Hospitals of the future

A technical brief on re-thinking the architecture of hospitals

World Health Organization
European Region

ABSTRACT

The COVID-19 pandemic has highlighted the importance of national preparedness for natural and human-induced disasters, emergencies and other social crises. The ability to deliver uninterrupted health services is crucial in these situations, and the design of architecture for health is a way to address the multiple drivers that are transforming society, economy and the environment. Hospitals are particularly important in this regard as they best interpret these transformations, promote urban regeneration, and have positive impacts on a widespread scale across any given territory. For a hospital to remain functional during emergencies and disasters, it must be designed with strong and flexible infrastructure, high resistance to hazards, and a focus on safety and comfort. The COVID-19 pandemic has also emphasized the significance of the hospital environment in the transmission of pathogens and highlighted the need to ensure sustainable compliance with hygiene standards. World Health Assembly resolutions and the COP26 Health Programme are taking steps to address these issues and promote better health in Europe. This technical brief is structured as a guide for health care planners and designers to improve the safety, comfort and efficiency of refurbished and redesigned hospital projects and new hospital facilities across the WHO European Region.

Keywords

HOSPITAL, SOCIAL ENVIRONMENT, WORK PLACE, SAFETY

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CONTENTS

Acknowledgements iii

Abbreviations iv

1. Why a technical brief about health care infrastructures? 1

2. Purpose, methods and structure of this brief for action 3

3. Target audience 4

4. Outside the hospital: integrating the new hospital building with the community, natural and social environments 5

   4.1 Hospital localization, urban regeneration and the contextual relationship, urban functions, services and amenities 5

   4.2 Health care network and the synergies between hospitals 6

   4.3 Landscape and healing outdoor environments 7

   4.4 Accessibility and universal design strategies 10

5. Inside the hospital: interventions needed for hospitals in relation to technical, structural and operational aspects 12

   5.1 Functional design and innovative layouts 12

   5.2 Health care infrastructure sustainability 15

   5.3 Flexibility, resilience and future-proofing 16

   5.4 Healthy working areas 19

   5.5 Safety and security issues 20

   5.6 Organizational strategies for infection control capability and indoor air quality 21

   5.7 Digitalization of the hospital from the management to the end-users 23

   5.8 Soft qualities and wayfinding 25

6. Suggestions to monitor and measure the effectiveness of the interventions 26

7. Key messages 27

8. References 28

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The project was completed in preparation for the First Regional Meeting on Hospitals, planned to be held on 5–7 June 2023 in Baku, Azerbaijan.

Abbreviations

ACSQHC	Australian Commission on Safety and Quality in Health Care
AMR	antimicrobial resistance
BAM	built asset management
BIM	building information modelling
CAFM	computer-aided facilities management
COP	United Nations Climate Change Conference
COVID-19	coronavirus disease 2019
EBD	evidence-based design
EMS	emergency medical services
EPW	European Programme of Work
EU-OSHA	European Agency for Safety and Health at Work
HAI	health care-associated infection
HVAC	heating, ventilation and air conditioning
IoT	Internet of Things
IPC	infection prevention and control
KPI	key performance indicator
NZEB	net zero energy building
OSHA	Occupational Safety and Health Administration
POE	post-occupancy evaluation
SUVA	Swiss National Accident Insurance Organization
UNICEF	United Nations Children’s Fund
WASH	water, sanitation and hygiene

1. Why a technical brief about health care infrastructures?

Among the realizations emerging from the COVID-19 pandemic is the importance of being prepared for both predictable and unpredictable natural or human-induced disasters, emergencies and other social crises. Such predicaments include ageing societies, demographic challenges, the various energy crises, and so on, occurring around all the world, in tandem with advancing technological innovations. The ability of critical infrastructures such as health care facilities to deliver health services without interruption in these situations is a matter of life and death. Today, the design of architectures for health is an opportunity to interpret multiple drivers that are transforming contemporary social, economic and environmental paradigms.

In fact, the global challenges of an ageing population, inclusion, digitalization and climate change find synthesis in the project of architecture. In particular, the hospital is the social architecture that best interprets these transformations, as well as being a promoter of urban regeneration and a bearer of important positive impacts on a national scale. Care settings are today contaminated by the great demographic, technological and epidemiological revolutions, but at the same time they can interpret an integrated approach to health care in a physical-spatial perspective and contribute to global health through the creation of healthier, more efficient and more comfortable care environments for all users.

For a hospital to remain safe and functioning – including during emergencies and disasters – it must be designed and built to a level of safety that offers a strong and flexible infrastructure while incorporating resilience to hazards. Health care systems and their hospital facilities face huge challenges during emergency situations (such as during the COVID-19 pandemic) relating to the management of health care settings and building layouts, environmental contamination risks, and infection prevention and control (IPC) requirements and standards.

During the pandemic, hospitals were encountering difficulties dedicating staff, equipment and rooms to isolate or cohort patients with suspected or confirmed COVID-19 infection, while simultaneously providing routine care to patients. In terms of lessons identified, not only could the individual health care facilities have benefited from better resilience, but it also became clear that greater synergy was required among whole health care systems and the related supply chains, including the procurement, production, and distribution of essential medical supplies and equipment.

In addition, the COVID-19 pandemic highlighted the problematic nature of the hospital environment in the transmission of pathogens, which was already and will continue to be challenged by both antimicrobial resistance (AMR) and health care-associated infections (HAIs). HAIs are a threat to public health, increasing morbidity, mortality and health care costs globally. The hospital environment plays a key role in the spread of such infections.

Hospital facilities have at last begun to be considered fundamental in recent policy reports, specifically regarding hygiene and sustainability. For example, a recent World Health Assembly resolution focused on water, sanitation and hygiene (WASH) as a priority for high-quality health care, protecting patient safety and tackling AMR (WHO/UNICEF, 2022). At the same time, the COP26 health programme is fostering key actions to support countries in developing climate-resilient and low-carbon sustainable health systems.

Taking into consideration WHO European Programme of Work, 2020–2025 (EPW) – “United Action for Better Health in Europe”, the recommendations stemming from the Pan-European Commission on Health and

Sustainable Development, and the clear interdependency of human and environmental health, the WHO European Health Workforce and Service Delivery Unit is addressing the issue of best practices and tools for today's most urgent and challenging health care design issues for safer and healthier hospitals of the future.

This technical brief is structured as a contribution to guide health care infrastructure planners and designers on how to improve the safety, comfort and efficiency in refurbished and redesigned hospital projects, including measures to be considered in the design of new hospital facilities across the WHO European Region. It is important to clarify that this report is focused on the architectural aspects of hospitals, without exploring service delivery or the ideal combination of hospital-based services; the aim is to inspire a variety of forward-thinking hospital designs that can be adapted to different contexts. The project is the result of a vision of how important collective learning is, following the COVID-19 pandemic. That realization led to the organization of a meeting of experts to discuss the future of hospitals in Europe in April 2022, at which the main concepts detailed in this brief were shared. The project was completed in preparation for the first Regional Meeting on Hospitals to be held on 5–7 June 2023 in Baku, Azerbaijan.

2. Purpose, methods and structure of this brief for action

The purpose of this technical brief is to orientate stakeholders from WHO European Region Member States when considering building new hospitals or planning to improve existing facilities. In particular, it focuses on how to mitigate better the environmental and epidemiological risks, along with minimizing inefficient and stressful health care settings for workers, patients and organizations, from a technical-structural and operational point of view. It also looks at how to integrate better the hospital building itself within the community, and its natural and social environments.

Using as a starting point the challenges that emerged during the COVID-19 pandemic – summarized in the paper *COVID-19 and healthcare facilities: a decalogue of design strategies for resilient hospitals* (Capolongo et al., 2020) – an exploration of scientific and technical literature was conducted in order to highlight the most recent and effective trends in the field of hospital and health care design. Specific evidence and practice-based strategies were explored in depth and are briefly discussed in this technical brief. The aim is to support stakeholders in highlighting key actions and items for improvement in new hospital projects, while also benefiting the future development of health care systems.

The brief targets the following audiences:

- transnational health care institutions, associations, networks and organizations;
- welfare system governance bodies, leaders and strategic managers;
- general managers, medical directors and strategic directors of health care infrastructures;
- planners and designers of health care infrastructures;
- technical directors and facility managers of health care infrastructures.

The brief provides synthetic actions to support the process of re-thinking the architectures for health and it is divided into two main sections, which detail the strategies to be tackled (a) outside and (b) inside the hospital.

In the first section, "Outside the hospital," which deals with integrating the new hospital building with the community and natural and social environments, topics covered include **strategic localization, synergies through the health network, landscapes and healing gardens**, and **universal design and inclusion**.

The second section, "Inside the Hospital," discusses interventions needed for hospitals in relation to technical structural and operational aspects. This section includes details on **functional design, infrastructure sustainability, flexibility and resilience, healthy working environment, prevention and safety issues, infection and air-quality control, and health care digitalization**. It is important to note that in this document, resilience is not explored in depth, as it is comprehensively covered by the Hospital Safety Index developed by WHO as an instrument to be used by health authorities and various interdisciplinary collaborators to assess the likelihood of a health facility maintaining safety and functionality during emergencies (WHO & PAHO, 2015). This indispensable resource comprises evaluation forms, guidance for assessors, and a safety index computation tool, which together provide comprehensive coverage of the resilience topic.

For each aspect, a series of actionable topics is included, and all associated key references are listed at the end, to allow follow-up. A chapter is also provided on measurability, with strategies for assessing the state of the art and monitoring the improvements to be achieved.

Images are included in several sections, as visual references for good practices; however, these cannot be considered as fully representative, nor as representative of that specific topic alone. These details would need to be explored based on the local context, culture and constraints.

3. Target audience

- **Transnational** health care institutions, associations, networks and organizations
- **Welfare** system governance bodies, leaders and strategic managers
- **General managers**, medical directors and strategic directors of health care infrastructures
- **Planners and designers** of health care infrastructures
- **Technical directors** and facility managers of health care infrastructures

4. Outside the hospital: integrating the new hospital building with the community, natural and social environments

Bijgaardehof Co-Housing and Healthcare Center | BOGDAN & VAN BROECK, 2022 | Ghent, Belgium

An abandoned factory site was transformed into a flourishing community including co-housing groups and a community health centre, renovated with the material from the old factory building, and supplied with local geothermal energy for heating, and passive cooling for summer.

4.1 Hospital localization, urban regeneration and the contextual relationship, urban functions, services and amenities

Hospital site selection is a crucial topic in planning decision-making processes that affect the environmental, social and economic sustainability of health care structures and the efficiency of health services. A suitable strategic location represents an opportunity for fostering urban regeneration processes in areas close to the health care facility (Capolongo et al., 2020; Dell'Ovo, Oppio & Capolongo, 2020). The functional orientation of the hospitals in the city centre and at city boundaries should be distinct at the urban planning level and they must be considered with a broad overview of the whole health care supply chain.

The following aspects should be considered.

- Health care facilities in the city centre and at the city boundaries can serve different functions, according to the local urban planning situation, forming a local health care service network.
- In the city centre, functional integrated facilities should be available to provide an advanced level of health services, including primary care, prevention and health promotion services on a neighbourhood scale,

fostering the Proximity City urban planning concept.
- Hospitals located at the city boundaries can guarantee both (a) the limitation of flows from outside urban areas into cities, reducing opportunities for infection transmission in high-density city centres; and (b) the accessibility of health care services to people from different areas (Capolongo et al., 2020).

Fig. 1. Territorial Healthcare Network | Visualization of "Territorial Healthcare Network" by Politecnico di Milano Design & Health Lab

4.2 Health care network and the synergies between hospitals

The synergy between so-called territorial services (local or regional-level community or primary care) and hospital organizations (acute care facilities) plays a crucial role in health promotion (Capolongo et al., 2020).

From the point of view of hospitals, the network ensures even distribution of services among the population, avoids overcrowding, and increases the resilience and use of health care services (Battisto & Wilhelm, 2019; Setola et al., 2022). From the citizens' point of view, the close proximity and lack of transportation difficulties can increase willingness to access health care services.

The following aspects should be considered.

- The need to ensure and realize the resilience of each building and of the health care system cannot be separated from the reorganization of the welfare system at the local or regional (territorial) level; this is a prerequisite for the planning stages.
- The whole network must be re-thought according to the current landscape, adapting it based on digital health care developments and dematerialization needs (Setola et al., 2022).
- A successful health care network encourages the population to access the care they need.
- Establishing the health care network can reduce patients' need to transfer across regions.

- With an effective network, overcrowding can be decreased in emergency departments (Barish, McGauly & Arnold, 2012).
- Meanwhile, less transfer of patients between facilities and less overcrowding will minimize hospital-based cross-contamination (Capolongo et al., 2020).
- Interaction among hospitals within the network can improve service levels (and/or restore normal operation during crises), reduce patient waiting times, and enhance health care services for the whole community (Hassan & Mahmoud, 2020).
- Emergency medical services (EMS) can be better supported with a community-based, local/regional network, to increase accessibility for the communities further away from the city centres. This is especially important for vulnerable populations, such as the elderly.
- The network of health care facilities can reduce unnecessary use of EMS to transport patients between the services available in the city centre and the boundary areas (Zhu et al., 2021).

The General Hospital of Komotini | Renzo Piano's studio 2025 | Thessaloniki, Greece

Gardens will form a key part of the campus, with a mix of green spaces and play areas for patients and families but also for the staff. The interiors are lined with large windows to ensure visual connections to these areas.

4.3 Landscape and healing outdoor environments

Many studies have highlighted the role of the landscape in enhancing the psychological aspects of humans, and the connection with outdoor environments (Alkaisi, Ibrahim & Khaleefa, 2021). Natural healing spaces, including the design of landscapes and healing gardens, could provide environments in which users can relax, finding relief from psychological stress and daily pressures (Capolongo et al., 2020).

The following aspects should be considered.

- Spaces designed for psycho-physical well-being positively influence the performance of medical staff.
- Maximum benefit is found in green working environments.
- Nature can influence well-being, even in a short space of time (Gola et al., 2021a).
- Availability of nature and landscape design gives patients a sense of intimacy and spatial comfort.

- The presence of multiple colours in a healing garden brings a sense of joy.
- The presence of paths in a garden enhances its recreational capacity, encourages the pleasure of walking and exercising, and gives the user a sense of control.
- Availability and clarity of wayfinding make the garden more accessible.
- The presence of lighting elements and their distribution give the user a sense of security.
- Availability of fences, entrances and gates in the garden enhances feelings of safety and privacy and reduces feelings of intrusion. In addition, fences protect from certain types of pollution.
- Availability of shaded green spaces and water features stimulates the five senses.
- Increasing the density of plant cover in a garden provides a sense of quietness by contributing to blocking noise.
- Availability of seating in appropriate quantity and proximity stimulates social interaction.
- It is important to pay attention to providing all the design components for this type of garden to maximize the chances of achieving an ideal hospital environment.
- Spreading awareness about the importance of incorporating healing gardens into the design of facilities will also be helpful (Alkaisi, Ibrahim & Khaleefa, 2021).

Ha-Emek Medical Center | Afula, Israel, 2020

Healing landscapes provide opportunities to relieve the stress for all users. © Whitaker Studio

Ha-Emek Medical Center | Afula, Israel, 2020

Appropriate seating and its spacing are important, both inside and out. © Whitaker Studio

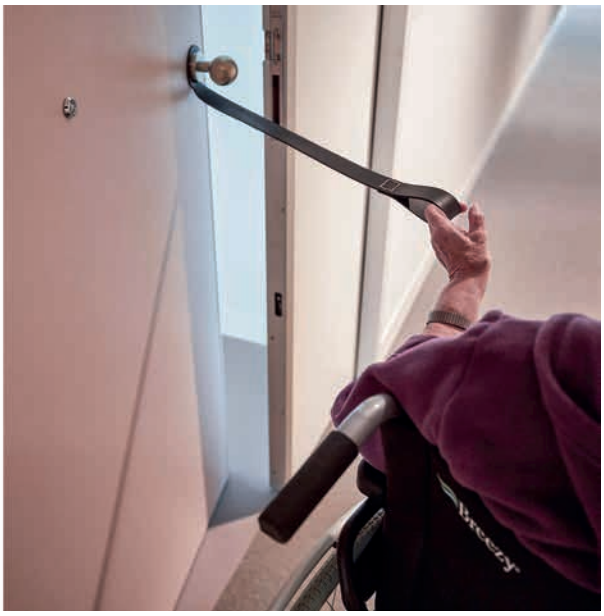
Ha-Emek Medical Center | Afula, Israel, 2020

Healing landscapes provide opportunities to relieve stress for all users. © Whitaker Studio

Ha-Emek Medical Center | Afula, Israel, 2020

Fences, seating and shaded green space all enhance the healing capacity of the hospital environment. © Whitaker Studio

Domstate Zorghotel | Utrecht, Netherlands, 2020



Privacy, convenient positions for wheelchairs and beneficial design considerations improve the facilities for wheelchair users.

4.4 Accessibility and universal design strategies

Universal design and inclusion strategy aims to meet the needs of the greatest number of people, regardless of age, gender, physical and cultural features, abilities or disabilities. The concept consists of various quality elements (physical-spatial, sensorial-cognitive, and social), along with several criteria on usability, functionality, security and privacy, wayfinding, understanding, environmental factors, well-being, and social inclusion (Mosca & Capolongo, 2020), as well as proximity of location in the urban context.

The following aspects should be considered.

- Usability: to design a space that is navigable independently by the patient, even with mobility impairment.
- Functionality: to satisfy the preferences of different users through flexibility and adaptation of an outdoor or indoor space in terms of use and time (e.g. maintainability).
- Security and privacy: to guarantee security and privacy of different users in both emergency and everyday situations, by minimizing risks without introducing stigmatized solutions and ensuring acoustic and visual privacy in the functional design.
- Wayfinding: to orientate users with visual, tactile and verbal information to help them determine their own spatial position.
- Understanding: to communicate information in a simple, effective way through different methods, regardless of the environmental conditions or the cognitive and sensory abilities of users.
- Environmental factors: to evaluate the indoor comfort conditions of a building's environment by analysing air quality, thermal comfort, acoustics, and lighting.
- Well-being: to transfer positive emotions to different users by considering healthy behaviours, physical activity, the design of the environment and its soft qualities, pleasantness and aesthetics.
- Social inclusion: to foster active participation of different users in the design process, guarantee the same experience for all users, reinforce the cultural values of any design project, and treat all groups with dignity and respect (Mosca & Capolongo, 2020).
- Urban context: to take into account proximity with public transportation and convenient access by private vehicles from the early design stage.

St. Olavs Hospital | Trondheim, Norway

Integration of a welcoming transition area improved the proximity for visitors and patients arriving by various means of transportation.

© Jiri Havran Photography

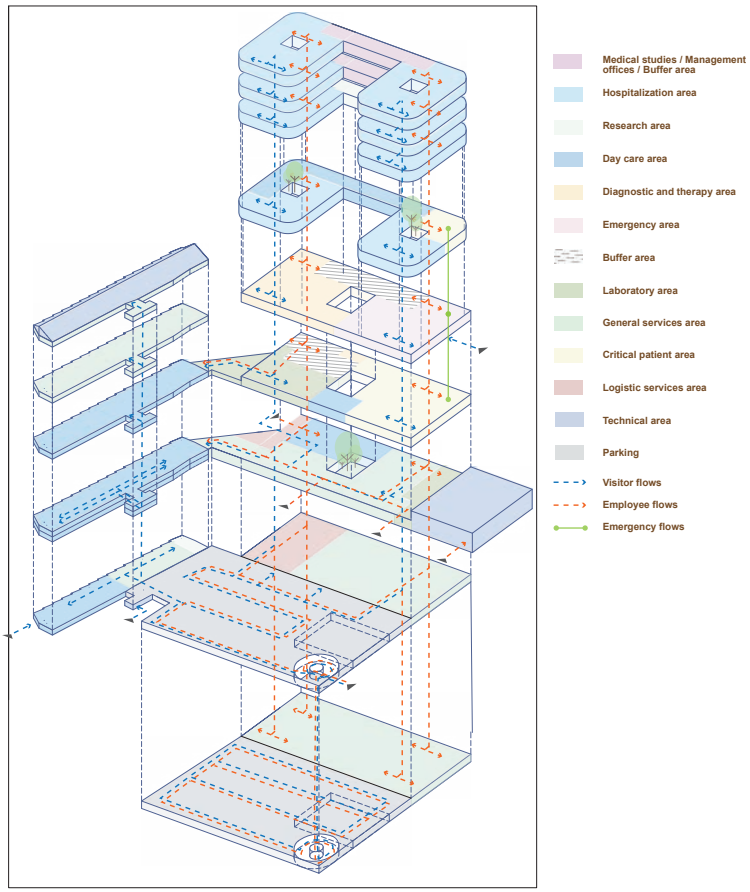
St. Olavs Hospital | Trondheim, Norway

Urban context considered in the hospital design strategy.

© Jiri Havran Photography

5. Inside the hospital: interventions needed for hospitals in relation to technical, structural and operational aspects

Fig. 2. Proposal for functional model applied to “New San Marino Hospital” research project by Politecnico di Milano Design & Health Lab | Republic of San Marino, 2021



Appropriate design directly takes users to the function they are looking for and minimizes the risk of infection among different groups of people.

5.1 Functional design and innovative layouts

A functional programme is fundamental in complex facilities like hospitals. This refers to the location and distribution of all departments and their interrelationships. It is necessary to distinguish the access points to different pathways, distribute flows with clear signage, and different medical departments inside various treatment areas.

Highly functional buildings respect the flow and transportation of patients, health care workers, and the logistics and supply chain. Separating certain work areas from the main working space with individual entrances provides more resilience and flexibility (Wagenaar et al., 2018; Capolongo et al., 2020; Setola et al., 2022).

The following aspects should be considered.

- Distribution of flows is of central importance to the design of the functional programme.
- Recognizable signage must effectively indicate changes in hospital routing (including temporary changes).
- Access points for health care workers are ideally separated from those for patients and visitors.
- Treatment areas for patients who pose a risk of transmission to others should be isolated

through clear separation of routes, limiting cross-contamination by avoiding the use of vertical and horizontal connections for multiple areas, while also balancing their functionality.
- Separate working areas from the main care-provision area are recommended, while maintaining proximity and minimizing distance between frequently used spaces (e.g. the distance between the nurses' station and patients' beds).
- The visual supervision of patients by a limited number of staff in emergency departments requires careful planning in the early design phase.
- Storage areas should be cleverly designed to add value to the logistics network and supply chain, by minimizing waiting time and transportation (Capolongo et al., 2020; Wagenaar et al., 2018).
- The flows of infectious waste across all functions, encompassing human tissue and laboratory waste directly related to specimen processing, should adhere to policies that focus on minimizing, segregating, collecting, transporting, storing, treating, and disposing of waste, in order to effectively reduce the risk of HAIs.
- Separate, dedicated lifts for waste, clean supplies, food, and patients and visitors should be carefully positioned within the functional design.
- The system of pneumatic tubes and networks for moving physical items within the hospital should be organized using a functional design approach, to minimize supply-chain transfer times, increasing efficiency and improving overall function.
- Two separate entrances are recommended to triage patients who pose a risk of infection transmission to others, with separate pathways through the various spaces and separate waiting and treatment areas (Setola et al., 2022).
- The design process should involve collaboration and active technical dialogue between stakeholders, including clinical and non-clinical staff, as well as service user groups, to ensure needs are met from all perspectives (Afacan & Erbug, 2009).

Skåne University Hospital campus | Kjell Nyberg, 2024 | Malmö, Sweden

As part of the modernization, approximately 200 nurses, physicians and other staff members at Skåne University Hospital took part in planning the renovation, together with architects and staff working with medical technology, cleaning, deliveries and other services. Patients also played an active role from the start of the planning process.

Skåne University Hospital campus | Kjell Nyberg, 2024 | Malmö, Sweden

Renovation project to modernize, with patient participation in the planning process.

© White Arkitekter

Skåne University Hospital campus | Kjell Nyberg, 2024 | Malmö, Sweden

Stakeholders worked together to design optimal spaces with appropriate flows.

© White Arkitekter

San Martino Horizon 2040 | Genoa, Italy, 2018

Visualization of hospital refurbishment within the "San Martino Horizon 2040" research project by Politecnico di Milano Design & Health Lab.

5.2 Health care infrastructure sustainability

Sustainable development is an important prerequisite for guaranteeing health, touching on the social, economic and ecological (environmental) dimensions of sustainability. It includes aspects of the architectural system, building components, as well as the impact on surroundings and other management considerations (Brambilla & Capolongo, 2019). To achieve a sustainability goal like **net zero energy buildings (NZEBs)**, management and design must be coordinated from the early stages (Abdellah et al., 2017) and can be supported by digitalization tools, such as building information modelling (BIM) (Montiel-Santiago, Hermoso-Orzáez & Terrados-Cepada, 2020).

The following aspects should be considered.

- The sustainability of building **systems** includes energy consumption, energy sources, thermal comfort, water use, waste management, heating, ventilation and air conditioning (HVAC) system efficiency, and lighting efficiency. The sustainability of building **components** includes material sustainability, with recycled, reusable and local materials and careful construction choices.
- Evaluation should be conducted where facilities already exist, in order to reduce soil consumption and enhance the value of existing infrastructural settings, where possible, to foster urban regeneration strategies.
- Analysing the impact on surroundings includes aspects such as site management, environmental pollution, transportation sustainability, passive environmental strategies and heat island effect.
- Other aspects include life-cycle assessment, green rating tools, sustainability education and management of environmental policies (Onaran, 2009; Brambilla & Capolongo, 2019).
- Holistic assessment of sustainability should be targeted through the implementation and use of evidence-based evaluation models (Brambilla et al., 2021).
- Designing NZEBs involves three key steps: (1) a passive design approach, which includes architecture design strategies for thermal comfort and energy sustainability (such as optimized window opening for natural ventilation); (2) energy-efficient systems; and (3) renewable energy systems (Abdellah et al., 2017).

- The **circularity** of health care devices and equipment is also a promising direction for health care sustainability (provided that decontamination and reprocessing of reusable medical equipment/devices are performed between uses). Such sustainability measures can be achieved by: (a) substituting single-use products with recyclable ones; (b) extending the life-cycle of instruments through repair instead of disposal; (c) recycling raw materials from waste; and (d) limiting waste-handling costs (Leissner & Ryan-Fogarty, 2019; van Straten et al., 2021).

5.3 Flexibility, resilience and future-proofing

In order to ensure effective emergency risk management, a fundamental aspect to consider in the hospital design process is flexibility, from the overall building system to the individual functional and environmental units (Capolongo et al., 2020). **Agile hospitals** incorporate five levels of flexibility, including processes, hospital complex, buildings, functional units and individual rooms, with different types of flexibility at each level (Brambilla et al., 2021; Astley et al., 2015). These levels of flexibility can be applied into transformable functional areas and buffer spaces in hospitals.

- The **process** level of flexibility includes project and construction management; competitive dialogue; public and private dialogue; standard agreement; and benchmark variability.
- The **hospital complex** level of flexibility includes functional flexibility of the system; networked information systems; automation and control; reuse of the hospital complex; existence of building land for future extension; use of flexible contractual/financial arrangements; and outsourcing of support services.
- The **building** level of flexibility includes existence of shell space for expansion; oversizing of load-bearing structures; blank facades; modular, replaceable and maintainable plants and systems; efficient programmed maintenance, and so on.
- The **functional unit level** of flexibility includes the use of moveable internal (dry) partition walls and wall-mounted fittings; the presence of spaces for service building infrastructure; the possibility of extending the entire functional unit upwards or sideways; and ensuring a facility with flexibility of use.
- The **individual room** level of flexibility includes functional flexibility of the rooms; the possibility of upward/sideways extension; multifunctional rooms, plants and information systems; use of moveable furniture and vertical screening for customizable humanization of the room (Brambilla et al., 2021; Astley et al., 2015).
- Empty and support areas (**buffer spaces**) should be preserved among different departments to accommodate expansion, reconfiguration or isolation areas.
- Functional areas should be included that can be easily converted for emergency use or when needed for different functions, including non-sanitary hospital areas that can be easily transformed and equipped with a minimum of investment (Capolongo et al., 2020).

Massive Vaccination Center research project for the Lombardy Region by Politecnico di Milano Design & Health Lab | Milan, Italy, 2020

The functional design will benefit the management of facilities and distribute flows to avoid infection among patients and health care workers.

- Adequate response to arising patient needs can be guaranteed by ensuring various departments and types of services are available to provide comprehensive health care assistance (Setola et al., 2022).
- Health care facility vulnerability can be assessed with the checklist for climate change (WHO, 2021; WHO & PAHO, 2015) to evaluate if the facilities are resilient enough to counter potential climate change events and natural hazards, including flood, storm, drought, wildfire, sea-level rise, and other direct hazards from extreme temperatures.

Leszczynski Antoniny Manor Intervention | NA NO WO architekci 2015 | Leszno, Poland

Restoration and extension of three of the former farm buildings and a new building were turned into a coherent complex with all the necessary diverse functions of an elderly care centre, with hospital rooms for people with Alzheimer disease, those undergoing cardiac and orthopaedic rehabilitation and a general hospital ward.

Leszczynski Antoniny Manor Intervention | NA NO WO architekci 2015 | Leszno, Poland

Restoration and extension to become a comprehensive elderly care centre.

Martini Hospital | Dutch Hospital Design 2007 | Groningen, Netherlands

Building modules with 60 x 16m dimensions could be functionally totally interchangeable in the design phase, as well as later, once the building is being used. Also, extensions can be hung on the facade to gain extra floor area so that bigger departments can be created and more people accomodated.

Martini Hospital | Dutch Hospital Design 2007 | Groningen, Netherlands

Functionally interchangeable 60 x 16m modules ensure flexibility in the hospital design.

Beit Shulamit Cancer Center | Afula, Israel, 2022

An open view can relieve stress for both patients and health care workers. © Ron Arad Associates

5.4 Healthy working areas

A healthy health care work environment is a workplace that is safe, empowering, and satisfying (Wei et al., 2018). It implies physical safety and mental health, which call for support from design, management and sociocultural improvement perspectives (Soheili et al., 2021; Shamian & El-Jardali, 2007; Brusamolin, Brambilla & Capolongo, 2022), reducing stress in the work environment to support workers' health and productivity.

Patient groups, health conditions, patient pathways, workforce aspects, and technology will all impact sizing of health care staff areas and organizations, along with factors such as population size and challenges relating to training programmes (McKee et al., 2020).

The following aspects should be considered.

- For physical protection, a safe physical environment and adequate equipment are required to reduce medical exposure to physical risks (such as hazardous drugs for chemotherapy).
- Focus should be placed on improving mental health in the work environment and on relieving occupational stressors, such as physical health threats, care-related challenges, and fears about cancer development and medication errors.
- Health care organizations need to have coherent policies which ensure workers' health, adequate staff ratio, reduce staff shortages, and provide employees with financial support and welfare services.
- Sociocultural improvement includes the need for family support and empathy in order to maintain and improve the work–life balance (Soheili et al., 2021; Elshamy et al., 2010).
- So-called "re-charge rooms" with natural design elements can be developed for health care workers, to support their recovery from physically and mentally taxing shifts.
- Simple visual devices, wayfinding strategies and design nudges to steer user responses can help to mitigate the transmission of infections, reduce mental fatigue and to align behaviours with the protocols to be followed (Capolongo et al., 2020).
- Management aspects include leadership; clarity regarding roles; trust, respect, and being valued in the teamwork setting; cultural readiness; and fostering a culture of acceptance within the workplace (Shamian & El-Jardali, 2007).

5.5 Safety and security issues

Considering WHO's approach to safe health facilities (WHO & PAHO, 2015), it is important to recognize various dimensions that contribute to safety in hospitals. These aspects, which are intended to support the WHO guidance, consist of: (1) general and occupational safety enhancement, (2) patient safety, (3) climate hazard prevention, (4) fire prevention, and (5) seismic adaptation (Brambilla & Capolongo, 2019; OSHA, n.d.; SUVA, n.d.).

The following aspects should be considered.

- For **general and occupational safety enhancement**, apart from the universal design for protection, there are eight aspects to consider, taking into account staff and other users of health care facilities, including: (1) culture of safety, (2) preventing infectious diseases, (3) safe patient handling, (4) protecting people from workplace violence, (5) protecting against biological influences, (6) avoiding exposure to chemical agents, (7) preventing diseases of the musculoskeletal system, and (8) implementing measures against ionizing and non-ionizing radiation (SUVA, n.d.; OSHA, n.d.).
- In terms of **patient safety**, the most concerning aspects include: medication errors, HAIs, unsafe surgical care procedures, unsafe injection or transfusion practices, diagnostic or radiation errors, sepsis, and venous thromboembolism (blood clots) (WHO, Meyer & Debaga 2 IDP Camp Medical Clinic, 2019).
- For **climate hazards**, including extremes of temperature, flood, storm, rising sea levels, drought, heatwave, wildfire, etc., four aspects should be considered: (1) the health workforce, (2) WASH and health care waste management, (3) energy, and (4) infrastructure, technologies, and other relevant products (WHO, 2020; 2021).
- For **fire** events in particular, alongside the basic fire prevention regulations for architecture, all staff should be aware of potential fire sources, such as the oxygen supply in health care facilities, and should be trained to know the position of fire extinguishers and how to use them (de Almeida et al., 2012).
- In terms of **seismic adaptation**, for seismic-frequent regions, identifying structural deficiencies will be useful for planning prevention measures, such as evacuation routes. Also, for both newly designed and renovation projects, the primary seismic elements (structural) and secondary elements (non-structural) are both important. Their capacity and appropriate anchoring can be increased to prevent problems resulting from fallout and collapse (Uros et al., 2020).
- Seismic isolation systems can be adapted, but only with the reliable definition of seismic input, appropriate selection, design, manufacturing, installation, protection, and maintenance, as well as careful consideration of further construction (Ansal, 2015).
- For various hazardous events, conducting frequent evacuation drills remains a very useful tool to teach all users in the building how and where to evacuate and check that emergency-related facilities and devices are working properly (D'Orazio et al., 2020).
- Ensuring the availability of suitable backup spaces and the operability of backup systems has demonstrated a considerable effect on reducing the immediate consequences of hazardous events (Hassan & Mahmoud, 2020).

Copenhagen's Rigshospitalet | København Ø, Denmark, 2015

A central indoor open area can provide clear guidance during an evacuation (in an emergency).

Courtesy of 3XN, Photo © Adam Mørk

The following useful links provide more information about guidance and legislation for safety in health care facilities as workplaces.

- European directives on safety and health at work [website]. Bilbao: European Agency for Safety and Health at Work (EU-OSHA) (no date) (https://osha.europa.eu/en/safety-and-health-legislation/european-directives).
- Berufskrankheiten im Gesundheitswesen verhüten [Preventing occupational diseases in health care] [website] (in German). Luzern: Swiss National Accident Insurance Organization (SUVA) (no date) (https://www.suva.ch/de-ch/praevention/nach-branchen/berufskrankheiten-im-gesundheitswesen-verhueten).
- The NSQHS standards [website]. Sydney (NSW): Australian Commission on Safety and Quality in Health Care (ACSQHC); 2023 (https://www.safetyandquality.gov.au/standards/nsqhs-standards).
- WHO, Meyer S, Debaga 2 IDP Camp Medical Clinic. Patient safety. Geneva: World Health Organization; 2019 (https://www.who.int/news-room/fact-sheets/detail/patient-safety).
- Safety and health topics. Healthcare [website]. Washington (DC): United States Department of Labor Occupational Safety and Health Administration (OSHA) (no date) (https://www.osha.gov/healthcare).
- WHO guidance for climate-resilient and environmentally sustainable health care facilities. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/335909).

5.6 Organizational strategies for infection control capability and indoor air quality

IPC played a strategic role in terms of management of the COVID-19 pandemic (Capolongo et al., 2020). Health care facilities have a significant part to play in terms of surfaces and layout (Stiller et al., 2016; Facciolà et al., 2019), as well as in regard to the design aspects of HVAC systems and finishing materials (Gola et al., 2021b). For indoor air quality, there are **four macro areas** to consider: (1) outdoor air and microclimactic factors, (2) management activities, (3) design factors, and (4) human presence and medical activities (Gola, Settimo & Capolongo, 2019; Capolongo, Settimo & Gola, 2017).

The following aspects should be considered.

- Building upon the comprehensive WHO recommendations for IPC programmes (WHO, 2016; 2019), a few key aspects for **HAI prevention strategies** should be highlighted: (1) active surveillance, detection and early intervention with regular checks; (2) environmental control; (3) regular maintenance or even renovation; and (4) multi-modal prevention strategies, such as frequent handwashing and limiting antibiotic use.
- **Layout** planning should be considered, including the minimum distance between patient beds, access to toilets/bathrooms and the issue of single versus multiple beds and rooms; infection control is a complex and multifaceted area of study, but based on specific evidence from available studies, single rooms with flexible solutions should be favoured (Stiller et al., 2016; O'Neil, Park & Rosinia, 2018; van der Schoor et al., 2022).
- Environmental **cleaning and disinfection** is one other key aspect to ensure, including (a) cleaning methods; (b) standards to ensure adequacy (and efficacy) of cleaning; and (c) support for cleaning staff to train and organize them to carry out the cleaning effectively.

- Other interventions to prevent HAI include: (1) hand hygiene, which is one of the most effective IPC measures; (2) transmission-based precautions, with proper protection during health care interventions; (3) decolonization, which is needed for certain colonized patients undergoing surgery to avoid surgical site infection; (4) use of implementation tools, such as care bundles, which aim to improve the care process and patient outcomes in a structured manner; and (5) antimicrobial stewardship for infection prevention (Fernando, Gray & Gottlieb, 2017; Lavallée et al., 2017).
- It is necessary to use high-performance, long-lasting and easy-to-clean materials that also meet medical needs (Capolongo et al., 2020).
- The solutions used in emergency contexts should be investigated and taken into consideration, including those used for sanitary functions but which also generate toxic air pollutants, thus requiring careful environmental consideration (Capolongo et al., 2020).
- **Management activities** related to cleaning, maintenance and HVAC systems should be conducted with extra care to avoid emitting pollutants.
- If the ventilation system is properly **designed and maintained**, it can be effective in improving air quality (Gola et al., 2021b).
- Isolation rooms are an essential part of infection control; design considerations include the number and location of them, as well as corresponding facilities (e.g. sanitary facilities, or the need to maintain a specific pressure differential between adjacent areas).
- **Human presence and behaviours**, including external visitors, are a potential source of contaminants within the health care environment. Some visiting rooms can be designed with a barrier (such as a transparent division or wall) to minimize infection risk between patients and visitors, while allowing people to see each other.
- Medical activities involving equipment and certain medicines – such as anaesthetic gases – need better management to reduce airborne contamination risk (Gola, Settimo & Capolongo, 2019).

Waldkliniken Eisenberg hospital | Eisenberg, Germany, 2021

Rooms such as single patient wards can be subdivided according to visual, acoustic, air quality and privacy needs, to improve the quality of the indoor space.

Rigshospitalet's new North Wing | Copenhagen, Denmark, 2020

Enough exchange of air needs to be ensured in public areas for crowds to stay and rest, in case of unwanted infections.

© Adam Mørk

5.7 Digitalization of the hospital from the management to the end-users

The introduction of new digital technologies can support patients' treatment and care processes, both in hospital facilities and within the wider health care network (Capolongo et al., 2020). Digitalization encompasses all levels, moving outward from the central system of the facility, including digital management and reaching as far as the end-user equipment (Visconti & Morea, 2020; Koch, Hansen & Jacobsen, 2019; Rai et al., 2017; Brusamolin, Brambilla & Capolongo, 2022).

Furthermore, Empowerment through Digital Health serves as one of four key initiatives that supplement the central objectives of the European Programme of Work (2020-2025) and acts as an impetus for change. Adopted by all Member States, the "Regional Digital Health Action Plan for the WHO European Region 2023-2030" presents a strategic blueprint for harnessing and expanding the digital transformation in Member States to improve health outcomes and align with their specific health requirements. This plan supports health authorities in strengthening health information systems to bolster the health system's responsiveness, as well as developing and refining digital health services to minimize service interruptions and ensure the delivery of high-quality primary healthcare.

The following aspects should be considered.

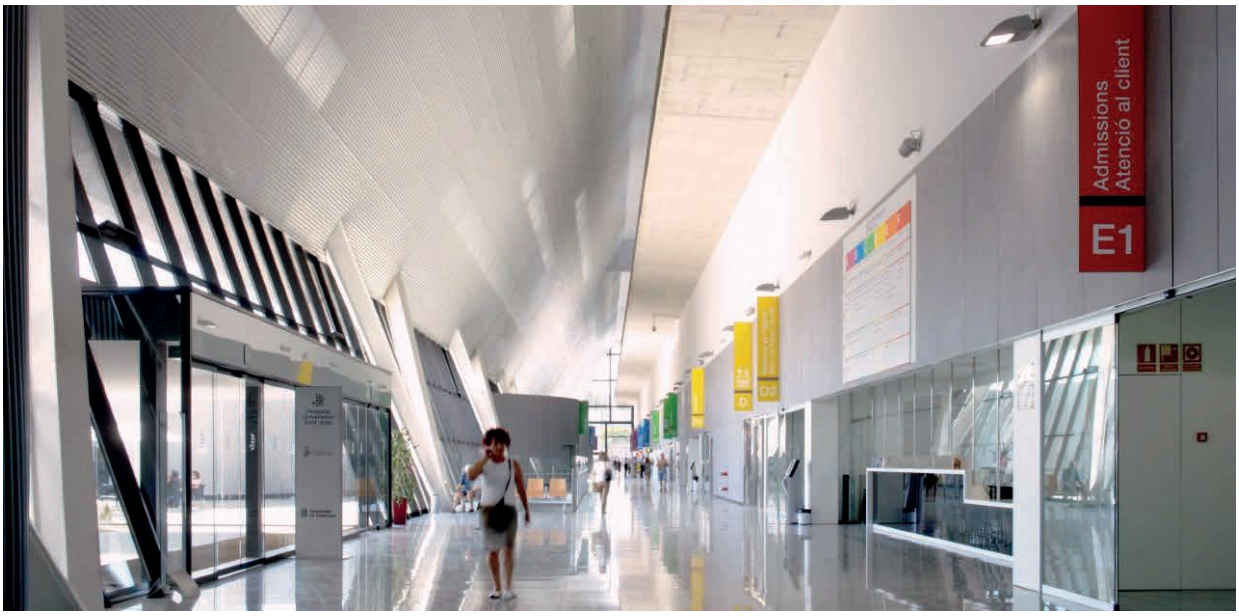
- From an **architectural design** point of view, BIM has the potential to facilitate better informed built asset management (BAM) decision-making by integrating a wide range of information related to the physical condition of built assets, resources available for BAM and the built asset's contribution to health care provision within an organization (Wanigarathna et al., 2019).

- From a **facilities management** viewpoint, a comprehensive technology strategy should be developed as part of the master planning process of a new hospital.
- Digital devices, connected to the Internet (e.g. smart phones, digital wrist bands/ watches) allow hospitals to guarantee a **personalized experience** dedicated to each user, monitoring the degree of comfort and satisfaction.
- IT systems can provide **continuous monitoring and control** of vital parameters, which can guarantee better management of the hospitalization.
- Modular planning and forecasting of projects or tasks can put **real-time data and analysis** to good use, for example in terms of directing ambulances appropriately to health care facilities, optimizing the use of resources and improving outcomes.
- Constant monitoring and technological advancements allow the use of some electro-medical equipment **remotely**, decreasing contact between (infected) patients and hospital staff, and increasing overall control and a more efficient use of resources (Capolongo et al., 2020).
- Digitalization of management involves many aspects and a range of concepts, such as computer-aided facilities management (CAFM) systems, BIM, other software that support operations, big data technologies, the Internet of Things (IoT), augmented reality, digital twins, blockchains and building information standards (Koch, Hansen & Jacobsen, 2019).
- Big data - which are continuously generated by wearable devices, feeding to digital health applications – foster co-creation values and facilitate **patient-centricity**, improving the experience for the end-user.
- Digitalization advances can also help with the real-time geo-localization (through smartphone tracking or other GPS devices) of potentially contagious individuals, thereby **reducing viral spread** through real-time location tracking (Visconti & Morea, 2020).
- Connecting end-user equipment to the network, for example using convenient devices such as a control panel on the wall or a smartphone in the pocket, can be useful to display relevant data (Rai et al., 2017).
- Virtual care centres for physicians should be considered for providing customized **remote monitoring of patients** through telehealth consulting services.

The Dialog device | Artefact, Seattle (WA), United States, 2014

Tiny digital end-user devices can keep monitoring patients' health conditions to provide better health care services.

Hospital Sant Joan de Reus | Mario Corea, Lluís Moran and Pich-Aguilera Architects | Tarragona, Spain, 2009



Clear wayfinding, designed with colours and signage increases the user experience when moving around the facility.

Courtesy of Mario Corea Arquitectura, Photo © Pepo Segura

5.8 Soft qualities and wayfinding

Soft qualities are among the key aspects for a designer to consider in creating high-quality environments: shape, lighting, inside and outside views, finishing materials and colour schemes, as well as decoration, furniture, and green areas. These are all determining factors in the creation of welcoming, harmonious and reassuring spaces (Capolongo et al., 2014). Such features can enhance the visual environment, quality of patients' rooms and navigation around the buildings (Brambilla & Capolongo, 2019; Morag, Heylighen & Pintelon, 2016).

The following aspects should be considered.

- The **visual environment** is important, in terms of interior and exterior design appearance, outdoor views and access, lighting control including artificial and natural light, light pollution, and privacy.
- **Quality of patients' rooms** should be considered in terms of bathroom, privacy, furniture quality, nutrition, availability of space, and medical utilities.
- **Quality of break rooms for staff** is also a vital aspect to consider to improve their well-being and satisfaction during breaks and meals.
- **Easy navigation** around the buildings will enhance occupants' satisfaction, optimize logistics, and reduce the risk of falls (e.g., among fragile people).
- Eight key aspects can benefit from strategic wayfinding, including: (1) indoor/outdoor signage, (2) layout, (3) entrances, (4) architectural features, (5) distances between functions, (6) finishings, and (7) logistics flow management (Brambilla & Capolongo, 2019; Morag, Heylighen & Pintelon, 2016).
- The design of soft qualities should consider all elements in an integrated, holistic approach.
- A specific colour is only relatively important in itself; instead, an appropriate contrast between colours and building elements should be considered.
- Emotions and the final evaluation of an environment are influenced by all the elements combined that characterize that environment.
- Light exerts a powerful influence on emotions and a person's overall judgement of the environment.
- In the presence of strong structural constraints, the **strategic use of one or more elements** may induce a different overall perception (Capolongo et al., 2014).

6. Suggestions to monitor and measure the effectiveness of the interventions

Hospitals have always been considered a building type which requires mainly technical and engineering competencies, historically excluding or highly limiting the role of architecture and design disciplines in their development (Wagenaar et al., 2018). More recently, the role of health care architecture and its relationship with hygiene and public health has been gradually rediscovered and new challenges are arising (Azzopardi-Muscat et al., 2020). Hospital buildings remain complex and the architect's role should be to overcome strict professional boundaries and be aware of the **impact that hospital design choices have on staff, patient and visitor flows, emergency resilience and technological evolution**.

Within such a complex system it is vital to **assess the impact of design solutions on the efficiency of medical processes**, expanding the scope of design work to functional planning, including features such as logistics, public space, wayfinding, layout, ergonomics, organization, and infrastructure (Wagenaar et al., 2018).

The lists of possible strategies or elements to consider provided in the previous sections are not exhaustive but a comprehensive group of inputs that can positively impact the planning, design and construction process of health care infrastructures, as well guiding designers on management aspects.

Since the second half of the previous century, several **tools and methodologies have been developed in order to assess the qualities of the physical environment and built facilities** (Fronczek-Munter, 2013). This is the result of a growing awareness of the benefits that a positive physical environment can provide to the various occupants and stakeholders (Li, Froese & Brager, 2018). When applying an evidence-based design (EBD) methodology, a very effective and well-structured approach is post-occupancy evaluation (POE), defined as the process of systematically comparing actual building performance after completion and occupation (Connellan et al., 2013; National Research Council, 2001; Preiser, 1989, 2002).

A successful scheme for evaluation is likely to be one that **sets realistic but challenging goals**, recognizes the constraints that the hospital faces and seeks to be helpful rather than negative and/or punitive. Additionally, it should be resilient enough to adapt and evolve dynamically according to the evolution of the measured system and the boundary conditions, regulations, and best practices.

The European Observatory on Health Systems and Policies confirmed that "the first step in achieving the desired outcome of high-quality, cost-effective care is ensuring that the right physical structures are in place" (McKee, Healy & European Observatory on Health Care Systems, 2002). Measurement models, key performance indicators (KPIs) and continuous processes of quality improvement should therefore be implemented.

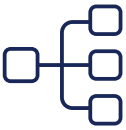
Operating models exist for certain strategic issues, such as sustainability, inclusion or flexibility considerations. These can be developed in conjunction with checklists for assessment and continuous monitoring of health care quality, underpinned by a robust and reliable evidence-informed framework. Operational assessment tools and methodologies – based on systematic evidence, best practices and adapted to user characteristics – must be put in place at various levels to measure the effectiveness of any solutions applied, and to ensure appropriate implementation within the new concept: Hospitals of the future.

7. Key messages

The **strategic localization** of hospitals with different functional orientations in the city centre and boundary areas can foster urban regeneration.

Well-designed **landscapes and healing gardens** can benefit both patients and health care workers, physically and psychologically.

A **healthy working environment** can improve physical protection and mental health from design, management and sociocultural viewpoints.



Functional design is fundamental in hospitals to fulfil the needs of different people by separating different hygienic departments and distributing all kinds of flows.

Universal design should be considered to meet the needs of all segments of the population by improving the soft quality aspects, both inside and outside of health care facilities.

Digitalization can greatly benefit the management of facility assets and services, organization of tasks and services across the territory, and increase user-friendly services.

Assessment and POEs are encouraged for measuring the quality and effectiveness of the interventions.

The **synergies through the local/ regional (territorial) health network** can improve services and resilience of the health care system, and increase patient willingness to access services by resolving proximity issues.

Awareness is required of invisible indoor infection risks; attention should be paid to **air-quality control** during the design and construction phases, as well as focusing on medical, management and cleaning activities.

The **sustainability** of the hospital's social, economic, and ecological (environmental) dimensions needs to be developed as part of the whole life-cycle of the facilities, including energy and resource management, focusing on environmental quality.

Designing for **flexibility and resilience** starts in the early phases of a new hospital project, to meet the future needs or in preparation for emergency situations, such as a pandemic or major trauma event.

Prevention of safety issues is essential, including general safety, fire and seismic events. These can be considered from several points of view: design and construction, maintenance management, training, and emergency preparedness and resilience, including backup functions and territorial networks.

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World Health Organization Regional Office for Europe
UN City, Marmorvej 51, DK-2100 Copenhagen Ø, Denmark
Tel.: +45 45 33 70 00 Fax: +45 45 33 70 01
Email: eurocontact@who.int
Website: www.who.int/europe