UNIVERSIDAD POLITÉCNICA DE MADRID

Escuela Técnica Superior de Arquitectura de Madrid

**Evaluation of Functional & Environmental Factors in Spanish
Acute-care Hospital Design**

*Evaluación de los factores funcionales y ambientales en el diseño de
hospitales de agudos españoles*

Ph.D. Dissertation (RD 99/2011)

Laura Cambra Rufino · Architect · 2021

Departamento de Construcción y Tecnología Arquitectónicas
Escuela Técnica Superior de Arquitectura de Madrid

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2021

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English abstract

The aim of this doctoral thesis is to explore the evaluation of functional and environmental factors in acute-care hospital design that might have an impact on healthcare outcomes.

Despite the progress of the evidence-based design process in North-European and North American countries, in Spain it still has not been fully developed. The purpose of this design process is to establish a link between design variables and health-related outcomes. Acute-care hospitals are buildings in constant change to cope with the evolving demands of clinical progress and the social context. Thus, acknowledging the functional and environmental factors that impact on the care process and evaluating them in existing acute-care hospitals becomes of paramount importance.

This dissertation follows a mixed-method methodology based on four perspectives: 1) the field, with an ethnographic study during a three-month placement in an acute-care hospital; 2) the theory, with literature analysis; 3) the future, with an ethnographic study of sixteen acute-care hospital visits considered as best practice, and 4) the present, with the evaluation of four acute-care hospitals in Spain.

The primary result of this work is the tool CURARQ. The purpose of this tool is, on the one hand to provide a first diagnostic of the functional and environmental quality of the studied unit, and on the other hand to guide in the design decision process of a new development. This tool has been created for seven units in the acute-care hospital and has been tested in four acute-care hospitals in "Comunidad Valenciana". Secondary results include: 1) feedback and scripts from users during the acute-care hospital placement; 2) evaluation through architectural layouts and photographs of the acute-care hospital visits; and 3) evaluation of CURARQ scores of the four evaluated acute-care hospitals.

This document provides a current overview of functional and environmental factors in acute-care hospitals, which evidence: 1) the need for refurbishment to promote clinical innovation; 2) the need to update national standards, 3) the usefulness of CURARQ tool to identify priority buildings to intervene, and 4) the usefulness of CURARQ tool to generate synergies between healthcare staff, patients, researchers, and architects to promote the potential of the evidence-based design process in Spain.

Keywords: *acute-care hospital, evidence-based design, healing architecture, healthcare architecture, evaluation tool, Spain*

Spanish abstract

El objetivo de esta tesis doctoral es explorar la evaluación de los factores funcionales y ambientales en el diseño de los hospitales de agudos, que puedan afectar a los resultados sanitarios.

A pesar del progreso del proceso de diseño basado en evidencias en países del norte de Europa y de Norteamérica, en España todavía está poco desarrollado. La finalidad de este proceso de diseño es establecer vínculos entre variables de diseño y resultados sanitarios. El hospital de agudos es un edificio en constante evolución para responder a las demandas del desarrollo clínico y su contexto social. Por este motivo, es vital identificar los factores funcionales y ambientales que impactan en el proceso de los cuidados y evaluarlos en hospitales de agudos existentes.

La metodología de esta tesis se basa en los métodos mixtos desde cuatro perspectivas distintas: 1) la práctica, con estudio etnográfico durante una estancia de tres meses en un hospital de agudos; 2) la teoría, con el análisis de la literatura; 3) el futuro, con estudio etnográfico de dieciséis hospitales de agudos considerados como buenas prácticas; y 4) el presente, con la evaluación de cuatro hospitales de agudos en España.

El principal resultado de este trabajo es la herramienta CURARQ. La finalidad de esta herramienta es por un lado obtener un primer diagnóstico de la calidad funcional y ambiental de la unidad estudiada, y por otro guiar la toma de decisiones para futuros diseños. Esta herramienta se ha creado para siete unidades del hospital de agudos y se ha aplicado en cuatro casos de la Comunidad Valenciana. Los resultados secundarios incluyen: 1) evaluación y rutinas según las personas usuarias de la estancia en el hospital de agudos; 2) evaluación mediante el estudio de las distribuciones en planta y fotografías de las visitas a hospitales de agudos; y 3) evaluación de las puntuaciones obtenidas con la herramienta CURARQ en los cuatro hospitales de agudos evaluados.

Esta tesis ofrece una visión general de la situación de los factores funcionales y ambientales en los hospitales de agudos, lo que evidencia: 1) la necesidad de renovar los edificios para promover la innovación clínica, 2) la necesidad de actualizar los estándares nacionales, 3) la utilidad de la herramienta CURARQ para identificar los edificios donde es necesario intervenir con prioridad y 4) la utilidad de la herramienta CURARQ para generar sinergias entre el personal sanitario, pacientes, investigadores/as y arquitectos/as que permitan explotar el potencial del proceso de diseño basado en evidencias en España.

Palabras clave: *hospital de agudos, diseño basado en evidencias, arquitectura sanadora, arquitectura sanitaria, herramienta de evaluación, España*

Visual Abstract

Preface

My initial interest in architecture came up one day at primary school while observing an anthill. Almost without realizing it, I was convinced to become an architect. I studied at "Universitat Politècnica de València" and one academic year at "Universidad Politécnica de Madrid" (UPM). For my master's thesis, my fascination for people circulation started by designing a transportation centre.

After finishing my master's degree in 2012, I moved to London to work for Ove Arup & Partners Ltd in their vertical transportation department. Julian Olley introduced me to the global market of the multidisciplinary consulting firms. I worked in Julian's team for two and a half years taken up by the enchantment of their high professionalism and wisdom. Moreover, I had the opportunity to be involved in teams with highly experienced people and worked in almost all building typologies, being the acute-care hospital, one of the most difficult in terms of user flows. While in London, I received a hand-written letter by Alfonso del Águila García (UPM) encouraging me to carry out a doctoral dissertation. His invitation came at a perfect time because by then I was considering moving closer to my relatives.

Therefore, I came back to Spain and settled down in Madrid. From my overseas experience I became aware of the importance of the built environment impact on people's health. Particularly relevant was the death by pancreatic cancer of my uncle and godfather José Luís Cambra Mataix in 2012. He made me ask myself what architects could do to facilitate the acute-care hospital experience and take sensitive care of people. With this idea in mind, I talked with José Fariña Tojo (UPM), who kindly put me in contact with José León Paniagua Caparrós. Simultaneously, I got a residency at "Hospital de Dénia" (funded by "Factoría Cultural and DKV Seguros"). As if by magic, José León Paniagua Caparrós happened to be co-author of "Hospital de Dénia" design, extensively knowledgeable in acute-care hospital architecture and willing to become my doctoral dissertation director.

Another matter was the search for funding. After the first doctoral course (2015/2016) with no funds and exhausting application processes for scholarships, I started my second course (2016/2017) with a predoctoral contract thanks to César Bedoya Frutos (UPM) and the "Ayudas para la Formación de Doctores del Programa Nacional de Formación de Profesorado Universitario del Ministerio de Educación, Cultura y Deporte" (FPU15/02660). In the following courses, I was involved in teaching support activities for several subjects at "Departamento de Construcción y Tecnología Arquitectónicas". In 2018 I spent three months in the Centre for Healthcare Architecture at "Chalmers Tekniska Högskola" as a visiting Ph.D. student thanks to "Fundación Margit y Folke Pehrzon" scholarship.

Significant life milestones interrupted my dedication to this work such as the birth of my son Bruno (May 2017), my daughter Maika (December 2019), the death of my father-in-law Agustín (October 2020) and the whole coronavirus pandemic.

Balancing motherhood with caring of dependents, constant readjustment to social measures, and telework has become my most complex challenge so far. However, it has reinforced my conviction on placing care at the centre of the focus, also in acute-care hospital architecture, which precisely is the intention of this doctoral dissertation.

Acknowledgements

Estoy convencida de que trabajando en equipo se obtienen mejores resultados. El doctorado es un proceso muy largo y solitario, pero en casi todo momento me he sentido acompañada por una red de personas bonitas que han hecho posible este arduo trabajo.

En primer lugar, mis directores de tesis. A César le agradezco su disponibilidad para orientarme por todos los trámites burocráticos y académicos imprescindibles para todo doctorando. A mi maestro José León, le admiro por su infinita generosidad, su conocimiento exquisito y su gran humildad. Por regalarme su tiempo cuando le abordé con una ingenuidad infantil y por saber reconocer que en esa ingenuidad estaba el germen de todo aprendizaje. *"Solo se aprende aquello que se ama"* y José León me ha hecho enamorarme de los hospitales hasta la médula.

En segundo lugar, quería agradecer el trato que he recibido en todos los hospitales, por un personal tan vocacional y terrenal que me han hecho sentir como en casa en un lugar que muchísimas personas no quieren pisar.

En tercer lugar, están mis amigos y amigas. Gracias a Carlitos, Maria y Arancha por nuestras conversaciones terapéuticas. Ha sido un gusto compartir conexión a internet, tupperes y cafés con Elena, Marlix, Miguel, Marta, Inês, Helena, Camila y Carmen. También más tarde con Elisa, con quien he gozado discutiendo intereses tan afines.

Por último, quería resaltar el tremendo esfuerzo que ha recaído sobre mi familia. A mis padres les agradezco su dedicación, apoyo y cuidado, tanto para mi como para mis hijos. A mi hermana, sus consejos y ayuda técnica. A mis tías, que me acompañaran hasta en Suecia. A mi hijo BRUNO, que ya reconoce su nombre en mayúsculas, le debo el haberme enseñado a ver la vida con sus ojos curiosos, a relativizar, a ser flexible y a vivir a demanda de las personas que quieres. Gracias a mi hija Maika he practicado la perseverancia, el cuidado incondicional y la intensidad de las emociones. A Antonio le quiero por ayudarme a reconectar con la vida cuando me he obsesionado y sobre todo porque incluso cuando el camino se ha vuelto insoportable, hemos decidido recorrerlo juntos.

"El camino es siempre mejor que la posada"

Al record del meu padrí José Luís,

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1.1 Healthcare Context

1.1.1 Healthcare System

According to the World Health Organization (WHO), Health Systems Strengthening Glossary, the health system is defined as:

"(i) all the activities whose primary purpose is to promote, restore and/or maintain health [1]; (ii) the people, institutions and resources, arranged together in accordance with established policies, to improve the health of the population they serve, while responding to people's legitimate expectations and protecting them against the cost of ill-health through a variety of activities whose primary intent is to improve health." [2]

Delving on health systems topics within the World Health Organization, the institution states that:

"A well-functioning health system working in harmony is built on having trained and motivated health workers, a well-maintained infrastructure, and a reliable supply of medicines and technologies, backed by adequate funding, strong health plans and evidence-based policies." [3]

While traditional disciplines such as medicine or nursing have played a major role in delivering care, there is the necessity of a wider perspective to understand the healthcare path and propose evidence-based policies [4]. Thus, healthcare policy-makers are in need of multidisciplinary experts in order to distribute healthcare facilities more efficiently, as these facilities might in turn impact on the healthcare delivered [4, 5].

In awareness of their ethical responsibility with society, architects in different nations such as Canada, USA, Sweden, or UK, are becoming more and more involved in the healthcare system. Examples of these collaborations are the research centres and teaching programs available in each country (Tab.1).

Particularly in Sweden, there is the "Centrum för vårdens arkitektur" (CVA) or Centre for Healthcare Architecture at the School of Architecture, "Chalmers Tekniska Högskola" in Göteborg. This centre offers a national platform for the interaction between academics and professionals in the healthcare sector. Architects, nurses, environmental psychologists and occupational therapists conduct research and training for the exchange and dissemination of knowledge about healthcare architecture. Thus, government decisions on healthcare facilities are founded on research-based knowledge which improves the long-term social investments.

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	North America		North Europe		South Europe	
	USA	Canada	Sweden	UK	Italy	Spain
Population (2018, persons)	327 167 434	37 058 856	10 175 214	66 435 550	60 421 797	46 733 038
Life expectancy at birth (2018, years)	81.2	84.1	84.3	83.1	85.6	86.3
	76.2	79.9	80.9	79.5	81.2	80.7
Health expenditure and financing (all functions 2019) US Dollar (Per capita, current prices, current Purchasing Power Parity PPPs) and share (%) of gross domestic product (GDP)	11 071.7	5 418.4	5 782.3	4 653.1	3 649.2	3 616.5
	17	10.8	10.9	10.3	8.7	9
	(E)	(P)	(P)	(E)	(P)	(E)
Acute hospital beds per 1000 population (2016)	2.77	2.6	2.34	2.57	3.17	2.97
Average length of stay in days (in-patient care, hospital aggregates 2017)	6.1	n.a.	5.8	6.9	7.8	7.3
Centres of collaboration	The Center for Health Design; American College of Healthcare Architects	Centre for Design + Health Innovation	Centre for Healthcare Architecture	Architects for Health	"Centro Nazionale per l'Edilizia e la Tecnica Ospedaliera" (C.N.E.T.O.)	Null!

Tab. 1 Organisation for Economic Co-operation and Development. Source: <https://stats.oecd.org/>. Data extracted on 19th October 2020. (E) for estimated value and (P) for provisional value.

1.1.2 Spanish Health System

Spain has a decentralised national health system or “Sistema Nacional de Salud” (SNS) which is funded by taxes. This public system is based on the principles of “universality, free access, equity and fairness of financing” [6]. The SNS is organised independently by the 17 regions and two autonomous cities with a national institution responsible for the overall coordination and monitoring of its performance (Fig. 1). Each region of the country is subdivided in “Áreas de Salud” or healthcare areas that consist of territorial demarcations that act as basic pieces of healthcare services. The concept of healthcare area has been modified through time, as each region has developed its own way for healthcare delivery and administration in its area of influence [7]. As an example, the region “Comunidad Valenciana” had 23 healthcare areas in 1986, 20 in 1993, in 2003 the term changed to “Departamentos de Salud” or healthcare departments, in 2005 there were 22 of them and from 2010 on, there are 24 in total [7] (Fig. 2). Each of these healthcare departments has its own centres for primary and special care that work as a network to provide the best care possible to any given patient.

Prior to the devolution of the national healthcare competences to every region of the country by a national law [9], Spain had a centralised healthcare system. Within this system there was the “Instituto Nacional de la Salud” (INSALUD) or national health institute created in 1978 and responsible for the design and maintenance of public healthcare facilities.

This institution had its own architects specialised in healthcare architecture [10]. As a consequence of the decentralisation of healthcare competences, the INSALUD disappeared in 2002. Since then, there has been a lack of coordination, knowledge, and expertise in healthcare planification, functional programming and acute-care hospital architecture which has its direct impact on the conservation status of many acute-care hospital facilities nowadays.

Fig. 1 Division of the healthcare competences into regions. Location of region “Comunidad Valenciana”.

Fig. 2 Healthcare Departments in “Comunidad Valenciana” in 2017. Figure by [8].

1.2 Acute-care Hospital

The acute-care hospital is the place where care is offered to patients with acute diseases. The adjective acute refers "to a severe or intense degree" and is related to a "short duration" of time [11]. *Acute-care includes "the health system components (...) used to treat sudden, often unexpected, urgent or emergent episodes of injury and illness that can lead to death or disability without rapid intervention. The term acute care encompasses a range of clinical healthcare functions, including emergency medicine, trauma care, pre-hospital emergency care, acute care surgery, critical care, urgent care and short term inpatient stabilization."* [12].

In the past, the global trend was to classify acute-care hospitals according to their number of beds (less than 250 beds, from 250 to 800 and about 1000) and it was assumed that the higher the number, the better the medical care [13]. However, nowadays acute-care hospitals are identified by the complexity and diversity of the healthcare services they provide which might be tailored to a specific group of patients, ages, or pathologies [14].

In addition to the many definitions of the acute-care hospital as a functional typology by the WHO [15], national laws [9] and other official documents [16], an acute-care hospital can be defined as the public or private institution that develops three main purposes: healthcare, education and research. Each one of these functions consist of:

1. Healthcare function: medical assistance, diagnostic and treatment procedures required by acute patients (such as surgical interventions, laboratory tests, radiology, rehabilitation, pharmacology, or pathological anatomy).
2. Educational function: additional activities, besides healthcare, that involve teaching and learning about healthcare practices for undergraduate students (medicine, nursery, radiology, laboratory technicians and others), postgraduate students (such as resident doctor, resident biologist or resident psychologist), and acute-care hospital staff (for the continuous learning process of both clinical and non-clinical staff).
3. Research function: depending on the complexity level of the acute-care hospital, research can be carried out in the acute-care hospital wards or in designated research departments such as laboratories.

1.3 Functional & Environmental Factors

Any acute-care hospital reflects a specific combination of design decisions defined by its financial, social and cultural context. In addition to its background, there are determinant variables that define its final design and which can be classified as functional and environmental factors. While functional factors are driven by the precise functionality of the building to perform properly, environmental factors deal with the additional qualities needed for creating an optimal atmosphere [17, 18].

1.3.1 Functional Factors

Several phases have to be followed for the inauguration of a new or renovated acute-care hospital which consist of planning, functional programme, project tender, design, works tender, construction and occupancy. Of all of them, the functional programme is the stage where the functional factors are defined. These factors are key for the performance of the acute-care hospital and include spatial logistics, organization and healthcare processes, which need to be tackled in an integral manner so that there is a correlation between programme and design [4].

In the functional programme phase, both the acute-care hospital model as well as the quantitative dimensioning of it are defined [19]. The acute-care hospital model comprises the main characteristics that define the healthcare organization, teaching and research that the future acute-care hospital will deliver. For the definition of the acute-care hospital model, a careful evaluation of the current and future variables must be made [19]:

1. Socio-demographic trends: including variations in the morbidity pattern, cultural changes and population expectations of the reference area.
2. National and regional healthcare system: health care organization and care modalities.
3. Biomedical technologies.
4. Information and communication technologies.
5. Organizational culture of current acute-care hospitals to facilitate the change.
6. Changes in the organization of the general services and the infrastructure services.

When these organizational and functional configurations are clearly defined, comes the quantitative dimensioning of the acute-care hospital. For doing so, the functional programme becomes an instrument that identifies the activities of the acute-care hospital and the rooms required for each activity [20]. However, the functional programme has its own limitations as it usually expresses functional and practical requirements, but it does not deal with many other sensitive aspects like the site, the landscape, orientation, views and, even more importantly, the psychological expectations of different users of the building [20]. Acute-care

hospital design does not come directly from the functional programme but from a clear understanding of not only the functional but also the environmental factors needed for its optimal performance.

1.3.2 Environmental Factors

Traditionally, environmental factors have focused on providing comfort to people. According to the dictionary [21], the first meaning of the word “comfort” relates to a physical state in which we have *“a feeling of being physically relaxed and satisfied, so that nothing is hurting you, making you feel too hot or cold”*. The second, has to do with an emotional state *“if someone or something gives you comfort, they make you feel calmer, happier, or more hopeful after you have been worried or unhappy”*.

In a similar way, architectural and engineering fields have traditionally focused on the physical aspects to achieve a comfortable design (hygrothermal, acoustics, lighting and olfactory parameters) [22]. On the contrary, the psychology field has more to do with the emotional level, starting with its interest in persons processes, later interactions between persons and for about the last 50 years, in the person-environment relation [23]. Environmental psychology studies the “transactions between individuals and their physical settings” [23] which include the natural environment (issues related to climate change, energy shortages or pollution) as well as the built environment (making buildings more humane). According to environmental psychology “individuals change the environment, and their behaviour and experiences are changed by the environment” [23]. Until the end of the 20thc., it was thought that the loss of neurons in adult humans was irreversible. It was not until the late 90s that neurogenesis was proven and linked to the environment [24]. This scientific milestone proved that changes in our environment could modify the brain, thus conditioning our behaviour. Since 2003, the “Academy of Neuroscience for Architecture” in California has aimed at exploring the architectural environments from a neuroscientific perspective [25].

These dualities between the physics and the psychics, and the natural and built environments have all merged in the field of healthcare architecture. Sustainable thinking translated to healthcare architecture is based on protecting health at all levels, focusing both on the ecological impact of the building as well as its influence on its user’s life quality [26]. These two views are classified as eco-effective design and evidence-based design [27]. The first is aimed at environmental global issues while the second cares about the building’s influence on relatives, patients and staff health and wellbeing. This thesis focuses on the second one and its ability to create healing environments.

“Well is the new green” [28]

1.4 Evidence-Based Design Process

Back in the 19thc., a highly educated English nurse called Florence Nightingale published a book [29] which gathered the first data that linked her observations on acute-care hospital design strategies with the patients' recovery process [30]. Her manuscript proved the importance of layout distribution, hygiene, lighting and silence and its impact on saving lives in military hospitals. Her contribution made the foundations of what nowadays is known as Evidence-Based Design (EBD).

The term "Evidence-Based Design" was printed for the first time back in 2000 [31] even though its origins stem from three key factors that happened several years before. The first one was the evidence-based medicine movement that emerged at the beginning of the 70s in Canada, whose goal was to determine the best medical evidence for treating patients [32]. The second factor happened at the end of the same decade, in the USA and consisted of the patient-centred care movement [33]. The third and determinant factor was in the 80s, again in the USA, when the environmental psychologist Roger S. Ulrich, published a scientific paper that linked a design variable (the views in the acute-care hospital patient bedroom) with medical outcomes (average length of stay and analgesics usage, among others) [34]. This empirical relation between design and healthcare outcomes brought to light not only the potential of architectural design on the recuperation process of patients, but also the financial benefits for the healthcare facilities. EBD is defined as "the process of basing decisions about the built environment on credible research to achieve the best possible outcomes" [5]. Its differentiating value consists of using research both to inform and to evaluate design strategies. The EBD process has derived from other evidence-based practices like medicine or nursing, and it is intimately linked to the research process. It can be applied to any stage of the design process, but its best potential is achieved when implemented from the beginning. The process consists of eight steps as shown in Fig. 3.

Fig. 3 EBD process, figure adapted from *The Centre for Health Design* [5].

The goal of the EBD process is to generate rigorous evidence that establishes a direct link between design variables and health-related outcomes, though it is also connected to organizational performance and healthcare facility management [35]. Despite its recent history, an increasing number of papers [36–38] from a wide range of fields (environmental psychology, architecture, nursing or medicine among others) are studying the relationships between design strategies and clinical outcomes, economic performance, customer satisfaction, productivity or cultural measures in healthcare facilities (Tab. 2).

Design Strategies or Environmental Interventions	Single-bed rooms	Access to daylight	Appropriate lighting	Views of nature	Family zone in patient rooms	Carpeting	Noise-reduced finishes	Ceiling lifts	Nursing floor layout	Decentralized supplies	Acuity-adaptable rooms
Healthcare Outcomes											
Reduced hospital-acquired infections	**										
Reduced medical errors	*		*				*				*
Reduced patient falls	*		*		*	*			*		*
Reduced pain		*	*	**			*				
Improved patient sleep	**	*	*				*				
Reduced patient stress	*	*	*	**	*		**				
Reduced depression		**	**	*	*						
Reduced <u>length of stay</u>		*	*	*							*
Improved patient privacy and confidentiality	**				*		*				
Improved communication with patients & family members	**				*		*				
Improved social support	*				*	*					
Increased patient satisfaction	**	*	*	*	*	*	*				
Decreased staff injuries								**			*
Decreased staff stress	*	*	*	*			*				
Increased staff effectiveness	*		*				*		*	*	*
Increased staff satisfaction	*	*	*	*			*				

Tab. 2 Adaptation of table "Summary of the relationships between design factors and healthcare outcomes" in paper [36]. * Indicates that the relationship was indicated, directly or indirectly by empirical studies and ** indicates that there is especially strong evidence for the relationship based on multiple rigorous studies.

In order to increase the chance of success of such an ambitious target, the traditional design team (made up of architect, owner, planners, contractors, and engineers) needs to be enlarged. The transdisciplinary team includes (Fig.4): 1) academics and researchers (professional or internal, academic, student and staff support); 2) practitioners (architects, interior designers, project manager, landscape architects, medical planner, engineers,

1. Introduction

operations expert, , construction manager, wayfinding and art experts, philanthropy manager, LEED consultant, Lean consultant, vendors and manufacturers); and 3) users consisting of the owner's representatives (board members, chief executive officer, chief of staff, chief financial officer, medical director, chief nursing officer, facilities, key manager, foundation, marketing, operation), plus the final users (caregivers, family members, patients, physicians, clinicians, nurses, community, infection control, quality improvement managers, medical records managers, information systems managers, facility managers) [39].

Managing collaboration, responsibilities, expectations and communication is fundamental for the performance of such a numerous team of people (Fig. 5) with different backgrounds and skills. In order to increase user engagement and the formulation of goals and needs from the early phase of the design process, participatory methodologies can be used. The design dialogues methodology [40] facilitates the collaborative production of design artefacts, with the aid of design games and scenarios (Fig. 6), that might enhance innovative thinking and improve the architectural design process.

Fig. 5 Workshop "LOKALER FÖR PSYKIATRI" at Chalmers University of Technology, Gothenburg 13/04/2018.

Fig. 6 Design dialogues workshop material at Chalmers University of Technology, Gothenburg.

Another key issue for creating a dialogue between team members is communication (Fig. 7). Architects have traditionally communicated visually but their role in a participatory design process depends on whether they achieve a common understanding of the graphical language that produces meaningful and productive design dialogues between all the team members [41].

1.4 Evidence-Based Design Process

Fig. 4 Composition of the transdisciplinary team.

Fig. 7 Triangular model for architectural representation by Irmeli Magnusson [41].

The ultimate goal of applying the evidence-based design process is to generate relevant evidence and translate this knowledge into practice [42]. Different types of evidence have traditionally been used in the design process (geometry, engineering or mathematics to mention just a few). However, and due to the impact on healthcare and financial outcomes, the evidence used to guide acute-care hospital design should come from the most rigorous sources in order to achieve the best possible outcomes [43]. The EBD only emphasizes the need for raising the level of rigour of the evidence that guides architectural design without excluding the tacit knowledge of intuition [44]. Due to its short history (Fig. 8), the field of EBD is still facing many limitations and scepticism (such as lack of architectural training on research [45], lack of evidences or not rigorous enough studies). These facts could be overcome by extrapolating other evidence-based disciplines like biology, medicine or neuroscience [46].

In 1993, a new organization called The Center for Health Design (CHD) was established in USA. Its mission is to transform the healthcare environment into places that are safer and healthier. This consortium works as a platform to share and connect knowledge between different healthcare institutions, universities, professional associations, administrative institutions, architectural firms and any person interested in healthcare architecture. In 2007, the CHD founded the peer-reviewed journal "Health Environments Research & Design" (HERD), for the publication and dissemination of evidence-based design from an interdisciplinary perspective.

In 2009 and in order to institutionalise and standardise the evidence-based design process, the EDAC programme was launched. EDAC stands for “Evidence-based Design Accreditation and Certification” programme and identifies individuals capable of applying the evidence-based design process to healthcare design projects. Since then, more than 2500 people have been certified, whose profiles include university professors, students, interior designers, architects, clinicians, nurses and manufacturers from different countries, mainly USA and Canada, but also from Spain [47, 48].

Fig. 8 EBD timeline, figure by [49].

1.5 Aim

1.5.1 Research Incentive

A recent survey study on Spanish healthcare design studios showed that only in 48% of the studios there were designers with specific training in healthcare design [50]. This fact was related to the inexistence of official healthcare design programmes at Spanish universities, and consequently, the lack of researchers or academics in this field. Interestingly, it was the professional practitioners who taught in the few postgraduate courses found nationally [50]. The lack of academics in healthcare architecture also has an impact on the low production of scientific publications which in terms determined the low usage of scientific papers by architects [50].

The research incentive of this doctoral dissertation relies on the presumption that, by generating original information from the existing acute-care hospitals, it will be incorporated by architects into their future designs (Fig. 9). The design evidence needs to be added to the extensive and complex inputs and variables that define a new acute-care hospital (population needs; healthcare resources; health technologies; management and logistics; clinical progress; demographic, socioeconomic, and urban analysis, etc) to improve the overall quality of the care delivered.

Fig. 9 Virtuous circle for incorporating research into the design process of acute-care hospitals.

1.5.2 Research Question

The research question of this dissertation is: How could we evaluate functional and environmental factors, in existing acute-care hospitals, that might have an impact on healthcare outcomes within the Spanish context?

1.5.3 Research Aim

This thesis uses an explorative approach whose purpose is to provide a general view of the topic without a predefined hypothesis. The overall aim of this thesis is to evaluate functional and environmental factors that might have an impact on healthcare outcomes from four different perspectives (theory, field, future and present). The reason behind this aim is to generate information that might provide a better understanding for both academics and practitioners and be applied to Spanish acute-care hospitals in use.

The specific aims based on the four perspectives are:

1. Field: To explore the evaluation of functional & environmental factors from the user's perspective.
2. Theory: To explore the evaluation of functional & environmental factors from the literature perspective.
3. Future: To explore the evaluation of functional & environmental factors from the analysis and documentation of best practice designs.
4. Present: To explore the evaluation of functional & environmental in current acute-care hospitals in Spain.

1.5.4 Delimitation

The study is focused on the Spanish context and in acute-care hospitals that are in use. As an acute-care hospital is a very complex building and the kind of users and length of their stay varies according to the unit considered, only seven units have been selected for the development of this study. The logic behind this selection criteria is based on a patient focus approach and the fact that if environmental and functional factors can affect healthcare outcomes, their impact will be higher in the areas where patients stay the longest, which are the in-patient units. To achieve a broad range of individuals with different life spans, the in-patient areas selected are the intensive care unit, the standard ward, the obstetric ward, the paediatric ward, the neonatal unit, and the labour ward (to complete the maternity process). Additionally, the circulation spaces have been considered because of their key role in determining the functionality of the whole building, as well as the care-path of patients and all the different users and services flows.

1.6 Dissertation Structure

This doctoral dissertation consists of five chapters, four appendixes and the website www.curarq.net. Each chapter, excluding chapter 5 conclusions, includes its own reference section with a list of the figures, tables, glossary (underlined words) and bibliography used. All this book is written in English, but more information can be accessed through the website that is written in Spanish. The structure of each chapter is as follows:

- **Chapter 1** provides an overview of the healthcare sector in Spain, an introduction to acute-care hospitals, the relevance of functional and environmental factors, and the impact of the evidence-based design process to justify the need and aim of this doctoral dissertation.
- **Chapter 2** addresses the background of this work with the historical evolution of the acute-care hospital, current research on the seven units of the study and on post-occupancy evaluation.
- **Chapter 3** explains the methodology chosen and the four perspectives of the study: acute-care hospital placement, literature analysis, acute-care hospital visits and acute-care hospital cases. There is also the basic building information of the sixteen visits and the four study cases.
- **Chapter 4** introduces the tool CURARQ, the evaluation process with this tool and its discussion. Next, there are the results and discussion of the seven units of the study (circulation spaces, intensive care unit, standard ward, obstetric ward, paediatric ward, neonatal ward, and labour ward) according to the four perspectives mentioned in chapter 3.
- **Chapter 5** includes the conclusions of this work as well as the limitations of the study, contributions, and suggestions for academic research.
- **Appendixes** consist of the curriculum vitae, documentation (financing, placement and evaluated acute-care hospital certificates), and material from the acute-care hospital placement (interviews and summary of results).

1.7 References

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1.7.3 Glossary

- Length of stay: the period of confinement of a patient to a hospital or other health facility (Online Medical Dictionary).
- Morbidity: the proportion of patients with a particular disease during a given year per given unit of population.
- Neurogenesis: formation of neurons which involves the differentiation and division of stem cells in which one or both of the daughter cells become neurons (Online Medical Dictionary).
- Psychological: related to psychology. Psychology: the science dealing with the study of mental processes and behaviour in man and animals (Online Medical Dictionary).

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2. Background

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2.1 Hospital Evolution

Through history, the word hospital has been used to name institutions with very diverse forms, functions and meanings [1]. These buildings have been in constant development to cope with the evolving demands of clinical progress and social context.

In this schematic and shallow historical analysis, there is a selection of buildings in which one of its functions was related with the caring process of sick people. The timeframe established dates from the 3000 before Christ (B.C.) to the twenty-first century and is focused on a Western vision (North America and Europe). Tab. 1 summarises the basic information for each period considered.

	Model	Style	Funding	Treatment	Patients
Ancient Age (3000. B.C. - 476 A.C.)	Greek (900 B.C.)	Sanctuary	Civilian	Rituals, thermal water, medicinal plants	Sick people
	Roman (800 B.C.)	Consulting room	Civilian	Care, food, and accommodation	Slaves and legionnaires
Middle Age (1 st c. - 15 th c.)	Byzantine (1 st c. - 15 th c.)	Hospice	Religious	Care, food, and accommodation	Poor and/or sick people
	Gothic (12 th c. - 15 th c.)	Monastery	Religious and civilian	Rest, heat, hygiene, diet, and asylum (pain house)	Pilgrims, poor and/or sick people
Modern Age (15 th c. - 18 th c.)	Renaissance (15 th c. - 16 th c.)	Palace	Civilian	Surgery inception	Urban marginalised population
	Baroque (17 th c. - 18 th c.)	Monumental	Civilian	Therapeutic vocation, medicine as science	Soldiers, poor and/or sick people
Contemporary Age (18 th c. - 20 th c.)	Pavilions (19 th c. - 20 th c.)	Military barracks	Civilian	Ventilation, hygiene, sunlight, and surgery	Sick people
	Monoblock (20 th c.)	Compact block	Civilian (public and private)	Specialised medicine, privacy, and comfort	Sick people (with and without purchasing power)
	Poliblock (20 th c.)	Autonomous blocks connected	Civilian (public and private)	Development of diagnostic and treatment areas	Sick people
	Podium-tower (1950-1970)	Zoning	Civilian (public and private)	Diagnostic and treatment, in-patient wards, and general services	Sick people

Inflection point	20 th c.	National Health Service
		Megastructures
		Modern Movement
Present paradigm	21 st c.	Sustainability & Evidence-Based Design
		COVID-19 Pandemic

Tab. 1 Summary of hospital historical evolution. Based on references at each age considered.

Next, there are tables with the correlation between the clinical and social development, and the hospital architectural model, at each considered period. The texts highlighted with the symbol 🌟 describe with further detail a specific hospital that has been considered representative for that time.

2.1.1 Ancient Age (3500. B.C. - 476 A.C.)

Greek Model [1]	
Background:	Architectonic solution:
<ul style="list-style-type: none">• Health associated to religious rituals such as food offerings and ritual bathing.	<ul style="list-style-type: none">• Greek temples, "Asklepieion".• Sanctuaries located next to thermal water fountains and medicinal plants.
Roman Model [1]	
Background:	Architectonic solution:
<ul style="list-style-type: none">• Funded by city government.• Offered medical care to the population.	<ul style="list-style-type: none">• "Demosieuoentes iatroi" or public doctors.• "Iatrea" consulting rooms for some surgical procedures located in a room of the doctor's house.• "Valetudinarium" facilities of "valeduto" or health for the urgent care of slaves and legionnaires from the military camps (Fig. 1). They offered health care, food, and accommodation.

Fig. 1 Valetudinarium, Vetera. Germany (70 A.C.). Figure by [1].

Tab. 2 Ancient age summary.

2.1.2 Middle Age (1stc. – 15thc.)

Byzantine Model [1]

Background:

- Strong population growth concentrated in cities.
- Promoted by the church, for Christian charity, for the caring of the poor. The governments did not provide those services.

Architectonic solution:

- "Xenones" originated by the byzantine Christian church. Considered as a basic equipment of the city. Combined doctors' training activities with the caring of the sick. With bathrooms and chapels for religious functions.
- "Nosokomeia". "Nosos" illness + "komeo" city. Provided accommodation, food and medical care for sick people.
- "Ptochotropeia" or "ptocheia". "Ptochos" poor + "tropho" feed. For the poor people.
- "Xenodocheia". "Xenos" guest + "docheion" receptacle.
- Lodge or hospice. With doctoral staff and assistants for the care of the sick people.

Gothic Model [1]

Background:

Common treatments:

- Segregation: dying people were in a separate room away from the common room.
- Resting: wooden beds to be shared by the patients.
- Heat: chimneys in the common basilican rooms.
- Hygiene: bathrooms.
- Diet.

Architectonic solution:

- God's House. Building that received and treated the ones in need. It gave asylum to the poorest and hosted the pilgrims. House of charity and pain. It was part of the many buildings that formed the monastery (cathedral, bishop's palace, canons' school, monks' hospital, laymen hospital and "hospitum" for the poor people, travellers and pilgrims) (Fig. 2).
- Limited development of medieval surgery. The building was similar to the rest of the facilities associated with the monastery.
- Basilican typology.
- The patients were located aligned with the perimeter of the room to follow worship.
- Urban location next to the city accesses and rivers (supplies, laundry and waste disposal).

Fig. 2 Fountains Abbey site plan. Yorkshire, England (13th c.). Credit: Holly Hayes. Figure by [2].

<ul style="list-style-type: none"> • 11thc. growth of hospitals linked to pilgrimage roads. • Increase in the number of hospitals originated by laypersons (funded by kings, lords and bourgeoisie). 	<ul style="list-style-type: none"> • Adaptation of the "God's House" to the new city needs.
<ul style="list-style-type: none"> • Social instability at the end of the 12thc. • Bourgeoisie started to take control over hospitals to tackle poverty (linked to misery and sickness). • Creation of hospitaller orders (12thc. - 13thc.) due to pilgrimage to Christian holy places. 	<ul style="list-style-type: none"> • Fortified hospital model with cloistered arrangement (religious, military and hospital component).

Tab. 3 Middle age summary.

2.1.3 Modern Age (15thc. - 18thc.)

Renaissance Model [1]

Background:	Architectonic solution:
<ul style="list-style-type: none"> • Decrease of religious power and increase of civilian power. • Hospitals were important for controlling urban marginal population (linked to poverty and sickness) by monarchy. 	<ul style="list-style-type: none"> • The medieval model was still in use (it lasted until 18thc.) • Quite simple urban buildings. • Palace aesthetics and renaissance geometries (Fig. 3). Only differed in their bigger dimension and scale.
<ul style="list-style-type: none"> • Moderate development of surgery. Improvement in interventions and treatment of gunshot wounds. • More appropriate instrument development. • Advances in obstetric and ophthalmology specialities. 	<ul style="list-style-type: none"> • Surgical procedures were done in the same hospitalization room with other patients. • Undifferentiated rooms (became converted into other functions). • Hospitalization occupied 90% of the whole hospital building.

Fig. 3 Floor plan and section. Ospedale Maggiore, Milan, Italy, Filarete 1456. Figure by [3].

Baroque Model [4]

Background:	Architectonic solution:
<ul style="list-style-type: none"> • Place associated with death. • Designated for the poor and sick populations. • Little medicalized. 	<ul style="list-style-type: none"> • Hospital for incurables.
<ul style="list-style-type: none"> • Large variety and dispersion of hospital facilities in use. Economic and healthcare deficit. • Dispossession of religious properties by the State. Dissolution of clerical orders. Decrease in healthcare staff (mainly were nuns and priests). 	<ul style="list-style-type: none"> • Replacement of smaller hospitals by bigger hospitals located in the main cities.

2. Background

2.1 Hospital Evolution

- From a religious approach to a civilian approach, the healthcare function was more important than Christian charity.
- Hospitals managed by civilian commissions that reported back to the king.
- Socialisation of healthcare.
- French revolution (1790). New age of reason, hygiene, and science.
- Human beings were no longer God's creatures but citizens.
- Several states started organising healthcare systems. Inception of control and preventive medicine to reduce hospitalization cases (doctors as civil servants).
- Hospital as a place to cure some diseases. Before this time, the religious treatments offered consisted of leeches, purge, suction cups and rosaries. Therapeutic vocation.
- Medicine as a science. Doctors and surgeons in hospitals.
- Professional regulations, inception of professional associations for its control.
- Institutional monumental architecture that represented the social order.
- Architectural magnificence like other facilities such as the palace (power), the barracks (military), or the prison (neglected marginal population).
- New hospital model: big block surrounding a cloister (with a rectangular courtyard in the middle) and Greek cruciform layout.
- Architecture of large dimensions (Fig. 4).
- Natural ventilation problems and circulation issues (there were no corridors, flows through hospitalization rooms). Increased the risk of nosocomial infections.

Fig. 4 Royal Naval Hospital, Greenwich, London, UK. Christopher Wren, 1694. Figure by [3].

- Beginning of necropsy (17thc. - 18thc.).
- Beginning of rudimentary urine tests (18thc.).
- Development of equipment for patient exploration.
- Development of clinical trials.
- Introduction of medicines, beginnings of pharmacology.
- Doctors started to consider patients for diagnosis (listening to them and palpating them).
- Introduction of the autopsy room in some hospitals.
- Development of the first laboratory for clinical tests.
- Army development by professional soldiers (17thc. - 18thc.).
- The wars between states/nations produced a new type of patient whose health was key for the nation.
- The monarchs, who owned the army, promoted austere military hospitals.

- English Industrial Revolution (1760).
- Gross overcrowding of low-income populations in the cities, epidemics.
- Paris urban transformation by G.E. Haussmann (1848).
- Impact of hygiene studies in hospitals on urban planning. Application of ventilation, sanitation and sun-light principles to urban and building regulations.
- Cemeteries, asylums and hospitals far away from the urban centres.
- Improvement of citizens' living conditions (19thc.).
- Healthcare politics depend on the State. Inception of the concept of public health and the right to healthcare.
- Modernisation of surgical and medical education in all Europe.
- Developments in surgical anaesthesia, haemostasis, blood transfusions, antisepsis, asepsis, and equipment.
- Momentum of surgical development. Average mortality in operating rooms of 50%.
- New hospital model: healthcare + education + research.
- New and specific rooms for dissection, autopsy, laboratories, operating theatres, medical and surgical wards, and general services.
- Demand of rooms for surgical activities. Incorporation of specific space for surgical functions.

Fig. 7 Renkioi military hospital, Turkey (1855). Figure by [1].

- ★ Renkioi Military Hospital (Fig. 7)
 - Built by English engineers.
 - Wooden barracks that accommodated wounded and sick patients in 3000 beds.
 - Rooms with sanitary systems, drainage and support areas for nurses and doctors.
 - The influential nurse Florence Nightingale worked in this hospital (see chapter 1.4).
 - Hospital mortality 3%, against the 42% in the Hospital for Invalid Ladies in London where Nightingale worked at that time.

- Wars became a development factor for medicine and hospitals. Crimea war (1855-1856).
- Leading role of nursing staff in the hospital (hospitalisation room cleaning, patients washing; food service and drugs intake).
- When Florence Nightingale went back to the United Kingdom (1859), she published "Notes on Hospitals" and "Notes on Nursing" where she described best practices for hospital designs. These mainly consisted in the improvement of hygiene conditions.
- Her book propitiated a universal development of these hospital types until the beginning of the 20thc.
- Hospitalisation rooms:
 - Rectangular shape (40 m x 9 m).
 - For 30 patients.
 - Beds arranged in two lines, perpendicular to the walls with a central corridor.
 - Generous windows next to the beds (enough day light and natural cross-ventilation).
 - Sanitary facilities and support rooms .
- Pavilions:
 - One or two floors.
 - North-south orientation (optimal sunlight and ventilation).
 - Concrete foundations or air chamber (to avoid moisture).
- Outdoor area:
 - Gardens and pathways to connect pavilions.
 - Covered courtyards to allow outdoor physical activity.

Fig. 8 Hôpital Lariboisière,
Paris, France, Martin-Pierre
Gauthier, 1839-1854.
Figure by [3].

★ Lariboisière Hospital (Fig. 8)

- Based on the reconstruction proposal for the Hôtel-Dieu in Paris by the surgeon J.R. Tenon and the architect B. Poyet 1787.
- Three pavilions at each side of the courtyard with a total number of 905 beds.
- Three-floor height.
- Auxiliary rooms at both end sides of each hospitalisation room, and at both extremes of the building.
- Pavilion orientation and dimension to maximise optimal sunlight.
- Endorsed by Florence Nightingale as a referent model.

Monoblock Model [1]

Medical and social background:

- Consolidation of the hospital as the general healthcare model.
- Decrease of nursing presence due to the development and increasing room demands of surgery and radiology procedures.
- Improvements in specialised medicine.
- Attraction of wealthy patients.
- Development of public and private models.
- Bacteria discovered as a disease transmitter (L. Pasteur).
- Discovery of antiseptic treatment of wounds.
- Scientist concluded that the hospital pavilion model did not offer better results than the preceding models.

Architectonic solution:

- Hospital extension to attend the whole population.
- Irruption of new specialised hospitals (such as sight, cancer or orthopaedics).
- More privacy and comfort in hospitalisation rooms. Hotel imitation: hospitalisation rooms compartmentalised with light partitions, hospitalisation rooms with sinks, beds oriented to the windows to provide external views to patients.
- No need to provide fixed air volumes per bed. There was no longer justification for the pavilion model.
- Vertical development of hospitals:
 - Development of construction techniques (steel, reinforced concrete, and glass).
 - New installations (lifts, thermal power plant).
- Compact block, shorter and more efficient journeys than with the pavilion model.
- Less floor area needed in the plot. Encouraged the return of hospitals to the cities.

Fig. 9 Hospital Goldwater.
New York, USA (1910).
Figure by [1].

★ Goldwater Hospital (Fig. 9)

- Hospitalisation pavilions stacked in vertical.
- Layout with a "T" shape with an area for the vertical communication cores plus the support areas, and another area for the hospitalisation room.
- Difficulty in organising the different hospital units and their functional relationships in an effective manner.

Fig. 10 Hôpital Beaujon, Clichy, Paris, France, Jean Walter, Louis Plousey, Urbain Cassan, 1932-1935. Figure by [3].

⊛ Beaujon Hospital (Fig. 10)

- For the first time, there was a proposal to segregate the different user flows (sick people, visitors and staff) from the services.

- First World War (1914 - 1918).
- Development of antisepsis, asepsis, and surgical techniques.
- Second World War (1939 - 1945).
- Acceleration of surgery development:
 - Introduction of penicillin.
 - Occlusive treatment of wounds.
 - Anaesthesia development.

Poliblock [1]

Medical and social background:

- Increase of hospital functional programme complexity.
- Development of diagnostic and treatment facilities (such as emergency department, operating rooms, out-patient consultations, laboratories or radiological intervention).
- Treatment for tuberculosis: sun, pure air, and nature.
- Discovery of rifampin to cure tuberculosis.

Architectonic solution:

- Need for connecting, grouping and spatial proximity between related units (according to user type).
- Need to move in-patient wards away from general services.
- Sanatorium in contact with nature (outdoor life), horizontal structures (do not block views, natural ventilation, and sunlight).
- Demise of tuberculosis sanatoriums. Buildings converted into other functions (e.g. long-term hospitals).

Podium-tower [1]

Medical and social background:

- Development and increase of clinical services.
- The Athens Charter (1933, 1941) functional approach to urban planning.

Architectonic solution:

- Monoblock and poliblock models were too rigid to cope with hospital changes, resulting in additional buildings being connected to the hospital or the dispersion of functions within several floor areas. Increase in difficulty of circulation flows and hospital management.
- Functional zoning of the hospital:
 - Lower areas: diagnostic and treatment, administration and general services.
 - Higher areas: hospitalisation wards.
 - Building annexes: staff residency, supplies, resources and others.

Fig. 11 Herlev Hospital, Denmark. G. Bornebsuch, M. Brel, and J. Selchau (1965-1975). Figure by [1].

- Herlev Hospital (Fig. 11)
- Hospitalisation wards in vertical tower and the general services in the horizontal podium (treatment and diagnostic, support and general services).
- Concentration and efficiency of flows and staff and services journeys.
- Highly dependent on lift services.

Tab. 5 Contemporary age summary.

2.1.5 Inflection point (20thc.)

End of hospital typology (from the late 1980) [1]

Background:	Architectonic solution:
<ul style="list-style-type: none">• Shift in social demands and expectations over healthcare services.• Patient-centred clinical activity, functionality, and design.	<ul style="list-style-type: none">• Architecture as an added value.
<ul style="list-style-type: none">• Shift in medical training and practice.	<ul style="list-style-type: none">• Greater complexity and development of the functional programme. Shift in building scale and configuration. Hospital projects with more volumetric diversity.• Prevalence of horizontal development.
<ul style="list-style-type: none">• Increase in the importance of the healthcare sector for the national economy. Higher gross domestic product (GDP) investments.• Healthcare systems reform (new funding and management models for hospitals).	<ul style="list-style-type: none">• More efficient hospitals in terms of care and use of resources.
<ul style="list-style-type: none">• Beginning of telemedicine development.• Growth of out-patient assistance (out-patient department, day hospital, tests, and examinations).• Increase in the number of people attended each year and decrease in the average <u>length of stay</u> at the hospital.	<ul style="list-style-type: none">• The floor area dedicated for the in-patient department was reduced from 80% (since the 20thc.) to 25% of the whole building.
<ul style="list-style-type: none">• Most acute patients can be treated.	<ul style="list-style-type: none">• Increase in the floor area dedicated to the intensive care unit from 3% to 10% of the whole building.

National Health Service (United Kingdom) [5]

After World War II (1939-1945) and due to the progress of the welfare state in Great Britain, the National Health Service (NHS) was created. In addition to providing health care services, this institution had its own architectural department responsible for the analysis, development and evaluation of healthcare facilities. Since the National Health Act (1946) [6] all British hospitals became public which meant that there was a need for the reorganization of about 2000 national buildings. At that time (1950-1970) the predominant hospital model was still the podium-tower, but its configuration was becoming more and more inflexible due to the current change in needs and the small floorplan. The designers of this new institution experimented with new proposals based on several factors: low-rise, flexibility, smaller size, zonification of areas, prefabrication of construction systems, relevance of building services and special attention to environmental factors such as orientation, views or natural light. All their work was gathered in the Health Building Notes, documents created for its own evaluation and dissemination that are still in use and being updated [7].

Fig. 12 Wexham Park. Figure by [1].

Fig. 13 Northwick Park Hospital. Site plan and enclosed street. Figure by [1].

Fig. 14 Frimley Park Hospital. Best Buy concept. Figure by [1].

★ Wexham Park (1955-1966) (Fig. 12)

- Located in a park with a lake that had available land for future extension.
- Differentiation of accesses but mixed circulations (internal and external).
- Hospital arranged on one floor except for the administration tower.
- Natural light (windows and skylights), courtyards and outdoor views for all rooms with a permanent occupation.

★ Northwick Park Hospital (1963-1972) (Fig. 13)

- Urban design, village with streets and independent buildings, able to be modified without interfering with the rest of the hospital. Organic extension according to needs.
- Enclosed street with segregation of circulation in height (two or three levels: highest for patients, staff and visitors, middle for supplies, and the lower for building services).
- Zonification of buildings with different shapes and heights adapted to specific needs.

★ Standard Best Buy Hospital (1967) (Fig. 14)

- Experimental model or design concept to reduce the average budget and time: low-rise, ramps instead of lifts, electric cars for food and supply movement, nursing wards next to treatment and diagnosis services to shorten distances.
- Compact floor plan, rectangular grid structure with courtyards. Wards at the perimeter and clinical services in the middle of the building. Undefined limits between departments, shared use of equipment and rooms.
- Without available room for future demands. Only build what was needed.

Fig. 15 Diagram of a Harness Hospital System. Figure by [8].

Fig. 16 Development using Harness Departments. Figure by [8].

Fig. 17 Nucleus Standard Hospital with decentralised energy sources and cruciform templates. Figure by [9].

Fig. 18 Newham Hospital, UK. Figure by [9].

✪ Harness Hospital System (1971) (Fig. 15-16)

- Best buy hospitals with their standard plans could not meet the need for more flexibility in hospitals.
- Standardised system of hospital design and construction.
- Prefabricated modular project generated by the addition of modular pieces which had a crossed shape. Harness framework for the whole hospital.
- The modular pieces were joined to a main corridor (that hosted all the building services, communications and people flow). Each piece consisted of a structural grid of 15 m² with clear spans of 15 m.
- There were courtyards between the crossed modules.
- Each department to be resolved on one floor and covered by one or more basic pieces.

✪ Nucleus Hospital System [9] (Fig. 17-18)

- Combination of the cruciform shape and structural grid from harness and economical space use from Best Buy, after the oil crisis (1973).
- Definition of independent modular pieces for the growth and change of old hospitals. Hospital renovation by sections without interrupting its functioning, resulting in a new hospital with all parts plugged in.
- A cross-shaped basic piece with a 16.2 m side (able to host two nursing units of 28 beds each) allowed for natural lighting and ventilation. Able to stack up to three pieces in height, plugged into a main corridor with segregated circulation. Courtyards between the modules.

Mega-structures (Germany and Canada) [1]

During the economically prosperous years preceding the oil crisis (1973) hospital projects were conceived as gigantic transformers to cope with clinical and technological evolution. These sophisticated containers allowed for maximum flexibility of change and extension, with rooms capable of being converted in almost any required place. Such massive buildings had a highly specialised engineering solution. They used a grid of service rooms connected to vertical and horizontal flows with interstitial plan floors for the engineering pipes and conduits. Their façades had an industrial look. This design trend was influenced by the architectural movement lead by Archigram (Cedric Price) that promoted high tech solution for technological buildings (such as hospitals or universities). However, the oil crises shifted the context completely and the healthcare systems had to reconsider their investments to optimise their own resources.

Fig. 19 McMaster University Medical Centre interstitial floors. Figure by [10].

✦ McMaster University Medical Centre, Ontario [11] (1969) (Fig. 19)

- Structural mesh without columns of 25.6 m per 28.8 m, supported by 55 towers located at the corners with a size of 3.2 m per 6.4 m. The towers carried the loads to the ground as well as hosting the vertical communication cores.
- Interstitial floors for building services that allowed for maintenance flows and activities without interrupting the performance of the hospital.
- This mega-structure allowed future extensions in vertical, lengthening the service towers.

Fig. 20 University Hospital Aachen. General view by Uniklinik RWTH Aachen.

✦ University Hospital Aachen (Germany) (1969 – 1982) (Fig. 20)

- Goal to create a healing machine with maximum flexibility.
- Orthogonal grid with four main circulation streets (parallel and longitudinal), associated with the vertical communication cores and connected to each different hospital unit. Interstitial floor for building engineering services.

Modern Movement and Great Master of Architecture (20thc.) [1]

During the 20thc. there are well-known examples of hospital projects and buildings that surpass regular hospital prototypes. This was due to the work of great architectural masters of the Modern Movement that dared to confront healthcare design challenges in an innovative, compromised, and brave manner. Next, there is a small selection of interesting projects that take into account the synergies between functional and environmental factors.

Fig. 21 Zonnestraal. Hilversum, the Netherlands. Bernard Bijvoet, and Jan Duiker (1926-31). Figure by [12].

- ✧ Zonnestraal (1926-31), Hilversum, the Netherlands. Bernard Bijvoet (1889-1979) & Jan Duiker (1890-1935) (Fig. 21)
 - Tuberculosis sanatorium where treatment is based on contact with nature, air, heliotherapy, food and resting.
 - Buildings far away from the cities, with linear and horizontal shapes. Narrow and low height volumes to maximise sunlight and views.
 - Disaggregation of volumes organised as small clusters adapted to the site.

Fig. 22 Views from the Paimio Tuberculosis Sanatorium. Figure by [10].

- ✧ Paimio Tuberculosis Sanatorium (1929-33), Paimio (Finland), Alvar Aalto (1898-1976) & Aino Aalto (1894-1949) (Fig. 22)
 - Organic adaptation to the site with a therapeutic and functional vocation (optimal sunlight and views).
 - Sensory architecture that takes into account the physiological and psychological qualities of the spatial experience so that it does not interfere in the patients' hypersensitivity.
 - Double windows to avoid air flows, curved sinks to avoid water noise, light points away from the patient's direct sight, soft colours for interior design and soft and pleasant finishing materials for doorhandles.

Fig. 23 Hospital City in Lille Site plan. Figure by [10].

- ✧ Hospital City in Lille (1932), France. Proposal. Paul Nelson (1895-1975) (Fig. 23)
 - Consequence of the North American urban zoning: separation of the city into specialised areas with the same function (university city, sports city, sanitary city).
 - Proposal dismissed from consideration for being too innovative and utopic for the time.
 - Urban planning as an essential part of the hospital complex, connection to the city transportation and communication networks.
 - Unitary and autonomous project. A cluster for all the healthcare resources in the city (medical faculty, acute-care hospital, geriatric hospital, long-term hospital, administration and general services).
 - Monoblock geometry, two cruciform towers.

Fig. 24 Venice Hospital. Le Corbusier. Figure by [12].

- ✧ Venice Hospital (1964-65), Italy. Proposal. Le Corbusier (1887-1965) (Fig. 24)
 - Contest winning project. Different approach to hospital design, compared to the contest opponents.
 - Plastic adaptation of the building to the site constraints.
 - During the design stage there was a drastic reduction of the in-patient department, but the design proposal was able to cope with it without losing the essence of the project.
 - Careful design on a lower scale of detail for the in-patient bedroom. The in-patient bedroom becomes the module of the project that with an internal order configures the whole modular hospital.

Fig. 25 Outdoor areas and courtyards. Hospital SARAH. Figure by [10].

- ✧ Hospital SARAH Salvador, 1994, Brazil, João Filgueiras Lima (Lelé) (1932-2014) (Fig. 25-26)
 - Sarah Kubistchek Network of Rehabilitation Hospital.
 - Rational and sensitive usage of prefabricated architecture. Prefabricated components of reinforced concrete to design light shapes at a low production cost.
 - Efficient construction processes with lower costs and shorter completion times.
 - Detailed study of environmental factors: natural site locations, adaptation to the place (orientation according to sunlight and natural ventilation), indoor rooms linked to outdoor gardens, zenithal light, ceilings with different heights according to the room function, horizontal development, furniture designed for patient, white colour to avoid heat and art to humanise spaces.
 - Structural originality gives shape and character to the project. Conceptual clarity of the form and structure of the building.

Fig. 26 Hospitalisation room. Hospital SARAH. Figure by [10].

Tab. 6 Inflection point summary.

2.1.6 Present Paradigm (21stc.)

Sustainability & Evidence-Based Design [13]

Since the late 20th century, hospital design has evolved to cope with the constant changes in technology, diagnosis and treatment techniques, new devices and equipment, growth of out-patient surgery and patient care philosophy [14]. Fortunately, hospital architecture has moved from being considered as a difficult and slow field for invention and progress (losing skills and commitment in their development) to the frontline of architecture with unique design challenges [3]. Both the advances in psychology, medical technology, digital revolution and science are fundamental in the design of hospital buildings that should provide the best quality to its end users [3]. Next, there are several recent examples of hospital design. These showcase architectural firms that embrace the challenges of hospital complexity as a source of design inspiration.

Fig. 27 General view New Hospital North Zealand. Figure by [15].

✧ New Hospital North Zealand (ongoing in 2020) (Fig. 27)

- Hillerød (Denmark). Vilhelm Lauritzen Architects with Herzog & De Meuron
- Low-rise with an organic composition, set in a Danish forest. All the perimeter is stacked with patient bedrooms (maximising views and natural light) and the medical services are found in a subterranean basement. The hospital project is integrated into the surrounding landscaping work and a new urban area that includes commercial and residential buildings.

Fig. 28 General view Parametric Hospital in Puyo. Photographer Sebastian Crespo [16].

✧ Parametric Hospital (2013) (Fig. 28)

- Puyo (Ecuador). PMMT Arquitectura
- A parametric system designed to meet the extremely tight time requirements of an urgent national need that demanded the completion of the design, construction and equipment of the new facility in a time period shorter than a year. The solution is a modular project with a high degree of prefabrication and an inner organizational system.

Fig. 29 Atrium view at Haraldsplass Hospital in Bergen. Figure by [17].

✧ New Ward Building at Haraldsplass Hospital (2020) (Fig. 29)

- Bergen (Norway), C.F. Møller Architects
- The location of this new building was chosen to maximise the views of the surrounding natural elements (mountain Ulriken and river Møllendalselven). In addition to site, the building follows the river's course, the floor layout is arranged surrounding two covered atriums that provide natural light and visual perspective to the inner rooms.

COVID-19 Pandemic [18]

Background:

- Setback to public health policies from the 19thc.
- Temporary design solutions to increase hospital capacity (Fig. 30-31).
- Natural cross-ventilation to reduce the spread of infection.
- Reduction of social interaction and economic activity. Increase of mental health disorders.
- Highlighted disparities among people with different purchasing power.
- Highly specialised staff unable to change activities during an emergency.
- Boom of tele-medicine and virtual care. Patients in need of access to digital devices.
- Understanding of need for a culture approach rather than an individual approach to healthcare.
- Fragmented healthcare system, lack of coordination between primary and acute-care hospitals.
- Political incompetence to coordinate a national healthcare net, fragmentation between regional powers.
- Economic recession.

Architectonic solution:

*Fig. 30 Temporary hospital in Wuhan (China).
Figure by [19].*

Fig. 31 Transformation of the exhibition centre IFEMA into a hospital. Madrid, Spain. Figure by [20].

Future horizon

Background [18]:	Possible architectonic solution [21]:
<ul style="list-style-type: none"> • Need for proactive and cross-functional skills. Need for multiple non-health related profiles in hospitals. • Interconnectedness of the healthcare system at every level (from primary to acute care). Healthcare nets. • Increase of usage of predictive tools, artificial intelligence (AI) tools to simulate and predict future scenarios. • Governments with no more public money to invest in healthcare systems. • Investment in public health, health promotion and preventive medicine. • Community health centres to reduce stress in emergency departments and promote preventive medicine. • Dystopia, increase of inequality. 	<ul style="list-style-type: none"> • Diversification of the supply chain with at least some of the supplies and PPE material kept locally. Storage areas in the hospital. • Hospital plots with available area to increase capacity during emergencies. • Isolated areas for infectious patients. • Empty areas inside hospital departments to facilitate the reconfiguration of the building. • Additional filter rooms for dressing and undressing in the ICU. • External decontamination areas for ambulances and for pre-triage activities. • Rest rooms with natural themes for staff. Outdoor green areas to help support anxiety and depression. • Technical installations in areas to be reconverted (such as parking, rehabilitation, operating theatres, halls or waiting areas). • Heating, ventilation, and air conditioning (HVAC) flexible recirculation/all-air system and positive/negative pressure. • Reduce viral load by using long-lasting and easy to clean finishing materials. • Storage area for keeping corpses at low temperatures. • Segregated flows in all hospital. • Further segregated flows in the emergency department: 1) for staff; 2) for trauma patients; 3) for suspected infected patients; 4) for other patients. • Single-bed patient bedrooms with double capacity. This will allow the transformation into double rooms. Preinstallation of bed head beams and gases.

Tab. 7 Present paradigm summary.

2.2 Units Evolution

Chapter 2.1 considered the evolution of the acute-care hospital as a whole. However, since this thesis focuses on six ward types and the circulation spaces (see chapter 1.5), there can be further description of these areas. Next, there is the historical evolution and the latest research on functional and environmental factors within the areas of the study.

2.2.1 Circulation spaces

The circulation spaces of an acute-care hospital could be defined as an extensive group of volumes that provide all needed flows of resources (people, goods and services) for the permanent acute-care hospital activity.

Through history, the rapid evolution of clinical, technological and user demands has produced different hospital typologies shaped mainly by the circulation spaces strategy. The circulation spaces have always reflected the healthcare delivery process and determined the final shape of the acute-care hospital. Both with the functional and spatial compartmentalization between religious and secular spaces in the Middle Ages and the isolation of contagious patients thanks to the discovery of germs in the 19thc. [22]. That is the reason why the historical evolution of these spaces corresponds with that of the acute-care hospital as a whole (see chapter 2.1).

The acute-care hospital is an open system due to its functional programming instability. In a similar way to any high scale building, the circulation spaces are the ones that unite the functional programme [23]. These vital places of void or no apparent initial function do not appear in the functional programme and remain hidden between the conversion factor from net to gross area [23, 24].

One of the basic functions of acute-care hospital circulation spaces is the interdepartmental connection. They work as arteries linking different departments for optimal distribution of resources as well as for ensuring an optimal delivery of the healthcare path (Fig. 32).

Fig. 32 Samples of different strategies for general hospital circulation [25].

Acute-care hospitals are, together with airports, one of the architectural typologies in which there is a wide variety of different flows that include not only people but also supplies (fungible materials, equipment, linen, rubbish, and food). Acute-care hospitals are one of the major consumers of goods and services that have to be distributed within the building. Their circulation depends on the thorough understanding of the acute-care hospital's policies for supply, storage and disposal of laundry, catering, sterilization, pharmacy, pathology, and other services [1, 25]. This understanding will affect the amount of movement in the corridors (number of journeys per day), the space requirement for centralised or localised storage and the number of lifts needed according to the analysis of the vertical flow [25]. A negative consequence of overlooking this aspect is the informal usage of circulation space to store bulky equipment that has no other room. That is a constant challenge as there is never enough convenient storage space and it might become a potential hazard and cause inconvenience and inefficiency [25-27].

The acute-care hospital general shape determines the need for circulation space. While compact buildings might reduce the area of circulation, extended volumes might need longer circulation arteries. Excessive and long corridors might be exhausting for patients and staff (inefficient use of workload) and might reduce the floor area available for functional rooms, as well as increasing the number of lifts needed, the cost of cleaning and maintenance. On the contrary, not providing enough circulation spaces might cause chaos, inefficiencies in the healthcare delivery path and poorer user experience [1]. Circulation spaces might take from 10% to 40% of functional floor areas, which makes them expensive and extensive [27]. Therefore, designers tend to reduce them to the minimum to comply with existing fire safety and building regulations [26].

However, the circulation spaces are the ones that allow the coordinating function of the shape and are responsible for ensuring building efficiency at many levels [23]. There exists a duality between the strict requirements of acute-care hospital areas and the permeability of circulation spaces that have to join (both horizontally in plans but also vertically in section) all areas into a consistent whole. Exploring circulation spaces not only horizontally but also vertically might produce interesting volumes that link different levels, allowing for an enriched complexity in social and labour interactions [1]. This transition from a pure functional approach of the circulation routes to considering the social and spatial aspects of people movement is nowadays fundamental for the optimal design of an acute-care hospital [28].

Furthermore, the greater emphasis on patient-centred care together with caregivers and relatives' empowerment, the increase in out-patient activity and the reduction of average length of stay for hospitalised patients has raised the need for careful planning of acute-care hospital circulation spaces and specifically for the public movement of people in the building [22, 28]. Many circulation spaces are public spaces which means that the public can move

independently [28]. The main volume of pedestrian flow is directed to the out-patient area (out-patients and their companions).

Recent studies have shown that, in practice, circulation spaces become the framework for a wide range of activities associated to health-related outcomes. A literature review identified the following research themes associated to acute-care hospital circulation zones [22]: wayfinding difficulties; communication and socialization patterns; measures to control excessive noise; patient fall incidents; user stress level; user satisfaction level; and other patient-centred care issues.

Additionally, there is the impact of connectivity with nature, natural light and the sense of visual transparency, positive distraction and meaningful contact with the outdoor environment (Fig. 33) [22, 29, 30].

Fig. 33 Corridor intersection in the Helsingør Psychiatric Hospital, in Denmark.

Photo: Iwan Baan.

Fig. 34 Photography exhibition by Juan Manuel Castro Prieto. HD.

Moreover, studies have shown that circulation spaces provide neutral settings that give rise to more multidisciplinary communication among staff than in formal rooms [27]. This fact is fundamental as nowadays the delivery of healthcare depends on the performance of multidisciplinary teams [27]. Instead of guidelines for minimum width of corridors, these documents should include design help that promotes additional roles and experiences for these sometimes undervalued spaces to encourage informal interaction such as conversation nooks, quiet spaces, ledges for writing notes or leaning on, small stools or chairs [27].

Corridors can also be considered to have a medicinal function for patients with certain levels of ambulant capabilities who can use their immediate circulation spaces for rehabilitation exercise [22]. In the same way, they become part of the physical work environment for clinical and non-clinical staff [22].

Apart from their articulating function within the acute-care hospital, circulation spaces might also serve as transition places for entrance; from the outdoor to the indoor of each room [28]. This in-between situation gives them the opportunity to adjust peoples' emotional disposition for example before the announcement of the final diagnosis or a transcendental

communication. Hence, sensitive attention to detail and environmental qualities might reduce the anxiety and tension that accompanies acute-care hospital experience [23]. Artistic installations can also make a positive contribution to highly-specialised care environments, making them more human and welcoming, providing a framework for thought, feelings and bringing peace of mind (Fig. 34) [31].

Building services spaces such as vertical and horizontal distribution conduits (for energy, fluids, gases, communication, transport and evacuation), service rooms, machine rooms (technical floors at intermediate levels, basements or roofs) are closely linked to circulation spaces as they need to reach any acute-care hospital ward and unit [1]. Rapid technological innovation (transmission and communication), diverse and changing regulations and standards and their short life usefulness (from 20 to 25 years) need to be integrated into the circulation design so that it allows for further modifications (maintenance and upgrading) without compromising functional activity [1]. Their design is even more compromising for future remodulation than the building structure itself [1]. Circulation spaces are fundamental for ensuring future building expansion [1]. The general circulation routes not only determine the general layout of the acute-care hospital but also determine the future expansion of the building [1]. Acute-care hospitals are places built and expanded in phases across a wide period of time [22].

2.2.2 Intensive Care Unit

Even though intensive care is no different to medicine itself, the idea to accommodate a specific department within the acute-care hospital for seriously ill patients emerged in the middle of the 20thc. The concept of intensive care was of a nursing unit with concentrated care for seriously ill patients under more intense surveillance and treatment conditions [14]. This concept evolved into specialised intensive-care units for specific disease, trauma, or complications of the chronically ill, in order to save the lives of patients that otherwise would die [14, 32].

Previously to the ICU severely ill patients stayed in their beds in the open bay wards and were taken for specialised treatment and then brought back to the ward. At the end of the 19thc., these kinds of patients (contagious or moribund) were located into smaller rooms next to the ward rooms, separated from the rest of the less ill patients of the ward, mainly for the good of the healthier ones. The shift from the larger Nightingale type ward (see chapter 2.1.4) towards smaller patient bedrooms (with four to eight patients) developed during the beginning of the 20thc., together with the development of surgical procedures, required a higher need of nursing knowledge in special care. As the number of specialised nurses was insufficient, staff started to arrange patients with similar illnesses and care needs into room clusters to be cared for by specially trained nurses [14].

Postoperative recovery care and cardiac care were the medical specialities that promoted the consolidation of the ICU concept [14]. Postoperative or postanaesthetic special-care units emerged between World Wars I and II. This unit became the ICU for surgical patients. The first ICU designed was very similar to the post-anaesthetic care room: large open rooms with bed areas separated by curtains (to promote visual control and patient accessibility in emergency situations). However, patients in the ICU needed longer lengths of stay which increased the risk of cross-infection. Open rooms were inadequate also for providing patient privacy and resulted in the shared usage of equipment between different patients [33]. All these factors contributed to the design conversion into individual rooms. At the end of the 20thc., there was a tendency to separate surgical intensive care from postoperative care. In contrast to post-anaesthetic recovery units where patients were highly sedated and stayed for only a few hours, the patients in the ICU had the longest length of stay in all the acute-care hospital and could be conscious. Staff movement was also impeded by curtains and it favoured cross-infection. Hence, control over environmental factors such as noise, temperature or privacy became more important and could only be achieved by a new design based on individual rooms or boxes [34, 35].

ICU design has been determined by clinical progress, technological development of clinical equipment and the evidence of the effect of environmental factors on patient recovery process [36]. Studies have shown the importance of the relative location of the staff communication base to guarantee the safety and control of patients [37]; the importance of natural light for the patients' circadian rhythm [38]; the location of hand basins to promote hand hygiene [39]; the influence of noise levels on the patients' rest and recovery; the support rooms needed for the relatives' comfort [40]; and the therapeutic gardens to reduce relatives' stress and anxiety levels [41]. The current ICU tendency is to encourage the presence of relatives for psychological and emotional support of the patient, which increases the need of floor area per patient. Moreover, the mortality rate of an ICU is the highest in the whole acute-care hospital and the relative's engagement in palliative care needs to be promoted by the unit design [42].

An ICU in an acute-care hospital is linked to several health-related services (emergency department, operating theatre, diagnostic imaging, functional assessments, pharmacy, laboratory, rehabilitation and standard wards) as well as support services (linen, cleaning, maintenance, kitchen) [33]. According to the patient types and the healthcare services provided by the acute-care hospital, the ICU could be classified as [43]: medical surgical (including coronary); medical surgical (without coronary); medical (general, respiratory, digestive, hepatic or others); surgical (general, cardiac, transplants or others); coronary; neurocritical; traumatology; burns; paediatric; neonatal (see chapter 2.2.6); and others.

The provision of acute medical and surgical beds for the ICU has risen from a conventional 3

to 5% of the total number of acute-care hospital beds [14] to 10% for an acute-care hospital of reference [44]. Even though the optimal percentage needs to be tailored to the acute-care hospital population and healthcare offer, this increasing tendency responds to a higher demand of acute care (due to clinical advances, an ever-elderly population, and the increase in comorbidity patients) [45, 46]. Additionally, particular situations such as Influenzavirus A (in 2009) or the pandemic by COVID-19 (from 2020 and ongoing) produce an urgent need to increase the capacity to attend critically ill patients. These seasonal needs manifest the higher complexity of effective planning and management of one of the most expensive acute-care hospital resources [47]. However complicated, preparedness for emergencies could improve the healthcare response to the increasing outbreaks of infectious diseases [48].

2.2.3 Standard Ward

In-patient accommodation has historically been the core of the hospital [49]. The ward was the place where sick or poor people were put together in a common room for receiving the care of nurses (see chapter 2.1.3). The ward design followed the evolving clinical needs as well as the patients' demands (safety, privacy and comfort). While the initial open room was used for all patients and basic treatments (Fig. 35), there emerged the need for additional support rooms that started to configurate a more complex layout arrangement for locating specific functions in specific rooms of the ward (Fig. 36). This progressive evolution in room specialisation was also linked to the separation of patients by gender, pathology and age. As the ward was the core of the hospital, the number of beds was the variable that determined the size of it.

Fig. 35 View of the open ward. Hôtel-Dieu Paris. Figure by [12].

Fig. 36 In-patient ward at Hôpital Lariboisière Paris by architect Gauthier in 1853. Figure by [51].

However, since the 20thc., ward size in relationship to the whole hospital, and in consequence the number of in-patient beds, has been reduced due to technological advances in treatment and diagnosis, changes in treatment methods, the growth of out-patient treatment, the increase in day-stay surgery, public health measures, changes in nutrition, and preventive medicine [14]. Simultaneously, there has been an increase in the demand for special-care facilities as more and more acutely ill patients can now be treated. This may prolong their lifespan and in turn older patients are increasingly being admitted to acute-care hospitals [50].

Despite the global tendency towards shorter lengths of acute-care hospital-stay and the reduction in the number of beds, in-patient accommodation still accounts for a large amount of the floor area in an acute-care hospital [49]. Due to the shift towards individual in-patient bedrooms and the space requirements for sanitary facilities (to be used independently or with staff assistance) the floor area dedicated per bed has increased [49]. Hence it has been important to research the most cost-effective layouts with efficient circulation patterns (Fig. 37) [52].

The functional relationships of the in-patient ward are key to ensure flexibility and health care process efficiency. The departmental relationship mainly depends on the vertical and horizontal transportation strategy. Ward flexibility relies on its design capacity to cope with the different user demands over time [44]. Several specialities may require adjustments to the standard ward design, such as cardiac (space for telemetry monitoring), neurosurgery, respiratory units (isolation rooms with anterooms), infectious disease, orthopaedic (additional space for bathrooms and storage) or oncology (isolation rooms) [53].

As length of stay will be further reduced, in-patient wards might play a subsidiary role in the acute-care hospital, or even be externalised with the use of patient hotels, and the diagnostic and treatment departments might become the fundamental part of the acute-care hospital.

Fig. 37 Ward layout typology [52].

2.2.4 Obstetric Ward

The inclusion of the labour ward into the hospital (see chapter 2.2.7) resulted in the progressive specialisation of a standard ward (see chapter 2.2.3) for mothers into an obstetric ward.

After the shift of labour from home to the hospitals, the process became more and more medicalised (see chapter 2.2.7). Mothers were unable to freely move during the dilatation phase and had to take a passive and immobile role. This stiffness emphasized the need for pain control and analgesia started to be widely used [54]. However, the analgesic doses were so powerful that when the babies were born, mothers were unable to take care of them. Hence, both mother and baby were supervised by healthcare staff. This fact produced a separation pattern in which mother and babies were treated in separate places (the bedroom for mothers and the nest room for babies). This separation resulted in artificial feeding of babies according to strict schedules.

However, scientific progress has shown the benefits of babies co-sleeping with their mothers in terms of sleep quality for both, breastfeeding rates, and bonding [55]. Thus, nowadays the obstetric ward does not differ much from the standard ward (see chapter 2.2.3) but for some rooms for specific needs of mothers.

In Spain, mothers stay in the labour ward (see chapter 2.2.7) for the immediate recovery just after delivery (about two hours) and then the healthy baby with the mother are moved to the obstetric ward. The standard length of stay in the obstetric ward after a vaginal birth is 48h and 72h after a caesarean section [56].

2.2.5 Paediatric Ward

The paediatric ward is very similar to the standard ward (see chapter 2.2.3) but for several rooms needed for the specific needs of children and their families. Current research focuses on: the impact on social support of the usage of single occupancy rooms rather than multibed accommodation [57]; the symbolic experiences of children in non-medical spaces of the acute-care hospital such as atriums [58]; colour preferences and cultural implications [59]; impact of positive distractions on children's activities in waiting areas [60,61]; barriers in the use of healing gardens [62]; and multisensory stress reduction among others [63].

2.2.6 Neonatal Ward

Through history, the natural environment of a newborn infant had always been the family. Until the 19thc. babies were born at home, thanks to their mothers' effort and the occasional help of a relative. Mothers did not receive any health care while giving birth. Consequently, the maternal and child mortality rates were very high, mainly due to the spread of infection

because of inadequate hygiene conditions. Family members had to accept this fact as a part of the natural selection process.

At the end of the 19thc. the technological advances brought about by the industrial revolution, enabled the invention of the incubator. This equipment consisted of a closed chamber that allowed for personalised control of the neonates' environmental conditions. This invention was first displayed by Martin Couney at the 1896 World Exhibition in Berlin. To demonstrate it, premature babies with little chance of survival were presented in the incubators. The exhibit got exceptional attention and from 1903 to 1940s the "Child Hatchery" was showcased in several exhibitions and freak shows around the world, where humans with disabilities were shown for financial gain (Fig. 38) [64]. Despite this ethically questionable procedure, the invention of the incubator was proven to reduce infant mortality, thus it was extensively used during the 20thc. Before this invention, it was believed that weak children did not deserve additional care and naturally died. The new paradigm of the incubator, where preterm children could be saved with extra equipment and care, raised the need for neonatal spaces in hospitals. The original design of this new hospital area was a literal copy of the perinatal facilities in the exhibition stalls with the incubators located in lines, one next to the other, for the exclusive care of nurses in an open-bay room (Fig. 39).

Fig. 38 Entrance to the "Infant incubators with living infants" stand. Figure by [65].

Fig. 39 Nurses caring for preterm infants during the exhibition. Figure by [65].

In 1961, Dr. Mildred Stahlman successfully tested a miniature of a respirator prototype scaled down for the tiny body of a preterm girl. This combination of the incubator with the ability to monitor vital signs led to the first neonatal intensive care unit (NICU) [66]. As the perinatal medicine speciality evolved, so did the development of sophisticated NICU, offering the maximum medical support to preterm infants. The prevailing thinking of the NICU from the 1960s was that the open-space room allowed for an efficient usage of space, better staff satisfaction while allowing for the isolation of all babies from each other with strict hand-washing measures [67].

The extensive usage of the incubator and technological equipment resulted in the extreme separation of the infant from his or her mother and relatives (Fig. 40). Firstly, while pregnant, the mother was separated from her family members in the hospital and secondly, after giving

birth the baby was taken away from the mother and cared exclusively by staff. The strict measures in hospitals limited family participation and promoted artificial feeding of infants.

Fig. 40 Birth process from home to hospital and newborn infant separation.

Although remaining unquestioned during decades, from the 1970s parental involvement timidly started to become important in the NICU [68]. Even Martin Cooney found that when infants were ready to be discharged from his perinatal facility, parents had lost their parental-infant attachment, and they could not be found [67]. Later studies showed that parental presence and involvement was key to promote the parental-infant attachment and hence the neonatal development [67,69-71]. Parental presence promoted a gradual shift from the open-bay rooms to more separated spaces. From 2000 the Single-Family Room (SFR) has been established as a referent for quality of care [72]. Among the benefits of the SFR, the main ones are: 1) reduction of nosocomial infection [73], 2) control of noise and light levels [74] and 3) major parental involvement.

Several design standards and the European Foundation for the Care of Newborn Infants [75] have included SFR as the optimal design for the units [75-77] and there is a global tendency of NICU from open-bay design to SFR, being the hybrid units an alternative solution to facilitate this transition. The goal of this family-oriented units is to promote a concept shift towards "Neonatal Intensive Parenting Units" [78].

2.2.7 Labour Ward

The labour ward in an acute-care hospital is intimately linked to the obstetric ward (see chapter 2.2.4) and the neonatal ward (see chapter 2.2.6).

Until the 16th c. deliveries were a kind of mystery that belonged to feminine wisdom where women with midwifery skills were often accused of witchcraft [54]. Pregnant women were helped by other women during the delivery process. The empirical knowledge was learnt

by experience and transmitted through generations. It was in the 16thc. when several male doctors started to get interested in obstetrics and the traditional practice was questioned. This transition gradually shifted the domain of female midwives to male doctors. By the 17thc. deliveries were assisted by doctors and from the 18thc. mothers' reproductivity was a matter of the government and their interest in population increase [54].

From 19thc. European hospitals started to include labour wards. However, maternal mortality was very high as doctors attended labouring women just after practising autopsies without adequate hand hygiene [54]. Around the 20thc. hygiene measures improved at hospitals and consequently, maternal mortality rates decreased.

As an example of birth control, particularly in Spain, the Franco regime (1939-1975) had influence on fertility rates [54]. Political, medical and religious institutions promoted natality and banned contraceptive measures. That is why women had an average of 2.77 children in 1975 against the 1.24 in 2019 [79]. Nowadays in Spain, healthcare at birth follows an interventionist institutionalized model, where mothers are attended by medical staff and midwives at acute-care hospitals [56]. Delivery is one of the most frequent causes of admission at Spanish acute-care hospitals [56]. The total number of childbirths in 2018 was 369363 with a 24.64% of caesarean sections [80]. Traditional labour wards in Spain had a sequential model in which the mother was moved during the different stages of the delivery process (dilatation, labour, delivery of the placenta and recovery) [56]. Even though this model was shifted towards a more integrated one with labour-delivery-recovery (LDR) rooms, there are still plenty of labour wards with the outdated configuration. Not surprisingly, the depersonalization of the obstetric care at acute-care hospitals caused an increasing demand for home delivery, which has also led to the spread of alternative birth centres such as out-of-hospital birth centres [14].

As for any mammalian mother, women require a safe, private and secure environment to give birth [81-83]. Design factors of the labour environment might affect the outcomes of giving birth, which will be remembered by women throughout their lives and condition the women's birth decisions for future pregnancies [81,84,85]. A supportive environment where women feel relaxed and empowered impacts positively on the birth process [81, 86]. On the contrary, an unsettling atmosphere might inhibit oxytocin release and interrupt the natural labour process [81]. This might result in an increase in medical intervention, higher rates of synthetic oxytocin usage for augmentation of labour, and elevated percentages of caesarean sections [81-83,86,87]. Nowadays, there is a global concern about the increase in intrapartum intervention rates [88]. Apart from the economic effects of medical intervention during the birth process [89], they have an impact on the health of mother and child both in the short and long term [88]. This increase in interventions should be considered as a multifactorial factor, the built environment being one of them [88].

2.3 Post-Occupancy Evaluation

The constant evolution of the acute-care hospital units just analysed (chapter 2.2) and hence of the whole building (chapter 2.1) due to the changes in the healthcare field highlight the need of a dynamic design process for a building that will never be finished [90]. The creation process of an acute-care hospital is highly complex and consumes large amounts of different resources such as workload, time and budget. In order to improve the final building, evaluation mechanisms are being put in place as the last stage of the process (Fig. 41).

Post-occupancy evaluation (POE) is “a process of systematically evaluating the performance of buildings after they have been built and occupied for some time” [91]. It blossomed in the UK in the late 1960s and in the USA in the 1970s [92] and its theoretical fathers were mainly Wolfgang Preiser and Craig Zimring [93]. Environmental assessments are based on the impressions of a place or building of several observers who can be user groups, experts or special groups and it consists of the record of information through walking tours, photos, videos, models, sketches or audios in order to produce an appraisal [94].

Fig. 41 A circular production process for acute-care hospitals.

POE might focus on different domains such as safety, aesthetic quality, satisfaction, health, psychological comfort or efficiency [91]. But it can also be focused on other terms like: technical building performance, function/usability or form/beauty [95]. POE can be arranged as three perspectives of building evaluation: 1) occupants (demands and needs), 2) environmental performance (energy and water efficiency) and 3) economic performance (value and return on investment) [96]. POE has many benefits, among which are considering buildings as laboratories [97] and using them as tools for the learning process of architects, a link between professional practice and architectural research [98]. It also provides a structure or framework for collecting data, tests current guidelines and provides feedback for current and future review processes [93]. Some other benefits but also barriers that hinder POE development are summarised in Tab. 8.

Positive [99, 100]	Negative [95, 96, 100,101]:
+ Provision of feedback to design teams, feedback loop to enhance continuous improvement.	- Long and expensive process excluded from professional curricula and delivery expectations.
+ Provision of information to support future designs, validation of real needs.	- Fragmented incentives within the procurement and operation processes.
+ Generation of new knowledge.	- Multidisciplinary, it spans professions.
+ Clarification of programming issues.	- Potential liability for owners.
+ Enhancement of practitioner credibility, improved competitive advantage in the marketplace.	- Expensive process.
+ Enhancement of designer-client relationships.	- Lack of standardisation, lack of agreed and reliable indicators.
+ Corroboration of the effectiveness of prototypes and innovations, reduce expenses.	- Inconsistencies in data collection and/or data analysis.
+ Justification of design decisions that helps the selection of alternatives at the design stage.	- Reporting of conclusions in a useful format.

Tab. 8 Positive aspects and negative barriers of POE.

Because of the consolidation of governments as major clients of the healthcare systems, several countries like Norway [102], United Kingdom [103-107], Australia [101] or Canada [108] have included building evaluation into their accountability requirements. Spain has yet to include building evaluation procedures for the healthcare sector, which only timidly appear in a Catalan initiative [109].

In order to assist in the evaluation process, there is a need for usable and valid tools that evaluate the healthcare environment to help designers and users when thinking about building quality [103, 110, 111]. Tools are also needed for managing and combining the knowledge generated by isolated studies in a holistic way [112]. A review on evaluation tools carried out in academic literature in English from 1990 to 2016 found 23 tools [111]. A follow-up study carried out between 2010-2013 found 13 assessment tools [113]. There are several certification tools [114, 115] and also tools to evaluate healthcare environments [116-121] as well as residential or long-term care facilities for older people [122-126]. However, in many cases these tools are not used by actors other than the developers [111]. Another handicap is that they lack the rigour needed to make them scientifically consistent in terms of reliability (inter-rater or interobserver reliability, test-retest reliability, parallel-forms reliability and internal consistency reliability) as well as validity (internal validity, external validity, construct validity and conclusion validity) [111, 127]. These barriers mean that most evaluations focus on measurable quantitative criteria (temperature, energy, air quality), which are useful for scientific research but fail to grasp the intangible aspects of quality [128]. Building evaluation can be manageable if it focuses on a few factors of a big number of buildings. Despite

being of less interest for academic research, building evaluation as an empirical field is very useful for gathering lessons learnt, providing useful feedback to some case studies with a deep understanding rather than statistical data with generalizable outcomes [96]. Following are described several evaluation tools and in chapter 4.1 there is the description of the tool CURARQ, created as a result of this thesis.

2.3.1 Existing POE Tools

BUDSET: Birth Unit Design Spatial Evaluation Tool [129, 130]

- Why?
To assess and design better birth units that provide optimal childbirth.
- How?
 1. Literature reviews, government documents and reports: "What are the ideal design elements to support optimal childbirth?"
 2. Group and individual interviews: midwives, clinicians, researchers and architects (13 in total).
 3. Expert panel: the research team during a 2-year period.
- What?
The result was a set of domains and characteristics (design principles) with a list of requirements (Tab.9). The checklist provides a whole score for the birth unit and an average for any domain.
- When?
For both existing and new units.
- Who?
The evaluation process consists of a one-hour visit of researchers to collect the data, with informal conversations with staff and field notes.

Domain	Characteristic	Item
Fear	• Space—Arrival	"A small table and chairs placed near
Cascade	• Space—Reception	the window in the birth room provide
	• Sense of domesticity	both utility and a domestic feel."
	• (...)	
Facility	• Birth bath	"Two-sided access to the bath."
	• En suite bathroom facilities	
Aesthetics	• Colour	"Use of wood or wood like materials in
	• Texture	the rooms".
	• (...)	
Support	• Food and drink for woman	"Presence of playroom and/or
	• Accommodation for companions and birth attendants	provisions for the entertainment of additional children."

Tab. 9 Organisation of items at BUDSET tool [129].

EVOLVE [131]

- Why?
To evaluate older people's housing.
- How?
 1. Literature review: academic, standards, guides.
 2. Field trips: recent projects.
 3. Focus groups: people living in housing for elderly and their relatives.
 4. Interviews: architects, housing providers, care scheme managers, staff and commissioners.
- What?
About 500 items for a single dwelling and 2000 for a housing scheme. Each item scores 1 point (possible answers are yes, no, not in use or not applicable).
- When?
Both for the design of new schemes (an aid for commissioners, providers and architects) and the evaluation of existing ones (an aid for housing managers, housing providers and academic research).
- Who?
By architects, commissioners, researchers, housing providers or house buyers.

File	Characteristic	Place	Domain	Item
• Living unit	• Generic	• Layout	• Personal re-	<i>"The bathroom</i>
• Communal facilities	• Entrance	• Building element	alisation and	<i>is separate from</i>
• Circulation spaces	• Hall	• Environmental design	choice	<i>other rooms"</i>
• Staff facilities	• Lounge	• Services and sys-	• Dignity and	
• Scheme site & location	• Kitchen	tems	privacy	
	• Double-bed-room	• Finishes	• Social support	
	• (...)		inside building	
			• (...)	

Tab. 10 Organisation of items at EVOLVE tool [131].

Patient Room Design Evaluation Tool [132]

• Why?

To evaluate how well an acute-care hospital patient room (adult medical-surgical, adult intensive care or maternity care) performs against key evidence-based design elements and healthcare goals.

• How?

Review of research, site tests, surveys, validation and review by expert advisory council members.

• What?

Items organized around 23 evidence-based design goals or healthcare outcomes impacted by building design.

• When?

After construction and occupancy.

• Who?

By interior designers or an interdisciplinary team.

Room	Category	EBD Goals	Assessment item	Assessment aid
Adult medical-surgical	• Patient safety	• Provide efficient	<i>"There is</i>	Lighting to
	• Worker Safety & effectiveness	delivery of care	<i>sufficient</i>	support patient
	• Quality of care & patient experience	• Improve communication	<i>illumination for caregivers</i>	care activities in the room without
	• Organizational performance	• Improve staff health	<i>to provide care around the patient bed."</i>	disturbing the patient at any time of the day/night.

Tab. 11 Organisation of items at Patient Room Design Evaluation tool [133].

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2.4.3 Glossary

- Anaesthesia: the use of anaesthetics in medicine (Longman Dictionary of Contemporary English Online).
Anaesthetics: a drug that stops you feeling pain (Longman Dictionary of Contemporary English Online).
- Antisepsis: the destruction of germs causing disease (Online Medical Dictionary).
- Asepsis: the prevention of access by infecting organisms to the locus of potential infection (Online Medical Dictionary).
- Augmentation of labour: induced labour: Artificially induced uterine contraction. (Medical Dictionary Online).
- Autopsies: postmortem examination of the body. (Medical Dictionary Online).
- Blood transfusions: the introduction of whole blood or blood component directly into the blood stream (Online Medical Dictionary).
- Caesarean section: extraction of the foetus by means of abdominal hysterotomy. Hysterotomy: an incision in the uterus, performed through either the abdomen or the vagina. (Medical Dictionary Online).
- Cardiac care: a specialty concerned with the nursing care of patients suffering from disorders of the cardiovascular system as well as those identified as at risk for adverse cardiac or vascular events (Online Medical Dictionary).
- Comorbidity: the presence of co-existing or additional diseases with reference to an initial diagnosis or with reference to the index condition that is the subject of study (Online Medical Dictionary).
- Clinical trials: a work that reports on the results of a clinical study in which participants are assigned to receive one or more interventions so that researchers can evaluate the interventions on biomedical or health-related outcomes (Online Medical Dictionary).
- Contraceptive: chemical substances that prevent or reduce the probability of conception. (Medical Dictionary Online).
- Cross-infection: nosocomial infection: any infection which a patient contracts in a health-care institution (Online Medical Dictionary).
- Haemostasis: the process which spontaneously arrests the flow of blood from vessels carrying blood under pressure. It is accomplished by contraction of the vessels, adhesion and aggregation of formed blood elements (Online Medical Dictionary).
- Hatchery: a place for hatching large numbers of eggs, especially fish or chicken eggs. Hatching: to come out of an egg (Cambridge Dictionary Online).
- Heliotherapy: the treatment of disease by exposing the body to sunlight, a therapeutic use of sunbathing (Online Medical Dictionary).
- Intrapartum intervention: all interventions occurring from the onset of labour up to and including the expulsion of the placenta and membranes. Intrapartum interventions include, but are not limited to, the induction of labour, the use of intravenous oxytocin, artificial rupture of the amniotic membranes, epidural anaesthesia, electronic foetal health rate monitoring, episiotomy, caesarean section. [47]
- Leech: a small soft creature that fixes itself to the skin of animals in order to drink their blood (Longman Dictionary of Contemporary English Online).
- Length of stay: the period of confinement of a patient to a hospital or other health facility (Online Medical Dictionary).
- Midwifery: the practice of assisting women in childbirth. (Medical Dictionary Online).
- Midwives: the practice of assisting women in childbirth. (Medical Dictionary Online).
- Mortality rates: all deaths reported in a given population (Online Medical Dictionary).
- Necropsy: the examination of a body after death; autopsy (Dictionary.com).
- Nosocomial: Any infection which a patient contracts in a health-care institution. (Online Medical Dictionary).
- Obstetrics: a medical-surgical specialty concerned with management and care of women during pregnancy, parturition, and the puerperium. (Medical Dictionary Online).

- Occlusive: occluding or tending to occlude. Occlude: to close, shut, or stop up (Dictionary.com).
- Oxytocin: a hormone made in the brain that plays a role in childbirth and lactation by causing muscles to contract in the uterus (womb) and the mammary glands in the breast. (MedicineNet).
- Palliative care: care alleviating symptoms without curing the underlying disease (Online Medical Dictionary).
- Penicillin: a group of antibiotics that contain 6-aminopenicillanic acid with a side chain attached to the 6-amino group (Online Medical Dictionary).
- Perinatal care: the care of women and a foetus or newborn given before, during, and after delivery from the 28th week of gestation through the 7th day after delivery (Online Medical Dictionary).
- Postanaesthetic care: the specialty or practice of nursing in the care of patients in the recovery room following surgery and/or anaesthesia (Online Medical Dictionary).
- Postoperative care: the period of care beginning when the patient is removed from surgery and aimed at meeting the patient's psychological and physical needs directly after surgery (Online Medical Dictionary).
- Preterm: a human infant born before 37 weeks of gestation (Online Medical Dictionary).
- Psychological: related to psychology. Psychology: the science dealing with the study of mental processes and behaviour in man and animals (Online Medical Dictionary).
- Physiological: the functions and properties of living organisms, including both the physical and chemical factors and processes, supporting life in single- or multi-cell organisms from their origin through the progression of life (Online Medical Dictionary).
- Purge: to take a substance that makes your bowels empty (Longman Dictionary of Contemporary English Online).

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3. Method

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3.1 Methodology

The research methodology used is a mixed method (or multi-method) approach with an emphasis on qualitative methods inspired by different references [1-5]. While the goal of qualitative approach is to understand complex topics from personal interactions, perspectives and experiences [6, 7], the quantitative methods allowed me to measure some variables and draw conclusions [8]. In order to fulfil the aim of the study, a four-stage-strategy was designed as indicated in Tab. 1.

	Acute-care hospital placement	Literature analysis	Acute-care hospital visits	Acute-care hospital cases
Approach	Field.	Theory.	Future.	Present.
Aim	To explore the evaluation of functional & environmental factors from the user's perspective.	To explore the evaluation of functional & environmental factors from the literature perspective.	To explore the evaluation of functional & environmental factors from the analysis and documentation of best practice designs.	To explore the evaluation of functional & environmental in current acute-care hospitals in Spain.
Research design	Ethnographic study.	Literature analysis.	Ethnographic study.	Case study.
Measurement tools	Observation & interviews.	Existing data (content analysis of national standards, design guidelines and papers).	Existing data (architectural layouts) and observation (site visits and photographs).	CURARQ tool, existing data (annual memoranda and architectural layouts), and observation (photographs).
Results	Acute-care hospital design feedback. Users' scripts. Users' concerns on functional and environmental factors. Content for CURARQ tool.	Framework and content for CURARQ tool.	Analysis of architectural layouts. Commented photographs. Content for CURARQ tool.	Percentages of achievement with CURARQ tool. Online feedback on improvement measures.

Tab. 1 Overview of the four stages of the study.

The research design, which consists of the framework of the research study that organises various components together [9], has consisted in the ethnographic study, the literature analysis, and the case study. The literature analysis allowed for identifying the functional and environmental factors from the academic and institutional field. However, the ethnographic study was appropriate for learning about current working conditions and usage of actual facilities. It was convenient to get an in-depth understanding of the context by focusing on a specific setting and a group of people [10]. Finally, the case study was useful for a deep investigation of several cases using different methods such as, observation, interviews or drawings. Different research measurement tools have been used for data collection at each stage of the work, which are:

- Observation: for the understanding of how people interact with the physical environment [5]. Of the three possible types of observation (causal, systematic, and participant observation [11]), only casual observation was used. This kind of observation is usually useful at the beginning of the study to familiarize the researcher with the setting and to develop the structure and instruments for other techniques (such as interviews or systematic observation). Observation was widely used during the acute-care hospital placement and it was also appropriate during the acute-care hospital visits and the acute-care hospital cases.
- Interview: to examine people's opinions and feelings about complex topics. Allows for a higher rate of participation, more detailed answers and analysis of non-verbal behaviour. Two unstructured interviews were used at the beginning of the study for the development of the final semi-structured interviews. This tool was used exclusively during the acute-care hospital placement to get users perspective.
- Existing data: information from institutional reports, design guidelines, scientific papers, communications, annual memoranda of the acute-care hospital and architectural layouts. Mostly used during the literature stage (written material) but also at the acute-care hospital visits and acute-care hospital cases (graphical material).
- CURARQ tool (see chapter 4.1): developed mainly from the literature analysis for the Spanish context (see chapter 3.3), and also from the acute-care hospital placement (see chapter 3.2) and acute-care hospital visits (see chapter 3.4). It permitted quantitative variables to be added to the qualitative analysis of the acute-care hospital cases. The purpose of this tool is to evaluate existing acute-care hospitals in order to point out improvement measures (Fig. 1).

Next, there is the description of each of the four stages followed.

Fig. 1 Research design overview for each approach.

3.2 Acute-care Hospital Placement

According to architect Steen Eiler Rasmussen, architecture is not only an aggregation of plans, sections, and elevations [12]. The author argues that it is through a multisensorial experience that architecture should be analysed and not only by sight. Hence, the best text to learn architecture, is the architecture itself and the multisensorial experience can only be achieved by living in the spaces. This is the reason why a hospital

Fig. 2 Bedroom and office at "Hospital de Dénia".

placement was arranged for three months (April-June 2016). Thus, it was possible to live and work in and from the acute-care "Hospital de Dénia" (Fig. 2) (see chapter 3.5.1) thanks to the scholarship "Beca DKV Arte y Salud". The aim of this experience was to explore the functional & environmental factors from the user's perspective. The placement was structured in several phases previously published [13] to optimise the immersive experience.

3.2.1 Part 1 preparation (January-March 2016)

"Hospital de Dénia" had an art commission responsible for the promotion of artists' residences and the focus on the links between health and art. Prior to the placement came the analysis and study of graphical material (such as layouts, sections or elevations). Several coordination meetings were held online with the hospital art commissioners and in person with the head of the quality department and the head nurses.

3.2.2 Part 2 learning by drawing (April-May 2016)

This part was developed in the hospital (during weekdays). The first tasks included those that involved the least interaction with occupants, i.e., studying the building as a physical object: in-situ observation of the areas to study, analysis of the hospital by preparing graphical material such as functional diagrams, unit diagrams, sketches and pictures.

3.2.3 Part 3 learning by talking (May-June 2016)

The final part was also done in the hospital, this time in collaboration with the Hospital Quality Department in order to understand how quality was defined and measured in the hospital and also to agree on interview procedures.

For the interviews, the nodes of interaction between the occupants and the building (such as arriving, entering, storing personal belongings, working, visiting, resting, eating or sleeping) were identified and users were asked to rate their experience on these key points. In total,

28 members of staff and 12 patients or caregivers were interviewed. The interview results were used to describe user daily routines in each unit, user concerns on functional and environmental factors, and for providing specific feedback of the design of "Hospital de Dénia" (see sample in chapter [A.4](#)).

- Staff interview:
 - Participants: 28 persons, made up of nurses (n=10), midwives (n=3), assistant nurse (n=1), doctors (n=4), teacher (n=1), and general services specialists (n=9).
 - Eligibility criteria: the nursing supervisor named the most suitable staff for the study according to their interest or availability on the day.
 - Interview type: walking interviews, on the go talks and informal conversations.
 - Interview structure: To ask about their daily routine and the rooms where it takes place. To write and take notes about their experiences with the architectural design.
- Room interview:
 - Participants: 12 interviews with patients (n=5) and caregivers (n=7).
 - Eligibility criteria: patients or caregivers selected by the nursing team who were in a non-critical condition and had been at the acute-care hospital for a long period of time.
 - Interview type: semi-structured interviews arranged by a nurse in the patient's room.
 - Interview structure. Beginning: To knock on the door, to ask for permission to enter. To introduce myself, the project and the goal of the interview. To wash my hands. Development: To ask about the daily routine and the rooms where it takes place. To write about the activities, experiences and expectations of the architectural design at every key point of interference. End: To ask for additional comments or any further information. To sign photograph consent. To take a photograph. To express appreciation. To wash my hands and leave.

3.3 Literature Analysis

The literature analysed has been studied both for the historical research (see chapter 2.1 and chapter 2.2) as well as for the content and framework of the tool CURARQ (see chapter 4.1). The main way to proceed for generating CURARQ tool content (see chapter 4.1) was to elaborate a checklist from the Spanish design standards (available for most of the units studied and written by the Ministry of Health) [14] and to incorporate small additions from other sources found online and from the acute-care hospital placement and acute-care hospital visits. When the Spanish guidelines were available, a snowballing approach was used to follow the cited references in the guidelines. When the national guidelines did not exist, as was the case for the circulation spaces for example, I used Scopus database with the following keywords in the title/abstract/keywords: (“environmental factor” OR “environmental element”) AND (“circulation” W/16 “hospital”); (“evidence based design”) AND (“corridor” W/16 “hospital”); (“evidence based design”) AND (“corridor” W/16 “hospital”). Tab. 2 shows the variety of sources and several samples.

Source type	Sample
Technical reports, regulations and guidelines	• Spanish “Standards and Recommendation for Hospital Units” documents written by the “Ministerio de Sanidad, Política Social e Igualdad”, in collaboration with “Agencia de Calidad del Sistema Nacional de Salud” and expert groups.
	• Health Building Notes, Department of Health. United Kingdom.
	• Australasian Health Facility Guidelines.
Existing tools (see chapter 2.3.1)	• BUDSET: Birth Unit Design Spatial Evaluation Tool.
	• EVOLVE: A tool for evaluating the design of older people’s housing.
	• Patient Room Design Checklist and Evaluation Tool.
	• PLACE: Patient-Led Assessments of the Care Environment.
	• PHEQIs: Perceived Hospital Environment Quality Indicators.
	• ASPECT: A Staff and Patient Environment Calibration Toolkit.
	• The Environmental Audit Tool.
Websites	• The Center for Health Design.
	• AIA Academy of Architecture for Health.
	• Hospitecnia.

Tab. 2 Source types and samples.

3.4 Acute-care Hospital Visits

Tab. 3 shows a summary of the key information of all the acute-care hospital visited. The selection criteria for these visits were based on expert opinion (according to one of my supervisors for the Spanish hospitals and my Swedish tutor, during my international placement in Gothenburg, for the Swedish hospitals) and in convenience sampling for the Norwegian visit.

City	Hospital	Area of interest
Barcelona	"Hospital de la Santa Creu i Sant Pau"	Circulation spaces, out-patient and in-patient areas.
	"Hospital Sant Joan de Déu"	Paediatric in-patient wards, labour ward, emergency unit and circulation areas.
	"Hospital del Mar"	Circulation spaces, in-patient wards, intensive care units, research building ("Parc de la Recerca").
	"Hospital Sant Joan Despí Moisès Broggi"	Circulation spaces, out-patient department and in-patient wards.
Madrid	"Hospital Materno-Infantil 12 de Octubre"	Neonatal Intensive Care Unit.
	"Maternidad Gregorio Marañón"	Circulation spaces, paediatric and obstetric in-patient wards, labour ward, neonatal and paediatric intensive care units.
	"Hospital Madrid Nuevo Belén"	Labour ward.
Oviedo	"Hospital Universitario Central de Asturias"	Circulation spaces, out-patient and in-patient areas, labour ward and intensive care units.
Ciudad Real	"Hospital General Universitario de Ciudad Real"	Circulation spaces, out-patient and in-patient areas, labour ward and intensive care units.
Göteborg	"Sahlgrenska Universitetssjukhuset"	Bild och interventionscentrum (BOiC), Thorax Intensive Care, Post Operation, In-patient Wards, Cancer Centre Klinik.
	"Östra Hospital"	Acute Psychiatry Ward, Intensive Care, Queen Silvia Children's Hospital.
	"Angereds Närsjukhus"	Whole building.
Malmö	"Skånes Universitetssjukhus"	Intensive Care Unit, Emergency Department, Department of Internal Medicine, Department of Infectious Disease.
Linköping	"Universitetssjukhuset i Linköping"	Översikt förlossningen, Neonatal Intensive Care, Ortopeden Ward.
Stockholm	"Nya Karolinska Solna"	Circulation spaces and public areas.
Trondheim	St. Olav's Hospital	Mother and Child hospital

Tab. 3 Areas of interest in the acute-care hospital visited.

Next, the basic information of each building is provided. For further information on their healthcare services there are the links to the hospital websites.

3.4.1 “Hospital de la Santa Creu i Sant Pau” (HSCSP)

The “Hospital de la Santa Creu i Sant Pau” is located in Barcelona (Spain) and was visited on 09/10/2017 (Fig. 3-Fig. 4). The origins of the hospital date back to 1401 after the unification of six hospitals in Barcelona. Due to growth demands, a new building designed by Lluís Domènech i Montaner was inaugurated in 1930. This building became a referent of the Catalan Art Nouveau movement and was declared a World Heritage site by UNESCO in 1997. Later, the acute-care hospital activity was relocated to a new building designed by “Bonell i Gil Arquitectes” and inaugurated in 2009. This acute-care hospital is analysed in chapters 4.2.3, 4.4.3 and 4.6.3.

Fig. 3 General view HSCSP.

Fig. 4 Site plan HSCSP.

3.4.2 “Hospital Sant Joan de Déu” (HSJD)

The “Hospital Sant Joan de Déu” is a maternity and children’s acute-care hospital located in Barcelona (Spain) and was visited on 10/10/2017 (Fig. 5-Fig. 6). This acute-care hospital is analysed in chapters 4.5.3, 4.6.3, 4.7.3 and 4.8.3.

Fig. 5 General view HSJD.

Fig. 6 Site plan HSJD.

3.4.3 “Hospital del Mar” (HdM)

The “Hospital del Mar” is located on the Barcelona coast (Spain) and was visited on 11/10/2017 (Fig. 7-Fig. 8). The origins of this hospital date back to 1914 when it was created as an infectious disease hospital. In 1929, because of the Universal Exhibition, it was moved to a new pavilion hospital. This building had renovation works carried out during the 60s and main building and urban remodelations for the 1992 Olympic Games with a new out-patient building on the sea front with commercial areas, a new support and technical building, and a new public square for transit from the sea to the acute-care hospital. In 2006 the research institute was created, and the teaching facilities were enlarged. There was an expansion and remodeling project under way to increase its capacity. The design work since the 90s has been carried out by Pínearq. This acute-care hospital is analysed in chapters 4.2.3 and 4.3.3.

Fig. 7 General view HdM.

Fig. 8 Site plan HdM.

3.4.4 “Hospital Sant Joan Despí Moisès Broggi” (HSJDMB)

The “Hospital de Sant Joan Despí Moisès Broggi” is located in Sant Joan Despí, a city 15 km away from Barcelona (Spain) and was visited on 11/10/2017 (Fig. 9-Fig. 10). This new built acute-care hospital was designed by Pínearq with Manuel Brullet and inaugurated in 2010. This acute-care hospital is analysed in chapters 4.2.3 and 4.4.3.

Fig. 9 General view HSJDMB.

Fig. 10 Site plan HSJDMB.

3.4.5 “Hospital Materno-Infantil 12 de Octubre” (H12O)

The neonatal unit in the “[Hospital Materno-Infantil 12 de Octubre](#)” is located in Madrid and was visited on 30/11/2017 (Fig. 11-Fig. 12). This maternity and child’s acute-care hospital belongs to “[Hospital Universitario 12 de Octubre](#)” and even though the original hospital dates from 1973 (with its previous name as “Ciudad Sanitaria 1º de Octubre”) the building for the maternity acute-care hospital and its neonatal unit were inaugurated in 1980. The unit had renovation works carried out during 2019-20 by EACSN Estudio de Arquitectura. This acute-care hospital is analysed in chapter 4.7.3.

Fig. 11 Entrance to family rooms in H12O. Figure by [16].

Fig. 12 Site plan H12O.

3.4.6 “Maternidad Gregorio Marañón” (MGM)

The “[Maternidad Gregorio Marañón](#)” is a maternity and children’s acute-care hospital located in Madrid (Spain) and was visited on 02/11/2017 (Fig. 13-Fig. 14). This acute-care hospital belongs to “[Hospital General Universitario Gregorio Marañón](#)” located in the adjoining plot, with more than 400 years of history. The MGM originated from the merge of a paediatric acute-care hospital and a maternity acute-care hospital all in one building. This new building was designed by José Rafael Moneo Vallés with José María de la Mata Gorostizaga and was inaugurated in 2003. This acute-care hospital is analysed in chapters 4.2.3, 4.5.3, 4.6.3 and 4.8.3.

Fig. 13 Access view MGM.

Fig. 14 Site plan MGM.

3.4.7 “Hospital Madrid Nuevo Belén” (HMNB)

The “[Hospital Universitario HM Nuevo Belén](#)” is a private maternity and child acute-care hospital located in Madrid and inaugurated in 2011 (Fig. 15-Fig. 16). The building was visited on 01/07/2019. In 2013 and 2014 some renovation works were carried out in the in-patient ward for its conversion into four labour-delivery-recovery (LDR) rooms to facilitate natural birth. The design was done by Parra - Müller Arquitectura de maternidades. This acute-care hospital is analysed in chapter [4.8.3](#).

Fig. 15 View of LDR room by David Frutos. HMNB.

Fig. 16 Site plan HMNB.

3.4.8 “Hospital Universitario Central de Asturias” (HUCA)

The “[Hospital Universitario Central de Asturias](#)” is located in Oviedo (Spain) and was visited on 23/11/2017 (Fig. 17-Fig. 18). This building has its origins in the unification of three pre-existing healthcare facilities: “Hospital Nuestra Señora de Covadonga”, the “Instituto Nacional de Silicosis” and, the “Hospital General de Asturias”. The new acute-care hospital was inaugurated in 2014 and designed by Juan Navarro Baldeweg with Ángel Fernández Alba. This acute-care hospital is analysed in chapters [4.2.3](#), [4.4.3](#), [4.7.3](#) and [4.8.3](#).

Fig. 17 General view HUCA.

Fig. 18 Site plan HUCA.

3.4.9 “Hospital General Universitario de Ciudad Real” (HGUCR)

The “[Hospital General Universitario de Ciudad Real](#)” is located in Ciudad Real, 200 km away from Madrid (Spain) and was visited on 20/02/2018 (Fig. 19-Fig. 20). This newly built acute-care hospital was inaugurated in 2005 and designed by Ángel Fernández Alba with Soledad del Pino Iglesias. This acute-care hospital is analysed in chapters [4.2.3](#), [4.3.3](#), and [4.7.3](#).

Fig. 19 General view HGUCR.

Fig. 20 Site plan HGUCR.

3.4.10 “Sahlgrenska Universitetssjukhuset” (SAHLH)

Sahlgrenska Hospital is located in Gothenburg (Sweden) and was visited several times in April and May 2018 (Fig. 21-Fig. 22). This acute-care hospital belongs to “Sahlgrenska Universitetssjukhuset” or [Sahlgrenska University Hospital](#) together with several acute-care hospitals located in the Gothenburg region: Östra Hospital, Mölndal Hospital and Högsbo Hospital. The foundation of Sahlgrenska Hospital dates from the end of 1700 but its relocation to the current site was done in 1900. Since then, there has been considerable renovation work. The buildings considered in this thesis were designed by Pyramiden Arkitekter (“Bild och interventionscentrum” BOiC and “Intensivvard”) and FO Arkitektkontor (Cancer Centre Klinik and in-patient ward). This acute-care hospital is analysed in chapters [4.2.3](#), [4.3.3](#), and [4.4.3](#).

Fig. 21 Terrace for patients at the cancer clinic. SAHLH.

Fig. 22 Site plan SAHLH.

3.4.11 Östra Hospital (ÖH)

Östra Hospital is located in Gothenburg (Sweden) and was visited several times in May 2018 (Fig. 23-Fig. 24). This acute-care hospital belongs to “Sahlgrenska Universitetssjukhuset” or [Sahlgrenska University Hospital](#) together with several other hospitals located in the Gothenburg region: Sahlgrenska Hospital, Mölndal Hospital and Högsbo Hospital. The origin of this multiblock hospital dates back to 1965. Since then, several buildings have been built, upgraded or adapted to cope with healthcare needs. The departmental buildings visited were Psychiatric Ward (inaugurated in 2009 by White Arkitekter) and Queen Silvia’s Hospital for Children and Young People (under construction during the visit and designed by White Arkitekter). This acute-care hospital is analysed in chapters [4.2.3](#), [4.3.3](#), and [4.6.3](#).

Fig. 23 Psychiatric ward external view ÖH.

Fig. 24 Site plan ÖH.

3.4.12 “Angereds Närsjukhus” (AN)

“Angereds Närsjukhus” is located in Gothenburg (Sweden) and was visited on 24/05/2018 (Fig. 25-Fig. 26). The term “Närsjukhus” stands for a healthcare typology that addresses local healthcare needs with a focus on diseases caused by life-style factors. This building provides out-patient services that combine primary and specialist care. The design process considered the participation of key stakeholders with great emphasis on health promotion. The project was developed by SWECO and the building opened in 2015. This acute-care hospital is analysed in chapter [4.2.3](#).

Fig. 25 General view AN.

Fig. 26 Site plan AN.

3.4.13 “Skånes Universitetssjukhus” (SKU)

“Skånes Universitetssjukhus” is located in “Malmö” (Sweden) and was visited on 08/05/2018 (Fig. 27-Fig. 28). This acute-care hospital belongs to [Skåne University Hospital](#) together with other acute-care hospitals in “Trelleborg”, “Ystad” and “Landskrona”. The buildings visited for the object of this thesis were the Intensive Care Unit, Emergency Department, Department of Internal Medicine and the Department of Infectious Disease (inaugurated in 2016 and designed by Tage Møller Arkitektbyrå). This acute-care hospital is analysed in chapters [4.2.3](#), [4.3.3](#), and [4.4.3](#).

Fig. 27 General view SKU.

Fig. 28 Site plan SKU.

3.4.14 “Universitetssjukhuset i Linköping” (ULKÖ)

[Linköping University Hospital](#) is located in “Linköping” (Sweden) and was visited on 17/04/2018 (Fig. 29-Fig. 30). The whole acute-care hospital is undergoing major rebuilding and new construction work that includes the demolition of obsolete buildings, the renovation of several existing facilities and the construction of new buildings. These works started in 2011 and are planned to be finished in 2024. The building visited was designed by White Arkitekter and inaugurated in 2016. This acute-care hospital is analysed in chapters [4.4.3](#), [4.7.3](#), and [4.8.3](#).

Fig. 29 General View ULKÖ.

Fig. 30 Site plan ULKÖ.

3.4.15 “Nya Karolinska Solna” (NKS)

New Karolinska Solna is located in Stockholm (Sweden) and was visited on 16/05/2018 (Fig. 31-Fig. 32). This acute-care hospital is one of the largest acute-care university hospitals in Europe. Its location next to the “Karolinska Institutet” and other new research building centres and educational facilities constitute a world leading cluster in life sciences. The project for the NKS was developed by White Arkitekter with Tengbom arkitektkontor, and the building opened in 2018. This acute-care hospital is analysed in chapters 4.2.3 and 4.4.3.

Fig. 31 General view NKS.

Fig. 32 Site plan NKS.

3.4.16 St. Olav's Hospital (OLAV)

The Women and Children Center at the University Hospital of St. Olav's is located in Trondheim (Norway) and was visited on 13/06/2019 during the “ARCH19: 4th Conference on Architecture Research Care & Health” (Fig. 33-Fig. 34). The building belongs to a masterplan development of healthcare facilities (Neuro Centre, Gastro Centre, Mobility Centre, Knowledge Centre and the Centre for Pulmonary and Cardiovascular Disease) integrated into the existing urban framework. The aim of the whole acute-care hospital was to transform them from megastructures to friendly villages. The design of this new acute-care hospital was developed by the Nordic Office of Architecture and inaugurated in 2005. This acute-care hospital is analysed in chapter 4.6.3.

Fig. 33 General view OLAV.

Fig. 34 Site plan OLAV.

3.5 Acute-care Hospital Cases

The four study cases of this thesis, chosen by convenience sampling, are located in the “Comunitat Valenciana” region. The next table (Tab. 4) shows information related to the healthcare activity of each acute-care hospital.

	“Hospital de Dénia”	“Hospital Universitario del Vinalopó”	“Hospital Clínico Universitario de Valencia”	“Hospital Universitari i Politècnic La Fe”
Abbreviation	HD	HUV	HCUV	HUPF
Year of inauguration	2009	2010	1960	2010
Healthcare Department	“Dénia”	“Elche-Crevillent”	“Valencia-Clínico-Malvarrosa”	“Valencia-La Fe”
Population assigned to the department	166 108	154 017	341 972	281 720
Nº beds	262	230	582	1 050
Built area (m ²)	±55 000	±45 000	±80 000	±250 000
Bed/m ² ratio	210	196	137	238
Nº of emergencies	58 544	89 467	161 488	237 328
Total admissions (both emergency and planned)	11 908	12 846	24 105	45 109
Average length of stay (days)	5.54	5.09	6.39	6.48
Total nº of external consultations (first and successive)	207 668	240 761	574 215	618 050
Successive/first ratio	1.66	2.13	2.17	2.24

Tab. 4 Healthcare system information for each acute-care hospital.

In the following pages there is a general description of the case studies both literary and graphically.

3.5.1 “Hospital de Dénia” (HD)

Designed by architects Albert de Pineda (Pinearq) and José León Paniagua (supervisor of this doctoral dissertation), this acute-care hospital was inaugurated in 2009 as a public-private concession (Fig. 35-Fig. 39).

Located near the port city of Dénia, with a population of about 40 000 inhabitants that can reach over 200 000 during summer, attracting specially tourists and foreign residents.

Fig. 35 HD location.

The building is placed in its plot to maximise optimal orientation: sunlight exposition and views towards the sea, “Montgó” Natural Park and orange groves.

The volumetric composition consists of three longitudinal bars of low height, crossed by three transversal bars that create internal rectangular courtyards to ensure natural light in both circulation and service rooms.

The main materials used are white concrete for the structural and façade pieces, glass surfaces and wood finishes for sun protection.

Fig. 36 North façade HD.

Fig. 37 Site map HD.

Fig. 38 Acute-care hospital departments at HD. Ground floor to third floor.

Fig. 39 Acute-care hospital departments at HD. Basement 1 and 2.

3.5.2 “Hospital Universitario del Vinalopó” (HUV)

Designed by architects Carlos Ferrán, Fernando Navazo, Luis Herrero and José León Paniagua (supervisor of this doctoral dissertation). The HUV was inaugurated in 2010 as a public-private concession (Fig. 40-Fig. 43).

This acute-care hospital is located in the south-west part of Elche. The city, with a population of 230000, has two healthcare departments Elche- Crevillent (to which this acute-care hospital is assigned) and Elche-Hospital General.

The building is arranged in three longitudinal bars (two of them for diagnosis and treatment services and one for out-patients) and L-shaped in-patient wards.

Fig. 40 HUV location.

Fig. 41 South-east façade HUV.

Fig. 42 Site map HUV.

3. Method

3.5 Acute-care Hospital Cases

Fig. 43 Acute-care hospital departments at HUV.

3.5.3 “Hospital Clínico Universitario de Valencia” (HCUV)

The origin of this healthcare institution goes back to 1875 when the hospital was physically and legally linked to the current “Facultad de Medicina y Odontología de la Universitat de València” (Fig. 44-Fig. 49). The hospital was initially built in 1960 and has suffered many transformations such as the ones due to a fire in 1986 and a major remodeling in 1994 [15].

It is an urban acute-care hospital in the north-east part of València located over two different blocks separated by a road. The acute-care hospital units are placed in two different buildings linked by two bridges and some rooms of the “Facultad de Medicina y Odontología de la Universitat de València” are also connected at the basement level.

Fig. 44 HCUV location.

Fig. 45 West façade and main access HCUV.

Fig. 46 Site map HCUV.

Fig. 47 Acute-care hospital departments at HCUV. Fifth floor to eight floor.

Fig. 48 Acute-care hospital departments at HCUV. First floor to fourth floor.

Fig. 49 Acute-care hospital departments at HCUV. Basements and ground floor.

3.5.4 “Hospital Universitari i Politècnic La Fe València” (HUPF)

The origin of this healthcare institution was the “Ciudad Sanitaria de la Seguridad Social la Fe” opened in 1972 located in the north-west part of “València” (Fig. 50-Fig. 55). In 2010, the acute-care hospital moved to a new building in the south of the city designed by architects Alfonso Casares and Ramón Esteve.

Fig. 50 HUPF location.

This massive building is arranged as a large basement with six towers, a seventh tower for research and two low-rise blocks for teaching and building services.

The façade is made of prefabricated blocks of white concrete.

Fig. 51 South façade HUPF.

Fig. 52 Site plan HUPF.

Fig. 53 Acute-care hospital departments at HUPF. Third to seventh floor.

O	Out-patient Area	D	Diagnostic & Treatment Area:
Fa	Functional Assessment	Lw	Labour Ward
Dh	Day Hospital	Ot	Operating Theatres
Od	Out-patient Department	Po	Post-anesthesia Care
Dy	Dialysis	Lb	Laboratory
Te	Telemedicine	Bb	Blood Bank
Fe	Fertility		
Hh	Home Hospitalisation	T	Teaching & Research Area:
		Ef	Education Facilities
I	In-patient Area:	Rf	Research Facilities
Icu	Intensive Care Unit		
Ip	Paediatric Ward	S	Logistical & Medical Supply Area:
In	Neonatal Ward	Wk	Workspaces
		Os	Overnight Stay

Fig. 54 Acute-care hospital departments at HUPF. First and second floor.

Fig. 55 Acute-care hospital departments at HUPF. Basement and ground floor.

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4. Results & Discussion

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4.1 CURARQ Tool

As shown in Tab.1 of chapter 3.1, CURARQ tool is both a result of this thesis and a measurement tool for the evaluation of acute-care hospital cases (see chapter 3.6). Next, there is the same framework used for the analysis of existing POE tools (see chapter 2.3.1), but now for the description of CURARQ tool.

4.1.1 Tool Content

Why?

For the evaluation of environmental and functional factors in several units of Spanish acute-care hospitals in use. To allow researchers to analyse existing facilities and define improvement measures to align with existing knowledge. The whole acute-care hospital, and consequently, the design of its units is in constant change according to different variables (socio-demographic trends, healthcare systems, technologies, cultural changes, among others). Several documents, like planning guides, norms or recommendations, gathered the scientific evidence and best practice that define the design of the unit. These documents come from diverse healthcare organizations (public and private, scientific or research associations and healthcare services). In Spain the “[Estándares y Recomendaciones de unidades clínicas](#)” written by a group of experts and published by the “Ministerio de Sanidad, Consumo y Bienestar Social” includes information from the analysis of a wide group of international and national documents. The tool CURARQ includes mainly the recommendations of these documents and several others. That is why this tool has been written in Spanish and is adapted to the social, economic, and cultural context of the Spanish Healthcare System.

How?

Literature analysis, three-month acute-care hospital placement and sixteen acute-care hospital study visits.

What?

There are seven [CURARQ](#) Excel files, one for each area of this study:

- CURARQ-Circ: Circulation spaces
- CURARQ-UCI: Intensive Care Unit (Fig. 1)
- CURARQ-H: Standard Ward
- CURARQ-Hobste: Obstetric Ward
- CURARQ-Hpedi: Paediatric Ward
- CURARQ-UNeo: Neonatal Ward
- CURARQ-Pari: Labour Ward

Each file evaluates about 250 items that are aimed at one or more outcomes, taken from the Patient Room Design Evaluation Tool (see chapter 2.3.1), which allows for a detailed classification:

- Patient safety (reduce falls, reduce risk of contamination, improve hand sanitization) e.g.: "El suelo es continuo, las juntas están selladas y no hay cambios de nivel".
- Worker safety & effectiveness (improve job satisfaction, provide efficient delivery of care, improve staff health, improve communication) e.g.: "Equipamiento en columnas de techo o en pared para permitir la circulación completa alrededor de la incubadora".
- Quality of care & patient experience (reduce patient stress and anxiety, improve patient engagement, improve patient satisfaction, improve comfort, respect privacy) e.g.: "Cada cuna o incubadora dispone de dos sillones exclusivos, cómodos y reclinables para los familiares del neonato".
- Organizational performance (ensure durability, enable readiness for changes, enhance sustainability, provide a secure environment) e.g.: "Pared de fácil limpieza, lisa, continua y no porosa. Permite una limpieza agresiva y dispone de protecciones para resistir los impactos ocasionales de carros y equipos portátiles pesados".

To facilitate the evaluation process, the items are organised according to the area studied (circulation, access, patient, staff, nursing, support, or unit configuration as a general category for the unit as a whole), the specific room (such as the corridor, hall, patient bedroom, doctors' office, counter, or dirty utility room) and the design element. Each design element has an associated cost (in a scale from 1 to 5) as it would be more expensive for example to change the layout of a room than simply modify the furniture (Tab. 1):

Cost	Design element
5	layout
4	light openings, installation
3	equipment, flooring
2	ceiling, wall, door
1	furniture, signage or art

Tab. 1 Cost category for each design element.

Fig. 1 CURARQ-UCI content structure.

When?

For the post-occupancy evaluation of acute-care hospital units in order to identify the aspects that could be improved and start a diagnostic of the current design stage of the unit and its needs that could lead to a new design.

For the evaluation of new predesigns, to start a discussion about design aspects. In this case, not all items could be answered.

Who?

By architects or architecture students. It could also be used by acute-care hospital staff as the language used is quite simple.

4.1.2 Evaluation Process

Data collection

- A first email to the medical directors of the acute-care hospitals studied.
- A first meeting with the acute-care hospital representative appointed (medical director, institutional relationships, teaching or infrastructures manager). A short presentation for the introduction of the project.
- Approval from the acute-care hospital and schedule evaluation dates.
- During the evaluation (January-February 2018) the acute-care hospital representative introduced me to the head nurses of each unit studied.
- In each unit, I was introduced to staff, and to the unit through a tour and then I carried out the data collection on paper that lasted approximately two hours.
- I had informal conversations with staff during data collection and took notes about room names and functions as well as photographs.
- For each acute-care hospital, about four days were needed to gather all the data.

Data analysis

- Data on paper was transcribed to Excel files, in accordance with the following instructions:
 - A "yes" response when all the item text was met with a 5% allowance for dimensions.
 - A "no" response when the item was not met with a description of the reason in the comment section.
 - A "n.a." response that means "not available" or "not applicable" when the item was not available to check or not applicable due to the level of the unit.
- The Excel files were checked by one of the supervisors.
- Graphic material was generated, plans, ward location in the acute-care hospital, identification of the rooms evaluated in each unit in plan and photo.

Results

- Quantitative results with the CURARQ tool for each room and area:
 - A "yes" response: points are added to the score and the total points.
 - A "no" response: points are not added to the score, but they count on the total points.
 - A "n.a." response: points are neither added to the score nor to the total points.
- Qualitative results to visualise graphically the design strategies found.

4.1.3 Discussion

CURARQ tool has been generated from existing information sources that vary according to the unit considered. For example, the items for the standard ward came from the sources shown in Fig. 2:

Fig. 2 Source's type for the standard ward items.

However, when Spanish guidelines were not available (as is the case for the paediatric ward and circulation spaces), I have reutilised information from guidelines for similar units, international guidelines, and personal knowledge gathered from the acute-care hospital placement and acute-care hospital visits. Spanish guidelines were published around 2010 and some of their content is outdated, which shows the need for updating national guidelines as is done in other countries [1]. The tool item generation was carried out from a review of relevant literature, but also from the three-month acute-care hospital placement and the sixteen acute-care hospital visits. In order to increase its validity, which is related to the credibility of the conclusions, I have described each case, and used data triangulation from the tool results, the architectural layouts and the commented photographs [2]. Additionally, in order to improve its reliability, which is related to the consistency of the method, I have documented each stage of the process and have shared the tool's content online [2, 3]. It would have been very beneficial to validate the framework of the tool by external reviewers [4].

Regarding the tool usability, it depends on the healthcare services provided by the acute-care hospital studied which define the functions and rooms needed in the building. Hence, it was difficult to match the tool's room schedule with all acute-care hospitals. In many cases some ward rooms were in other acute-care hospital areas, for examples on call bedrooms in a staff facilities area instead of in the ward or centralised staff changing rooms. In other

cases, there were additional rooms like a room for administrative work in highly complex wards. It was difficult to evaluate the rooms when several functions were combined (e.g. dirty utility room with cleaners' room; mixed storage for material and equipment). It was also relevant to understand the acute-care hospital approach to logistical services and their needed space resources (central kitchen and trolley vs. regeneration kitchen in wards; dirty clothing management and real usage of pneumatic pipes) [5]. Alternative evaluation methods could be used for strengthening the results [6]. It would also be useful to gather additional information from the occupants regarding the real functions of the rooms, the possibilities of combining functions in the same room (due to functional convenience or space limitation) and the floor area needed.

Even though medicine is universal, the social, economic, and cultural context of each country play a major role in determining the final acute-care hospital design. For example, while in Sweden the single-family room in the neonatal ward is the present, in Spain this design is still considered as a future goal. That is why the CURARQ tool is written in Spanish and does not aim to be extrapolated to international contexts. Indeed, this tool can be used for updating the guidelines on healthcare facilities as it is customized to the context of Spanish society [7].

4.2 Circulation

4.2.1 Acute-care Hospital Placement

From the interviews held with miscellaneous staff (such as porters, barmen or receptionist), at “Hospital de Dénia”, the topics that came up were related to the signage system, wayfinding, security, lift size and location, art, natural light, and views (Fig. 3-Fig. 4). Additionally, the following information arose.

The most frequent movements of porters were the ones that linked:

- *The ICU with in-patient wards, operating theatres and blood bank.*
- *The labour ward with obstetric ward and emergency access.*
- *The post-anaesthesia unit with in-patient wards.*
- *Within in-patient ward for patient relocation.*

There was a general acceptance of artistic sculptures and exhibitions in the hospital with some exceptions with not appropriate pieces. Other comments were made regarding the chapel and the lack of intimacy due to the transparency of the walls. The finishing materials of the service/bed lifts were criticized. The corridor width and door width were too narrow in some cases. Other comments had to do with wayfinding problems due to a poor signage system and not enough previous information.

Fig. 3 Angry child trying to play with an artistic swing that cannot move. HD.

Fig. 4 Detail of water lilies and fish at an outdoor fountain. HD.

4.2.2 Literature Analysis

From the literature analysis, came the organisation of the acute-care hospital areas, user groups, acute-care hospital unit types and the classification of circulation flows as follows:

- Areas:
 - Out-patient area: out-patient department and public area.
 - In-patient area: in-patient wards.
 - Diagnostic and treatment area: of clinical domain, it attends both out-patient and in-patients.
 - Teaching and research area: education and research facilities.
 - Logistical and medical supply area: support to the healthcare activity.
- User groups:
 - Out-patients: patients who are treated in the acute-care hospital during the day (such as out-patient department or day hospital) but sleep at their homes.
 - Companions: relatives and patient carers.
 - In-patients: bedridden patients that stay overnight.
 - Clinical staff: such as doctors, physicians, nurses, midwives, nursing assistants, pharmacists, social workers, speech therapists, dietitians, or physiotherapists.
 - Non-clinical staff: such as porters, administrative staff, librarians, architects, engineers, technicians, teachers, drivers, telephonists, cleaners or waiters.
- Unit type:
 - Restricted access units exclusively used by clinical and non-clinical staff (red units in Fig. 5).
 - Accessible units for clinical and non-clinical staff, in-patients, out-patients and companions (orange units in Fig. 5).
 - Accessible units for clinical and non-clinical staff, out-patients and companions (green units in Fig. 5).
- Circulation flow:
 - External circulation for out-patients and companions (green in Fig. 5).
 - Internal circulation for staff, supplies and in-patients (orange in Fig. 5).
 - Internal circulation for staff and supplies (red in Fig. 5).
 - Internal circulation for building services and their maintenance (black in Fig. 5).

Fig. 5 Link between acute-care hospital areas and user groups.

The CURARQ tool framework developed for the evaluation of acute-care hospital cases in Spain, considered an acute-care hospital sample with five accesses (Fig. 5). This preliminary organization of areas and rooms (see Tab. 2) is based on numerous references [8-15], but may vary depending on the healthcare activity and the volumetric arrangement of the whole acute-care hospital evaluated. The following room schedule is not a standard but a representation of the most frequently visited acute-care hospitals in Spain. In addition to this room schedule, all the CURARQ-Circ tool requirements per each room can be read [online](#).

	Type	Room	Function
Out-patient	Arrival spaces	1. Car parking area	To park cars.
		2. Motorbike parking area	To park motorbikes.
		3. Bike and scooter parking area	To park bikes and electrical scooters.
		4. Taxi stop	To get in and out of the taxi.
		5. Public transportation stop	To get on and off the bus or metro.
		6. Entrance	To enter the out-patient department.
		7. Hall	To group people from the outdoors into the building.
		8. Reception and information	To provide basic information and directions.
		9. Equipment parking area	To park wheelchairs for patient transport.
		10. Waiting area	To spend time while waiting.
		11. Public toilet	To empty the body of urine or solid waste.
		12. Baby feeding and nappy changing room	To breast or bottle feed babies and for nappy changing.
	Support spaces	13. Outdoor	To provide respite and connection with nature.
		14. Courtyard	To provide an outdoor area within the building.
		15. Playground area	To entertain children and young people.

In-patient	Arrival spaces	16. Car parking area	To park cars.
		17. Motorbike parking area	To park motorbikes.
		18. Bike and scooter parking area	To park bikes and electrical scooters.
		19. Taxi stop	To get in and out of the taxi.
		20. Public transportation stop	To get on and off the bus or metro.
		21. Entrance	To enter the in-patient department.
		22. Hall	To group people from the outdoors into the building.
		23. Reception and information	To provide basic information to programmed in-patients.
		24. Charity area	To provide space for NGOs to carry out their work at the acute-care hospital.
		25. Equipment parking area	To park wheelchairs for patient transport.
		26. Waiting area	To spend time while waiting.
		27. Public toilet	To empty the body of urine or solid waste.
		28. Baby feeding and nappy changing room	To breast or bottle feed babies and for nappy changing.
	Support spaces	29. Outdoor	To provide respite and connection with nature.
		30. Courtyard	To provide an outdoor area within the building.
		31. Playground area	To entertain children and young people.
		32. Cafeteria	To offer food and drinks.
		33. Conference	To allow for scientific meetings or outreach events.
		34. Spiritual room	To provide a space for meditation and prayer.
		35. Shops	To allow people to buy miscellaneous items.
		36. ATM terminal	To withdraw money and do monetary transactions.
		37. Library	To promote the joy of reading in the acute-care hospital.

Emergency	Arrival spaces	38. Heliport	To allow the unloading of patients transported by helicopter.
		39. Ambulance loading area	To allow the unloading of patients transported by ambulance.
		40. Car parking area	To park cars.
		41. Motorbike parking area	To park motorbikes.
		42. Entrance	To enter the emergency department.
		43. Reception and information	To provide basic information.
		44. Waiting area	To spend time while waiting.
		45. Public toilet	To empty the body of urine or solid waste.
		46. Baby feeding and nappy changing room	To breast or bottle feed babies and for nappy changing.
	Support spaces	47. Outdoor	To provide respite and connection with nature.
Staff		48. Playground area	To entertain children and young people.
	Arrival spaces	49. Car parking area	To park cars.
		50. Motorbike parking area	To park motorbikes.
		51. Bike and scooter parking area	To park bikes and electrical scooters.
		52. Entrance	To enter the building.
	Support spaces	53. Outdoor	To provide respite and connection with nature.
Supplies		54. Courtyard	To provide an outdoor area within the building.
	Arrival spaces	55. Loading dock	To allow the unloading of supplies transported by vans and trucks.
	Support spaces	56. Entrance	To enter the building.

External circulation	Out- patients and companions	57. Gallery	To connect the public areas.
		58. Lift lobby	To allow for the gathering of people while waiting for the lift.
		59. Lift	To transport vertically.
		60. Staircase	To transport diagonally.
Internal circulation	Staff, supplies and in- patients	61. Gallery	To connect the internal areas.
		62. Lift lobby	To allow for the gathering of people and supplies while waiting for the lift.
		63. Lift	To transport vertically.
		64. Staircase	To transport diagonally.
Internal circulation	Staff and supplies	65. Gallery	To connect the most internal areas.
		66. Lift lobby	To allow for the gathering of people and supplies while waiting for the lift.
		67. Lift	To transport vertically.
Internal circulation	Building services	68. Gallery	To maintain and access to the building installations.

Tab. 2 Room schedule for the circulation spaces.

4.2.3 Acute-care Hospital Visits

“Hospital de la Santa Creu i Sant Pau” (HSCSP)

The HSCSP is organised in five buildings: a rectangular volume for the out-patient department and four smaller wings arranged like fingers that house the in-patient wards. These five buildings are connected by a communication space that organises the user flow (Fig. 6-Fig. 13). There are also three courtyards that vertically cross the communication space that has a different usage at each level: 1) internal circulation area in the basement; 2) the external circulation area on the ground floor; and 3) the terrace for paediatric and psychiatric patients. The basements house the logistical areas as well as the operating theatres. The circulation flows are segregated, with the out-patient department generating the main public flow, and an internal flow for supplies and in-patients.

Fig. 6 Ground floor with out-patient access, external circulation spaces and the three courtyards. HSCP.

Fig. 7 Automatised system for linen cleaning and delivery. There is no laundry in the acute-care hospital as the service is externalised. Staff have to identify themselves electronically each day and get their uniform. HSCP.

Fig. 8 At the end of their working day they have to return their clothing to a different machine. HSCP.

Fig. 9 Daylight openings between the internal circulation of the out-patient department. HSCP.

Fig. 10 Natural light in the internal corridor of the basement between pharmacy and laboratories. HSCP.

Fig. 11 Open space in the laboratories with natural light for staff. HSCP.

Fig. 12 View of the in-patient wards from the education facilities with the Sagrada Família in the background. HSCP.

Fig. 13 Out-patient department public circulation with escalators. HSCP.

“Hospital del Mar” (HdM)

This acute-care hospital has undergone several renovation works during its long history (Fig. 14-Fig. 24). There is a research centre, an educational building and the acute-care hospital itself. The circulation strategy is based on the original structure in pavilions. For the connection of the existing acute-care hospital to the out-patient block at the sea front, there is a public square that provides a soft transition between the sea and the building. At the back of the acute-care hospital is the teaching department.

Fig. 14 Ground floor HdM.

Fig. 15 External view of the out-patient department. HdM.

Fig. 16 Public atrium built in the 90s. HdM.

Fig. 17 Public corridor in the out-patient department. HdM.

Fig. 18 Waiting areas built in the 90s. HdM.

Fig. 19 Internal corridor. HdM.

Fig. 20 Cafeteria in the teaching facilities pavilion. HdM.

Fig. 21 Reading area with double height in the teaching facilities pavilion. HdM.

Fig. 22 Library and reading area at the back with continuous lighting fixtures for creating a virtual ceiling and promote concentration. HdM.

Fig. 23 "Parc de recerca biomèdica" or research institute. HdM.

Fig. 24 Socialising areas in the research institute. HdM.

“Hospital Sant Joan Despí Moisès Broggi” (HSJDMB)

The out-patient access to the acute-care hospital provides a clear flow strategy with a “U” shape for external circulation and a herringbone shape for internal circulation (Fig. 25-Fig. 28). Next to the access there is the cafeteria, the public gallery leads to the external vertical transportation cores with the lifts and staircase that connect the gallery with the in-patient wings at the higher levels.

Fig. 25 Ground floor (HSJDMB).

Fig. 26 Public access. Flooring changes for delimitating waiting from circulation area. (HSJDMB).

Fig. 27 Public circulation for out-patient department with natural light. (HSJDMB).

Fig. 28 Ceiling openings for providing natural light. (HSJDMB).

“Maternidad Gregorio Marañón” (MGM)

The MGM is an urban acute-care hospital with a compact structure organised around eight courtyards (Fig. 29-Fig. 32). The building houses two acute-care hospitals in one (maternity and paediatric). These two acute-care hospitals have their own accesses, consultancies and in-patient wards but share some departments such as operating theatres, emergency department, diagnostic department and general services. This independency of services is achieved by the circulation strategy. There are two independent access levels, one for maternity patients on the ground floor and another on the first floor for paediatric patients.

Fig. 29 Ground floor MGM.

Fig. 30 Access to the children's departments. MGM.

Fig. 31 Circulation space and waiting area. MGM.

Fig. 32 Daylight opening in the basement. MGM.

“Hospital Universitario Central de Asturias” (HUCA)

The HUCA is a highly complex building organised around five parts: 1) out-patient department; 2) general services that combine the diagnostic and treatment facilities with the logistical and medical supply areas; 3) the in-patient department; 4) teaching department; and 5) technical department (Fig. 33-Fig. 41). Each of these areas has independent arrival and access areas.

There is privacy limiting gradation from the public areas in the periphery of the building (out-patient department and entrance to in-patient departments) to the inner parts of the acute-care hospital with the internal areas exclusively used by restricted flows.

Fig. 33 Ground floor and diagram of departments. HUCA.

Fig. 34 Atrium that separates the hospitalisation building from the general services building. HUCA.

Fig. 35 Indoor atriums in the out-patient building. HUCA.

Fig. 36 Cafeteria in the teaching department. HUCA.

Fig. 37 Charging station at basement 2 for robots. HUCA.

Fig. 38 Automatised circulation of 12 robots. HUCA.

Fig. 39 Close up view of a robot. HUCA.

Fig. 40 Lobby lift in basement 2 and robotized lift. HUCA.

Fig. 41 Parking area for robots at each in-patient ward. HUCA.

“Hospital General Universitario de Ciudad Real” (HGUCR)

The circulation strategy in HGUCR relies on two access points, one for in-patient wards and another for the out-patient departments (Fig. 42-Fig. 44). There are two public galleries connected through the cafeteria to distribute public flow between these two areas. The first public gallery directs people to the three vertical transportation cores that take people to the hospitalization wings. In the second public gallery there are several staircases and lifts to connect the two out-patient floors. Internal circulation is resolved in the inner part of the building. The in-patient access faces a park while the out-patient area and the back of the building contain the outdoor parking areas.

Fig. 42 Ground floor HGUCR.

Fig. 43 Park in the acute-care hospital site. HGUCR.

Fig. 44 Piano in the external corridor. HGUCR.

“Sahlgrenska Universitetssjukhuset” (SAHLH)

The “Bild och interventionscentrum” at Sahlgrenska Hospital (SAHLH) is an imaging and intervention centre that combines the department of radiodiagnostics and imaging with the operating theatres department (Fig. 45-Fig. 51). This renovated building was placed in an existing facility of the acute-care hospital. Since the floor heights were higher than the adjacent building (for housing operating theatres and their required equipment) a void volume was designed facilitating the transition from the central building of the acute-care hospital to this new building. Thus, there is no horizontal connection to the central building of the acute-care hospital. Two thirds of the building are designated to technical installations mainly in the basement (for data, gases and electricity) and the roof (for ventilation) as well as the needed shafts through all the floors. The location of a magnetic resonance (MR) scanning room next to the operating theatres allows for a scan of the head and neck of the patient during brain surgery so that surgeons may work with updated images during the operation and without moving the patient.

Fig. 45 Fourth floor of building with departmental circulation. SAHLH.

Fig. 46 Goods flow in the basement with resistant finishes, sidewalk (to protect walls from wheel impacts), and suspended ceiling for covering the installations. SAHLH.

Fig. 47 Basement level with building services. SAHLH.

Fig. 48 Operating theatre of about 100 m² with daylight and workstations in each corner for specialist teams (one for anaesthetists, another for surgeons). Artificial lighting contrast for better visualization of screen images. SAHLH.

Fig. 49 Designated parking area in the internal corridor. SAHLH.

Fig. 50 Volume of nexus between the two buildings, which had different height levels, with a friendly waiting area. SAHLH.

Fig. 51 Internal lift for bed-ridden patients with a specific gases box for patient provision in case of lift failure. SAHLH.

“Östra Hospital” (ÖH)

This poliblock acute-care hospital is under a challenging and ambitious upgrading strategic plan with sustainable planning that started in 2011 and will be finished by 2030 (Fig. 52-Fig. 53).

Fig. 52 Birds-eye view of the whole acute-care hospital. ÖH.

Fig. 53 Planned buildings for acute-care hospital remodeling and extension. ÖH.

“Angereds Närsjukhus” (AN)

The building has three floors and a basement for car parking (Fig. 54-Fig. 68). The exterior shape is that of a square with four atriums that provide natural light and contain art installations. There are two opposite access points to the building, one in the north for external flow and the another in the south for internal flow. Next to the external access there is the directory, open stairs to encourage their usage, public toilets, café and the reception desk. Public circulation is arranged as a central spine that crosses two atriums. Internal circulation is organised from the public circulation into two clusters. There is only one entrance and reception desk for all external visitors (for primary and specialist care) so that everyone goes directly there and receives the right directions to their final destination. Directly from the external access, there is a view of the stairs to encourage their use but also a sign to the public lifts. The internal lift is close to the internal access.

Fig. 54 External view of building. AN.

Fig. 55 Open stairs next to access to promote their use. AN.

Fig. 56 Courtyard with artistic installations. AN.

Fig. 57 Waiting area with comfortable furniture and aquarium. AN.

Fig. 58 Ground floor with two opposite access points. AN.

Fig. 59 Furniture in waiting areas with material for children. AN.

Fig. 60 Cosy sofas for waiting. AN.

Fig. 61 Furniture for children's entertainment. AN.

4. Results & Discussion

4.2 Circulation

Fig. 62 Concealable Information desk. AN.

Fig. 63 Informative panel with basic information, in braille and a display with easy to change lines. AN.

Fig. 64 Contrasting colour surface in public toilets. AN.

Fig. 65 Drinking water tap. AN.

Fig. 66 Neutral spiritual room for all religions. AN.

Fig. 67 Cabinet for storage of complements for rituals like sacred books or carpets. AN.

Fig. 68 Tap for rituals that need water or water hygiene. AN.

“Skånes universitetssjukhus” (SKU)

Due to the whole hospital typology, the primary circulation system of this acute-care hospital is that of urban planning with streets and underpasses that connect several of the departmental buildings (Fig. 69-Fig. 83). However, the interdepartmental circulation spaces of the department of infectious disease are worthy of special attention. This building cares for infectious or immunosuppressed patients, thus the circulation flows have to be as safe as the patient areas. That is why this building uses a quick and short distance route from the ambulance to the in-patient bedroom, outdoor areas for the circulation of patients and visitors, and ante-rooms for the access of visitors and staff to the in-patient room.

Fig. 69 In-patient ward floor. SKU.

Fig. 70 Infectious disease building. SKU.

Fig. 71 Pedestrian access and drop-off area. SKU.

Fig. 72 Staircase windows to inner courtyard. SKU.

Fig. 73 Artistic installations on lift doors. SKU.

Fig. 74 Artistic installations in corridors. SKU.

Fig. 75 Staff resting area and kitchen. SKU.

Fig. 76 Staff balcony with views to acute-care hospital expansion. SKU.

Fig. 77 Ambulance bay for infectious patients who are treated separately from their arrival and go directly to the external lifts into the infectious patient rooms. SKU.

Fig. 78 External corridor to in-patient bedrooms. SKU.

Fig. 79 Ante room from the external corridor. SKU.

Fig. 80 In-patient room used individually but with double capacity to reduce costs. SKU.

Fig. 81 Staff anteroom with sink, personal protective equipment and patients' protocol information. Staff physical and mental transition to patient's bedroom. SKU.

Fig. 82 Air conditioning switches for positive or negative pressure, regulable both in the anteroom and the bedroom. Display to show the type of patient: contagious or immunocompromised. SKU.

Fig. 83 Internal corridor for staff with two accesses to the patient, one through the anteroom and another one directly to the bedroom for emergency situations. SKU.

“Nya Karolinska Solna” (NKS)

The building is designed to improve flexibility and resilience (Fig. 84-Fig. 114). During the pre-design stage, designers carried out research and acute-care hospital visits to other countries. The conclusions they reached were that the acute-care hospital had to be prepared for future infectious outbreaks. Hence, it was designed with double corridors for the segregated flow of internal and external users. It was also important to be able to modify departmental location within the acute-care hospital. The initial intention was to build all floors with enough ceiling height and structural load to house an operating theatre. However, due to the cost reduction during the construction stage, this was not possible at all levels. The main entrance leads to an immense hall area with a hotel type reception, cafeterias, and shops. There are several access points like the independent access to the conference room or the children's access.

Fig. 84 Ninth floor NKS.

Fig. 85 External view. NKS.

Fig. 86 Hall. NKS.

Fig. 87 Main directory in hall. NKS.

Fig. 88 Public cafeteria next to hall. NKS.

Fig. 89 Conference room with public access. NKS.

Fig. 90 Corridor with lockers. NKS.

Fig. 91 Concealed fire doors. NKS.

Fig. 92 Staircase with large window to promote its usage. NKS.

Fig. 93 Concealed goods lift. NKS.

Fig. 94 Parking area for goods trolleys in front of goods lift. Trolley bay for goods. NKS.

Fig. 95 Pavement signal warning of goods trolley movement from goods lift. NKS.

Fig. 96 Parking area for three-wheel scooters. NKS.

Fig. 97 Parking area for children's scooters. NKS.

Fig. 98 Lift lobby. NKS.

Fig. 99 Academic mall that connects NKS hospital with research centres and creates a pedestrian urban environment with urban furniture and art. NKS.

4. Results & Discussion

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Fig. 100 Ante room to religious room with furniture for children. NKS.

Fig. 101 Rituals room. NKS.

Fig. 102 Congregational rituals room. NKS.

Fig. 103 Piano in the religious room. NKS.

Fig. 104 Artistic installations in the acute-care hospital. Hospital developers had to invest from 1 to 3% of construction cost on artistic installations. NKS.

Fig. 105 Another artistic installation. NKS.

Fig. 106 Waiting area next to lift lobby with table football. NKS.

Fig. 107 Workspace with electrically height adjustable tables. NKS.

Biomedicum Laboratory Building, “Karolinska Institutet” (KI NKS)

Fig. 108 Karolinska Institutet external view. KI NKS.

Fig. 109 Roof of atrium. KI NKS.

Fig. 110 Staircase. KI NKS.

Fig. 111 Urban furniture of the atrium. KI NKS.

Fig. 112 Staff kitchen. KI NKS.

Fig. 113 Ante room for staff hygiene preparation before entering the laboratory. Flexible fixings for easy redesign. KI NKS.

Fig. 114 Laboratory room. Drawers hang from the table to facilitate floor cleaning. KI NKS.