electrical devices, oxygen and other medical gases are contained in a compact system that transforms a medical device into an architectural element (Fig. 4).

A potential criticality in the implementation of this model concerns the obsolescence of the technological apparatus for treatment and monitoring of patients, which involves the adoption of plant integration solutions that meet the requirements of disassembly, reversibility and implementability (Thiadens et alii, 2009). Specifically, the future challenges in integrating medical equipment into the patient's room will concern the following: 1) designing furnishings conceived not as aseptic objects intended

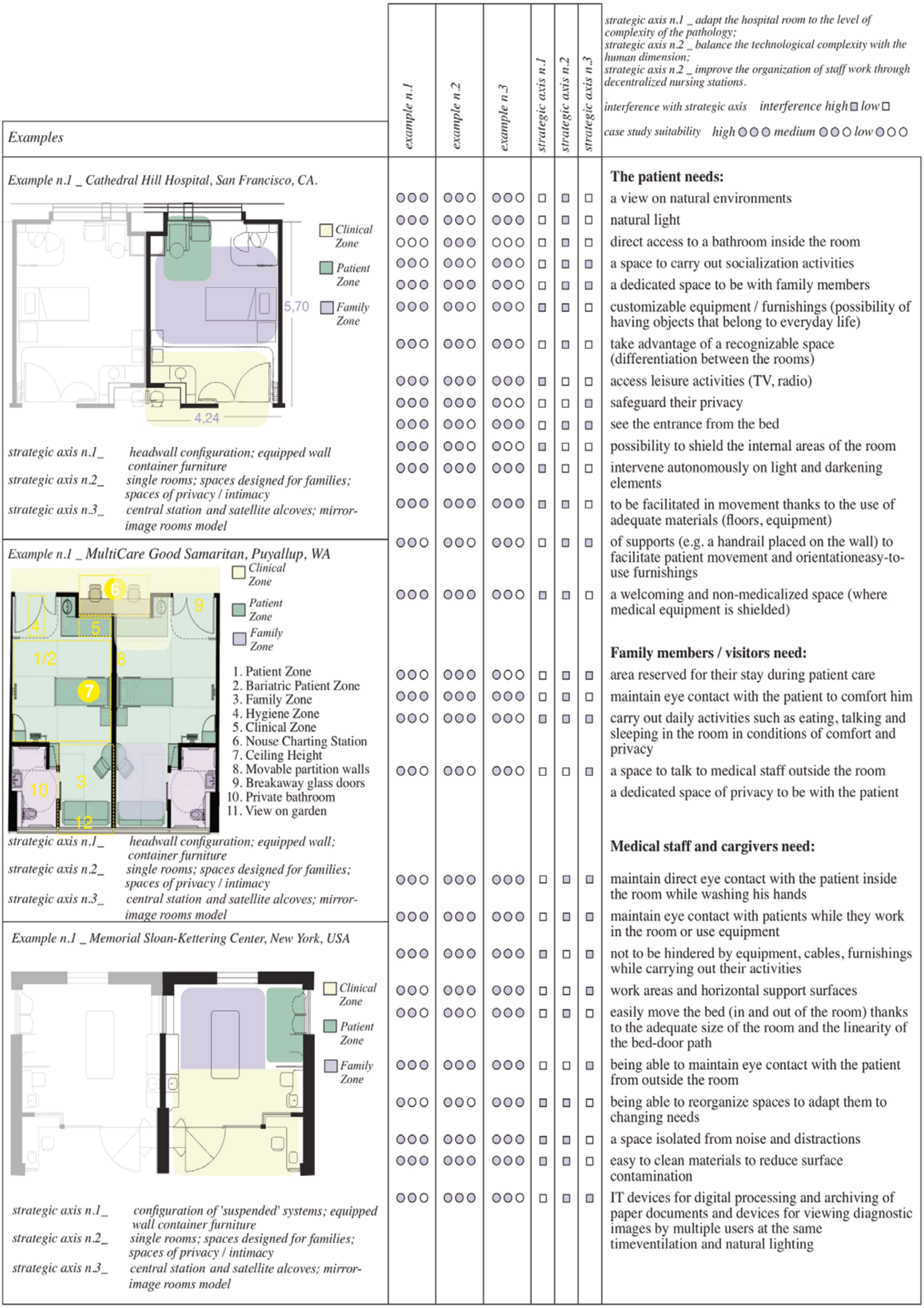


Fig. 3 | Evaluation matrix with respect to the needs of different users (credit: C. Cellucci).

to house medical equipment but therapeutic and wellness tools, integrated with new AI and robotic systems, capable of managing patients' medical information, monitoring vital parameters, distributing drugs or collecting samples, integrated with services capable of making sense of the time spent for treatment (internet, radio, television for personal use); 2) the use of technical interstitial spaces such as equipped floors and floors or technical nuclei between hospital rooms that can be expanded and integrated over time as the conditions of use change with respect to the individual conditions of the patient (intensity of care), which allow correct positioning and integration of sensors aimed at monitoring vital conditions. These interstitial spaces could be functional for the passage of the wiring for air, oxygen, and nitrogen at the service of the various bed stations with which they interface, as well as containing sensors (inserted in walls and floors) used to route trolleys, staff and patients along predetermined paths. All these devices can be hidden behind sliding panels with wooden or coloured finishes – to give the patient a positive perception – which can only be opened when using the equipment contained in them (Figg. 5, 6).

The adaptability of the hospital room to the evolution of technology must be supported by ergonomic considerations in the relationships between activities/spaces/equipment and users, which should ensure a 'wide fit' in the sizing of the room in order to provide for easy adaptability to different future organizational, spatial and technological conditions.

Balance between technological complexity and the human dimension | A common feature of the various adaptable room solutions is that of considering the methods, or 'how', through appropriate decision-making strategies, it is possible to create the environmental conditions to reduce the 'stress-inducing' factors and emphasize the 'stress-reducing' ones (Mokhtar, 2021). The approach to care through the patient-centred model has influenced not only the modalities of communicative exchange between patient

Fig. 4 | Jacobs Medical Center Headwall, San Diego (credit: shieldcasework).


Figg. 5, 6 | Walls equipped to accommodate the plant equipment of the Care Lab, by dmvA Architecten, Bruges (credits: B. Gosselin).

and medical staff but also the physical-functional (accessibility, distribution of spaces) and psycho-sensorial and perceptive characteristics of the care spaces, finding confirmation in Evidence-Based Design. Research experiences (Eilers et alii, 2021; Eijkelenboom and Bluyssen, 2022; Murphy, 2000) suggest considering the following strategies in hospital room design:

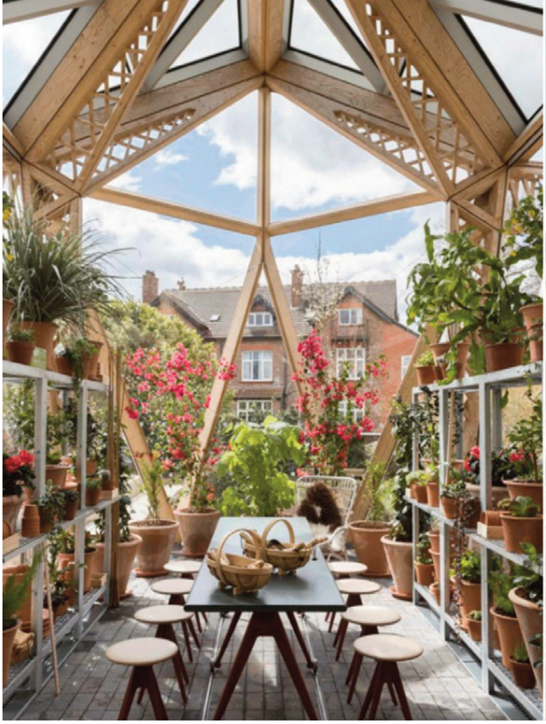
– Larger single rooms; rooms for single patients improve clinical outcomes by reducing the risk of infections, falls and stressful conditions, and at the same time ensure the possibility of configuring the room according to the need for positioning special equipment or wall space maneuvering for personnel to perform exceptional assistance activities (e.g. Loma Linda University Medical Center, California; Clarian Health System's Methodist Hospital, Ohio State University);

– Family-friendly spaces; the presence in the hospital room of a specific area intended to accommodate family members (including seating and services, and possibly beds) allows active involvement of family members in certain aspects of care as well as in psycho-physical support for the patient, with positive effects on clinical outcomes (decrease in hospitalization falls, reduction of nursing hours per patient) and on the increase in satisfaction with the hospital experience (e.g. Richard M. Ross Heart Hospital, Ohio; Clarian Health Methodist Hospital, Indiana);

– Spaces for privacy/intimacy; although the patient's room must respond to the needs of process efficiency and effectiveness of care, it cannot be neglected in a broader vision of health as psycho-physical well-being, with attention to characterization (for volumes, materials, colours) of spaces (New Children's Hospital in Finland, GAPS psychiatric hospital in Denmark) and personalization/appropriation of spaces for intimacy/privacy (the transformability of the wards in the Meyer Pediatric Hospital in Florence and the Agatharied in Germany); privacy must be particularly ensured during the later stages of hospitalization as patients typically only require intensive care ser-

vices for a limited period; this condition can be achieved through a spatial/functional organization of the room to avoid visibility of the privacy areas from the common areas or through movable partitions and glass doors that can be darkened;
– Healing gardens and positive distraction devices; the distributed presence of therapeutic gardens and healing gardens in which the internal-external correlation can be regulated by selective filters (light, air) according to the needs of users through the integration of automated systems (remote control of door, curtain and window opening, and lighting modulation), can affect the reduction of stress and improvement of clinical conditions by providing positive distractions for patients, families and staff. Other positive distractions often integrated into the room that can be adapted to the intensity of care are artworks, music and a family atmosphere (Isala Hospital in Zwolle, Holland, designed by Alberts and van Huut, 2013; Maggie's Cancer Center in Manchester, designed by Norman Foster, 2016; Figg. 7, 8).
– Environmentally responsible materials; another front is that of innovation in the field of building materials in which the frontiers of technological innovation focus on the possibility of having antibacterial and antiviral but also sustainable materials, free of toxic chemicals to improve internal air quality and reduce impacts on public health.

Decentralized nursing stations | Implementation of flexible solutions for adapting the patient's room to the levels of care also involves new solutions for the position of the nursing station. The traditional centralized nursing station – an operational model in which all the support spaces necessary for nurses to carry out their duties are located at one point in the physical hospital unit – is gradually being replaced by decentralized stations, in which nurses can directly see patient rooms so as to respond to problems more quickly. This solution makes it possible to reduce the time of assistance intervention (Pati, Harvey and Thurston, 2012), a greater interaction between medical staff and patient, better visibility of the patient and more time dedicated to his or her care (Hendrich, Fay and Sorrells, 2004). Many hospitals have experimented with the following nursing station solutions associated with Bedside Point of Care models:
– Nursing stations organised by clusters of hospital rooms; in this solution, the support spaces (which include spaces for documentation, drug storage, nursing supplies, equipment, etc.) necessary for nurses are distributed over several stations inside the physical hospital unit;
– Mini-stations between two rooms; in this solution, everything nurses need to perform their duties is provided immediately outside the patient room (or in the extreme case of decentralization within the patient room), Hendrich, Fay and Sorrells (2004) argue that after adopting this solution, Clarian Health System Methodist Hospital saw a decrease in the number of patient accidents by 75%;
– Hybrid service model; in this solution, decentralized service stations are combined with centralized service stations intended for meeting rooms for consultation between staff members; this model has been tested at the Banner Estrella Medical Center in




Figg. 7, 8 | Maggie's Cancer Center by Norman Foster, Manchester (credits: N. Young).

Arizona, with nursing alcoves outside each hospital room and a common workspace in each unit (with computer resources and small conference rooms), and is the best solution for designing nursing stations (Zborowsky et alii, 2010).

Other considerations to improve the nurses' workflow may concern:

– the orientation of the rooms according to the 'same-handed rooms models' (Parkland Hospital hospitalization room, Dallas, Texas) or 'mirror-image rooms' (Hallegiance Health solution); the former shares the wall that accommodates their headwalls, it is useful for positioning shafts/interstitial spaces functional to the headwall equipment; the latter places the headwall on the same side in all patient rooms, typically the left sidewall, which has been advanced as the optimum caregiver location; this solution encourages repetition and standardization that reduce the chance of errors and waste;

– the integration of ceiling-mounted patient lifts can be useful to reduce staff back injuries caused by lifting patients in and out of bed or a bathroom, staff sick time, and hospital costs (Fig. 9).

Conclusions | Although the concept of flexibility is very complex and includes a variety of characteristics such as versatility, redundancy, convertibility, transformability and scalability, the idea of designing a resilient structure capable of adapting to epidemiological, technological and social changes is always desirable, especially in light of the current Covid-19 pandemic. The solutions and alternatives analysed to improve the patient's room show that the physical environment can lead to positive results in terms of well-being (for users and operators); staff productivity (workflow); clinical safety (prevention of medical errors, incorrect application of therapy, contraction of nosocomial in-

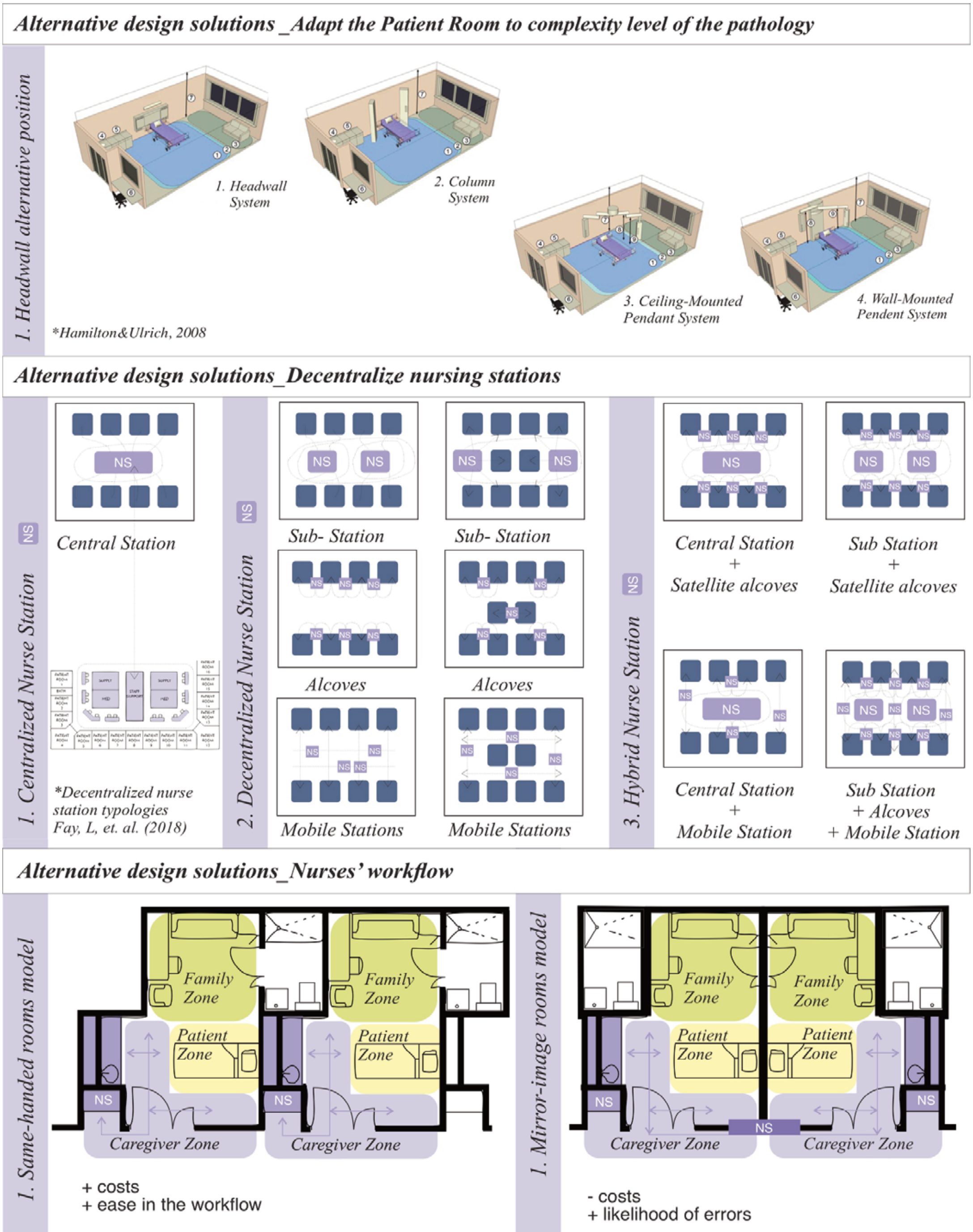


Fig. 9 | Alternative design strategies (credit: processed by C. Cellucci).

fection), psychological and physical safety, (prevention of medical errors, application of therapy, contraction of nosocomial infection and reduction of stress factors). However, the adaptability of the hospital room to meet these new needs clashes with the limits relating to the structural and typological constraints of existing hospitals, which constitute the main barrier to adaptation to new organizational/spatial models.

While for existing structures the transformations/adaptations should be appropriately evaluated from the point of view of feasibility according to the specific conditions of each structure in question, new hospitals constitute the main field of application of the solutions investigated. A further limitation derives from a rigid and cumbersome regulatory field of reference based on minimum structural, organizational and technological requirements (Presidential Decree 14/01/1997) which leave no room for creativity and design invention and would require alignment with international best practices (Health Building Notes; Healthcare Facilities Guidelines; etc.). There is also a problem of a psychological-behavioural nature due to the stressful conditions to which the medical-nursing staff will be subjected who find themselves working in new spatial models, with repercussions on tasks, duties, and workflows/habits. Precisely this complementarity between design actions aimed at guaranteeing the well-being of the users involved and organizational actions aimed at optimizing care suggest promising research spaces that can be investigated, further developed and possibly tested in real empirical contexts, through the involvement of figures belonging to different scientific disciplinary sectors in order to bridge the limits of a literature review conducted through databases (which may have led to exclusion of important contributions) and not on application cases.

However, the future research spaces in this field are ample, and the possible scenarios of use concern the development of tools for 'verifying' the adaptability of existing hospital structures; for 'guidelines', useful for public administrations in drafting innovative tenders for the construction of new hospitals; for 'support', for hospital strategic management and professionals to orientate actions towards new or existing structures, also through the use of simulation systems (Digital Twin) capable of verifying the possible transformation scenarios with the impacts on staff productivity, on the clinical safety/well-being of the patient and on accessibility to treatment.

Notes

1) The National Recovery and Resilience Plan is available on the web page: italiadomani.gov.it/it/home.html [Accessed 29 July 2022].

2) For more information see the web page: oneworldonehealth.wcs.org/About-Us/Mission/The-Manhattan-Principles.aspx [Accessed 29 July 2022].

3) Ricognizione del Ministero della Salute (2020), Rilevazione del fabbisogno di edilizia sanitaria, nota MdS prot. n. 17157 del 21/08/2020; Ricognizione del Ministero della Salute (2020), *Fabbisogno di informatizzazione*, nota MdS prot. n. 15809 del 31/07/2020.

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