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# Summary

## Editorial

Dear readers,

It is with great satisfaction that we present the 22nd issue of IPH Magazine, reaffirming our commitment to providing high-quality, analytical and multidisciplinary knowledge concerning architecture and hospital infrastructure.

This year we have put together a selection of original works that reflect the complexity and diversity of the themes related to planning, managing and the future of health facilities.

We open this edition with the article "Integrated Method for Quality and Performance Assessment and Certification of Healthcare Facility Buildings", which proposes an overarching model to assess and certificate healthcare buildings. The research presents objective criteria to qualify and quantify fundamental variables of conservation and performance, therefore significantly adding to the improvement of hospital infrastructure and evidence-based decisions.

The following article, "Hospital Architecture Responsive to Neurodiversity", approaches an emerging and pressing topic: the delicate inclusion of neurodivergent patients in pediatric healthcare facilities. Starting with applied research, the author introduces practical guidelines for the development of projects that prioritize the plainness, predictability and the control of the environment, providing more comfort and safety to patients and their families.

Focusing on an innovative and management-driven approach, the last article, “Healthcare 4.0 and Lean Healthcare in Santa Catarina Hospitals: Mapping Adoption and Exploring Integration”, gives an updated panorama of how such methodologies are being applied. The research reveals the low dissemination of lean healthcare practices, as well as the common challenges faced by institutions upon the adoption of new technologies and processes. Such a contribution is crucial to thinking about the digital and cultural transformations the hospital sector is demanding.

Besides the articles, we offer you the review of a new book about Jarbas Karman, architect and founder of IPH. This work honors his trajectory, gathering drawings, unpublished photos and valuable records that help telling the story of one of the main names of Brazilian hospital architecture.

IPH Magazine continues to strengthen its position as a space where health professionals, architects, engineers, managers, scholars, and anyone interested in the improvement of healthcare facilities, come together. The diversity of themes and the multidisciplinary nature of the texts illustrate the dynamism and the relevance of this field.

We encourage all researchers, professionals and students to submit their work and contribute to the next issues of IPH Magazine. Together, we can build more humanized, efficient and innovative healthcare environments.

Enjoy your reading!

**Arch. MSc. Marcio Nascimento de Oliveira, editor**

Article

# Integrated Method for Quality and Performance Assessment and Certification of Healthcare Facility Buildings

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## Abstract

This study presents a method for the assessment and certification of healthcare facility buildings, qualifying and quantifying critical variables related to maintenance and performance. The methodology involved experimental research, followed by the proposal of a standardized, multiparametric assessment model applied to two case studies: Super Centro Carioca de Vacinação (Rio de Janeiro) and Basic Health Unit 5 of Riacho Fundo II (Distrito Federal). The results demonstrate the applicability of the method in certifying buildings with varying degrees of conservation and complexity. A Quality and Performance Indicator ($I_{QD}$) was proposed to classify buildings into categories of excellence. It was concluded that the proposed model is flexible and adaptable, capable of being replicated across different facility types, offering support for decision-making and the implementation of public policies aimed at improving the quality of the built environment.

## Keywords

Health Management; Health Facilities; Hospital Design and Construction; Public Health Surveillance; Sustainable Development.

## Introduction

In Brazil, there is not enough academic literature concerning the quality of healthcare environments (MS, 2013). Without theoretical background, the usual practice is to repair a building just when it is critically damaged. This lack of a culture of maintenance affects the building directly, thus becoming a challenge that not only addresses the technical and material dimensions but also the theoretical framework of conservation (Moreira, 2011).

Nowadays, long-term preventive maintenance is one of the best strategies to preserve property assets, which includes the development of systems to carry out periodic inspection and maintenance that might replace repairs, as well as management systems aimed at the conservation and sustainability of real estate.

Maintenance, rehabilitation and improvement of buildings are strategies to boost their performance and efficiency, as they offer more advantages than building new spaces, whether for financial or environmental reasons. Therefore, such actions are beneficial not only for being sustainable – or ecological responsible –, but also for economically contributing to the management of buildings (Donegá, 2021).

Rehabilitation here is understood as operations aimed at the conservation and repair of architectural meaningful parts – considering historical, aesthetic and functional factors –, including an overall improvement to achieve the current levels of performance and demands. This concept can be applied to vast urban interventions as well as to building interventions. The improvement is a form of rehabilitation carried out to enable a higher-level performance (Paiva; Aguiar; Pinho, 2006).

Healthcare Facilities (HF) are worn out throughout their lifespan, whether due to natural aging or accidental natural or humane wrongdoings. Such changes compromise their functions, with possible risks to the safety of users (Pantoja *et al*., 2020).

High-quality buildings and a functional environment are crucial to ensure the safety of users, besides providing comfort to and welcoming users and professionals.

Adopting a welcoming attitude towards the management of healthcare facilities favors a dependable and engaging relationship among users, staff and services, enhancing a culture of solidarity and legitimizing the public health system. Consequently, a high-quality healthcare facility and an environment that is both comfortable and welcoming also boost the alliance among healthcare system users, professionals and managers in the defense of the *Unified Health System* (SUS) as a vital public policy aimed at the Brazilian population (MS, 2010).

In Brazil, the HFs answer directly to the recommendations and norms dictated by the Ministry of Health (MH) and, additionally, to further regulatory agencies, such as the Brazilian Health Regulatory Agency (Anvisa). As to the architectonic planning of such buildings, the main norm to be considered is the Sanitary Regulation RDC-050/2002 (Anvisa, 2002) known as RDC-50, which presents the minimum spatial and functional requirement for all sorts of healthcare facilities, public or private.

This study seeks to support managers in making informed decisions regarding the importance and necessity of maintenance in healthcare facilities. It does so by providing standardized and systematic data on infrastructure conditions, as well as on the functionality and quality of healthcare environments. By facilitating the monitoring of deterioration levels and building performance, this research serves as an additional strategy to safeguard individuals' constitutional right to health.

The multiparametric model proposed in this study qualifies and quantifies key variables relevant to the evaluation of the conservation status and performance of healthcare facilities. This model was subsequently applied to the selected units to conduct case studies.

## Methodology

This experimental research proposed a standardized assessment process using a multiparametric model designed to qualify and quantify the conservation status, performance, and certifications of healthcare facilities (HFs). The model was applied to two case studies, generating detailed information on the structural condition, functionality, and environmental quality of each facility.

Data was collected during site visits to the referenced units, during which documents and photographs were gathered to support the study's conclusions.

The assessment and certification process consisted of ten stages, covering the most relevant aspects of the analysis. These stages were organized in the most appropriate logical sequence for this type of evaluation, systematically structuring the various processes, as follows.

### Definition of the elements of the assessment

Chosen according to the RDC 50, these elements respect parameters that encompass HF different typologies. According to the norm, the elements chosen are crucial to guarantee the proper operation of the buildings and a functional and safe environment, in accordance with the following aspects:

• *Aspect:* assessment of the aesthetic maintenance of the environment.

• *Functionality*: analysis of flows and organization of spaces.

• *Safety*: compliance with safety and accessibility norms.

• *Environmental conditions to control infections*: assessment of the environmental requirements that minimize the risk of infections.

• *Physical and functional organization*: structure and physical disposition of indoor elements.

• *Building dimensions and facilities*: adjustment of dimensions and technical systems to ensure the proper operation of services.

## Assessing the conservation status (C)

The facilities are classified according to Heidecke's criterion by linking a Depreciation Coefficient (C) to the conservation status. The criterion results from the understanding that, throughout a building's lifespan, its conservation status will define future damage. There are nine conservation status proposed, (New = 0,000; Between new and regular = 0,003; Regular = 0,025; Between regular and simple repairs = 0,081; Simple repairs = 0,181; Between simple and important repairs = 0,332; Important repairs = 0,526; Between important repairs and no value = 0,752; and No value = 1,000), which will ascertain the qualitative and quantitative correlation that helps visual inspection (Oliveira; Pantoja, 2021).

## Building inspection using the $GUT_C$ Methodology

Proposed by Oliveira and Pantoja (2021), this model stands out for being easy and fast to apply in situations demanding problem solutions and risk management. Each element of the matrix (Severity (G), Urgency (U) and Tendency (T) has its own function and it is assessed for each attribute being inspected, showing the impact and intensity of building damage, the mean time to repair and potential to aggravate. Afterwards, there is a qualitative description of the damage with its respective score, according to each element criterion.

The values to Severity, Urgency and Tendency may reach five different levels, with weight and rate (None = 1; Low = 3; Average = 6; High = 8; and Total = 10). The rate and score matrix have specific criteria for each level (Oliveira; Pantoja, 2021). $GUT_C$ final value is calculated through the following equation (1):

$$GUT_C = \frac{(G+U+T)*(1+C)}{60} \qquad (1)$$

Where:

G = Weight adopted for severity

U = Weight adopted for urgency

T = Weight adopted for tendency

C = Heidecke conservation status

### Assessing cultural importance ($I_{sc}$)

Cultural importance is assessed as proposed by Guimarães (2021), using the seven criteria for heritage relevance developed by New South Wales Heritage Council, Australia (NSW). The variables analyze the values and their correlation with the history of the city, quantifying values concerning usage, economic appeal, history, artistic, cultural, symbolic and antique heritage.

For each value there are specific guidelines for inclusion or exclusion, which indicate how the assessment must be carried out. Therefore, *value* concerns the different qualities, features, meanings, perceptions or connections assigned to the elements to be maintained, including buildings, objects, places or landscapes.

For its qualifications, each value may receive a score of 1 to 0. The scores for each attribute are added up, resulting in the scale indicator that varies from 0 to 7. Afterwards, the value rate of each attribute is calculated, adding one weight for each, considering the relevance of each attribute to the building. The resulting value for $I_{sc}$ defines the level of relevance (Invasive = 0; No relevance = 1; Some relevance = 2 a 3; Considerable relevance = 4 a 5; Outstanding relevance = 6 a 7).

### Assessing patrimonial importance ($I_p$)

The weighted average of $I_{sc}$ multiplied by the weight of the assessed attribute in relation to the highest value results in a value between 0 and 1 equivalent to the patrimonial importance, which indicates the importance according to the importance indicator. Ip is parameterized, being 0 the value related to the real estate without patrimonial relevance and 1 the value related to the real estate with maximum patrimonial representation for that social group.

The importance ranges according to $I_p$ are: No importance = 0; Minor importance = 0,00 < $I_{sc}$ ≤ 0,25; Moderate importance = 0,25 < $I_{sc}$ ≤ 0,50; High importance = 0,50 < $I_{sc}$ ≤ 0,75; Very high importance = 0,75 < $I_{sc}$ ≤ 1,00 (Oliveira, 2023).

## Assessing damages (ID)

Damages are assessed during the inspection of the building when flaws, the evaluation of intensity, extension of damages and the condition are determined.

The parameters used to classify the importance of the flaws are mild, severe or critical. The intensity ranges from 1 to 3, i.e., minor, moderate or high. The extension varies from 1 to 5, with five levels of percentage rating (<2; 2 - 10; 10 - 30; 30 - 70; e ≥ 70). The parametrized condition is classified after a matrix that correlates the flaw and its intensity to the extension of damages, resulting in six possible ranges of classification (0,17; 0,33; 0,50; 0,67; 0,83; e 1,00), with its respective description: abysmal; severe; bad; regular; good; and excellent.

To establish how much intervention on the elements is necessary, there is an assessment of the main elements (DM), whose value is determined by the ratio between the different scores rate of the element conditions and the highest score of these conditions.

Next, it is calculated the assessment of the damages of the general elements (DG), which is the ratio between the sum of each element damage score and the sum of the maximum scores of damages.

As a result, there is the value for the damage indicator (ID), which places the building among three ranges of reference (ID < 0,40; 0,40 < ID < 0,55; e ID > 0,55), corresponding to three levels of damage: non-existent or weak; moderate; and very important. The ID is calculated through the following equation (2):

$$ID = 1 - \sqrt{\left(\frac{(1-DM)^2 + (1-DG)^2}{2}\right)} \qquad (2)$$

Where:

DM = Damage of main elements

DG = Damage of general elements

To classify the condition and the extension of the damage, each element must also be assessed according to the need of intervention and extension of the spotted problem. This score varies from 0 to 3 (Oliveira, 2023).

## Establishing the performance factor (D)

After calculating the damage indicator (ID), Oliveira (2023) proposes four equations to measure the performance factor (D), according to the features of the buildings to be evaluated and their purpose of usage, as follows: minimum ($D_M$), intermediate ($D_I$), superior ($D_S$), and special ($D_E$).

A property is considered of minimum performance when there is low investment concerning the quality of project, material and construction. It is seen as a low-endurance building, aimed at temporary occupation and doomed to go through more intense maintenance cycles, when compared to high-performance properties. The same reasoning is applied to properties of intermediary and high performances, which require higher criteria and investments at the initial phase of their life cycle (Oliveira, 2023).

On the other hand, properties of special performance propose studies concerning the cycles of maintenance and conservation, aiming at maximizing the quality of projects, materials, executive processes and preventive maintenance, avoiding damages. This group includes cultural patrimonies, bridges and overpasses of high importance, healthcare facilities, airport areas and other complex installations. The common characteristic in this group is that interrupting the service of such buildings would result in significant losses to the owners, whether private or public (Oliveira, 2023). The special performance curve is presented by the following equation (3):

$$D_E = -2{,}6868*(ID)^3 + 4{,}3466*(ID)^2 - 2{,}6683*(ID) + 1{,}0000 \qquad (3)$$

Where:

ID = Damage Indicator.

## Estimating a building lifespan (ESL)

The reference lifespan represents the estimate lifespan of the component or system, considering a projection of ideal usage and maintenance, i.e., it is an estimated period through which a component or system must function under ideal usage and maintenance conditions (ISO, 2008).

This value is calculated based on the Factorial Method presented by ISO 15686-8:2008 regulation, which evaluates components or systems in certain conditions of usage. It is expressed through a formula based on seven variable factors that affect the reference lifespan of the component under analysis (Meira; Zanoni, 2020). ISO 15686-8:2008 factors are: Component quality level (Factor A); Project quality level (Factor B); Execution quality level (Factor C); Indoor environment characteristics (Factor D); Outdoor environment characteristic (Factor E); Usage conditions (Factor F); and Level of maintenance (Factor G) (ISO, 2008).

There is the attribution of numerical values (0,6; 0,8; 1,0; 1,2) to quantify the factors, according to criteria previously specified for the value of each one during the evaluation (MEIRA; 2019).

Factors A, B and C are related to the inherent characteristics of building elements. Factors D and E are related to environmental, indoor, and outdoor conditions, respectively. Factors F and G concern the conditions of operations/maintenance. The estimated lifespan is the result of the evaluation of all seven factors.

### Integrated model to assess quality and performance ($I_{QD}$)

Combining all variables into one indicator, it is possible to assess and certificate the buildings, with emphasis on their performance, while considering cultural, historical and longevity aspects, using the Quality and Performance Indicator ($I_{QD}$), presented in the following equation (4):

$$I_{QD} = 0{,}9*D + 0{,}1*\left(\frac{I_{sc}}{7} + I_p + \frac{ESL}{1{,}2^7} - GUT_C - ID\right) \quad (4)$$

Where:

D = Performance indicator

Isc = Cultural relevance

Ip = Patrimonial importance

ESL = Lifespan estimative

GUTC = Assessment using the GUTC methodology

ID = Damage indicator

The formula prioritizes the performance factor, with corrections based on cultural relevance, patrimonial importance, estimated lifespan, the urgency of necessary interventions and damage indicator, resulting in one unique indicator for the certification.

## Certification

The certification is a formal process that legitimates that a construction is in conformance with established standards, boosting building quality, safety and sustainability. For HF, the certification gains an even further relevant role, considering the direct impact on users and professionals well-being and safety. There are several certification models that might be applied, including specific ones concerning sustainability, like LEED (GBC, 2024) and Aqua-HQE (Vanzolini, 2024), which assess criteria such as energetic efficiency and rational use of natural resources. In the Brazilian context, PBE Edifica (PBE Edifica, 2024) is a reference in the classification of energetic efficiency, while Anvisa's RDC 50 establishes essential parameters for the architectonic and functional planning of healthcare facilities.

Besides ensuring technical compliance, the certification adds strategic value to the HF management. Models such as ISO 9001 (ABNT, 2015), aimed at quality management, enhance the standardization of processes, while systems such as WELL Certification (Well, 2024) covers health and well-being aspects of the built environment. In historical buildings, certifications concerning patrimonial conservation recognize and value cultural relevance, ensuring the preservation of meaningful architectonic elements.

Therefore, the certification process not only ensures physical and functional quality of the buildings but also strengthens their sustainability, increases their lifespan and optimizes the planning of preventive and corrective interventions, being in accordance with the principles of efficient management and respecting the technical and regulatory norms.

This work uses the certification model proposed by Oliveira (2023), considering the causes and effects between damage and performance, making use of the value of reference provided by IQD. Such value, in percentage, classifies the building in one of the performance ranges, from A to E.

Category A ($D_E$ > 95%) includes new or refurbished properties, in an excellent state of conservation and minor visible damage. Category B (80% < $D_E$ < 95%) includes semi new properties in good state of conservation, with simple repairs that compromise neither their aesthetic nor their safety. Category C (60% < $D_E$ < 80%) includes properties that require specialized intervention due to visible flaws in their systems. Category D (40% < $D_E$ < 60%) includes properties that require severe intervention and present perceptible damage that affects safety. Category E ($D_E$ < 40%) includes properties with significant damage that require further analysis before possible refurbishments or their reuse.

After ranking the building based on their quality and performance indicator, it is possible to design a certification label that best represents the overall situation of the building and its components. The label follows the model proposed by PBE Edifica (2024), with adjustments, as presented after each case study analysis.

## Case study # 1

The building chosen was the *Super Centro Carioca de Vacinação* (SCCV), in Rio de Janeiro – RJ, which operates in the same building where *Desinfectório de Botafogo* was launched, in 1905. Just like *Castelo Mourisco da Fiocruz*, it was conceived by Oswaldo Cruz and built by architect Luiz Moraes Júnior.

The building is also home to the *Observatório Carioca de Atenção Primária e Vigilância em Saúde*, responsible for managing the registration carried out by the Family and Health Teams and for integrating the operations of primary attention and health surveillance; and to the *Centro de Referência de Imunobiológicos Especiais* (CRIE), which provides specialized assistance to people with congenital immunodeficiency, HIV, neurological diseases, heart diseases, lung diseases, and blood diseases, as well as those who have undergone transplants and people who are intolerant to common immune biologic therapies due to allergies or for being in contact with immunosuppressive people, like health professionals and immunosuppressive relatives. Moreover, CRIE supports the investigation of suspicious cases of adverse events after vaccination.

SCCV operates in a single structure building with two floors. It presents eclectic architectonic style and is built with two basic systems: (i) granite block and whale oil plaster masonry; and (ii) solid tile brick with traditional plaster masonry. The window frames are made with solid wood and cast iron, with handicraft glass panes. The roof is made of wood weaves and clay tiles.

This historical building is in Botafogo neighborhood, and its initial purpose was to shelter a leading unit to fight diseases such as bubonic plague, tuberculosis, cholera and yellow fever. Now, after its revitalization, the building is used as an immunization center, increasing the population access to vaccination.

The building's original floor plan, shown in Illustration 1, had thick walls and spaces with a great number of openings to favor natural light and ventilation, besides optimizing people's flow. The users would access the building through one side and exit through another, to avoid contact with those waiting for their appointment.

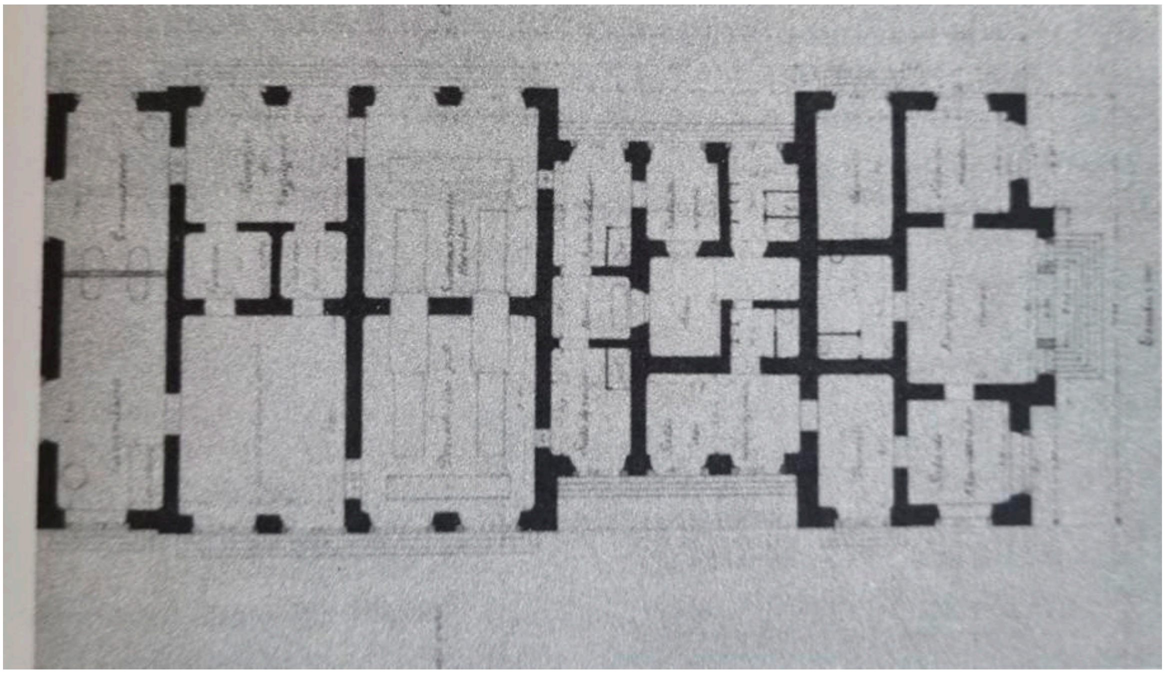

**Illustration 1.** *Desinfectório de Botafogo* floor plan, in 1905. Source: Rede OTICS-Rio.

With a smart communication between spaces, this building translates the mastery of architect Luiz Moraes Júnior, besides showing how, back then, the quality of healthcare buildings was already a strategy to control environmental infection.

To fulfill the needs of the new vaccination service, the building went through a complete refurbishment throughout 2022. The repairs preserved the building's original features, such as architectonic elements and building systems, which were integrated into a modern and functional structure. The operation combined tradition and contemporaneity, preserving the location's historic and cultural patrimony. Illustration 2 shows the current main façade of the building (northwest).

**Illustration 2.** Main façade of SCCV, in 2023. Source: Rio de Janeiro Municipal Health Department.

The building was reopened on January 28, 2023, as the *Super Centro Carioca de Vacinação*, 118 years after *Desinfectório de Botafogo* had gone into service. It is noteworthy that the general structure of spaces has hardly changed through decades of use, although handling the most diverse functions.

The physical and functional program of the establishment is customized and adapted to the specific needs of the location. Its responsibilities and activities are combined to offer a customized facility that ensures efficiency and suitability to the reality of the community to which it belongs.

Among the general responsibilities and activities developed at the *Super Centro Carioca de Vacinação*, according to RDC 50 classifications and observed during the technical visit, there are: ambulatory elective appointments aimed at health promotion and assistance; activities concerning health promotion and surveillance, and prevention against diseases in the community, with scheduled patient appointments and follow-ups; human resources and research development; appointments directly or indirectly related to health assistance and surveillance, concerning both teaching and research; supporting activities for administrative management and operation; and administrative support to the building.

## Results from case study #1

SCCV building was ranked as between new and regular, according to Heidecke's maintenance status. Even though its 119 years of usage, the maintenance employed in the building over a century  kept its functional capability.

The Isc 5 resulted from the values of usage, historical, artistic, cultural, and symbolic. For each element of the building, there were the following weights: façades = 0,30; structural system = 0,35; architectonic project = 0,20; and implementation = 0,15. From the $I_{sc}$ rate and the weight applied to each system, the building global Ip reached 0,71, suggesting that the building has high patrimonial importance, ranking in the classification range of $0{,}50 < I_{sc} \leq 0{,}75$.

After carrying out the building inspection and assessing the criteria for factors A to G, each factor received the following values: Factor A = 1,2; Factor B = 1,0; Factor C = 1,2; Factor D = 1,0; Factor E = 1,0; Factor F = 1,2; and Factor G = 1,0. The values together result in ESL = 1,728.

The building inspection was carried out under the Term of Technical Responsibility CRT/RJ CFT2403513830; the visits to the place took place on 2/8/2024, 5/20/2024 and 5/21/2024. The building's final $GUT_C$ value was 0,0657, which corresponds to the arithmetic rate of the value of all elements assessed.

The value found for the damage of the main elements of the building equals 0,1111; and the value found for the damage of the general elements equals 0,1333. Therefore, the structure damage Indicator is 0,1221, or 12,21%, classifying the structure damage as inexistent or weak. Consequently, the value for the special performance of the structure is 0,7341, or 73,41%.

Employing the values found for performance, cultural relevance, patrimonial importance, estimated lifespan, $GUT_C$ evaluation and damage indicator, it is possible to calculate SCCV's quality and performance indicator as 0,8325, or 83,25%.

On that ground, SCCV certification falls to category B for quality and performance, with an IQD of 83,25%.

Table 3 presents the values for each parameter assessed, the value for the quality and performance Indicator, and the corresponding range of certification.

| Element assessed/certified | | SCCV |
|---|---|---|
| Heidecke's conservation status (C) | | Between new and regular (0,003) |
| Building inspection using $GUT_C$ methodology (overall rate) | | 0,0657 |
| Cultural relevance ($I_{sc}$) | | Considerable relevance (5) |
| Patrimonial importance ($I_p$) | | 0,71 |
| Degradation of main elements (DM) | | 0,1111 |
| Degradation of general elements (DG) | | 0,1333 |
| Degradation indicator (ID) | | 0,1221 or 12,21% |
| Performance factor (D) | | 0,7341 or 73,41% |
| Estimated lifespan of the building | | 1,728 |
| Quality and performance indicator ($I_{QD}$) | Physical and functional organization | 69,17% |
| | Building dimensioning, quantification and facilities of spaces | 69,17% |
| | Aspect | 73,44% |
| | Functionality | 70,01% |
| | Safety | 70,61% |
| | Environmental conditions to control infection | 71,22% |
| | Overall | 83,25%<br>B (80% < $I_{QD}$ < 95%) |

**Table 3.** SCCV's parameters assessed and certification ranges.

Illustration 3 presents SCCV's certification label in category B for quality and general performance.

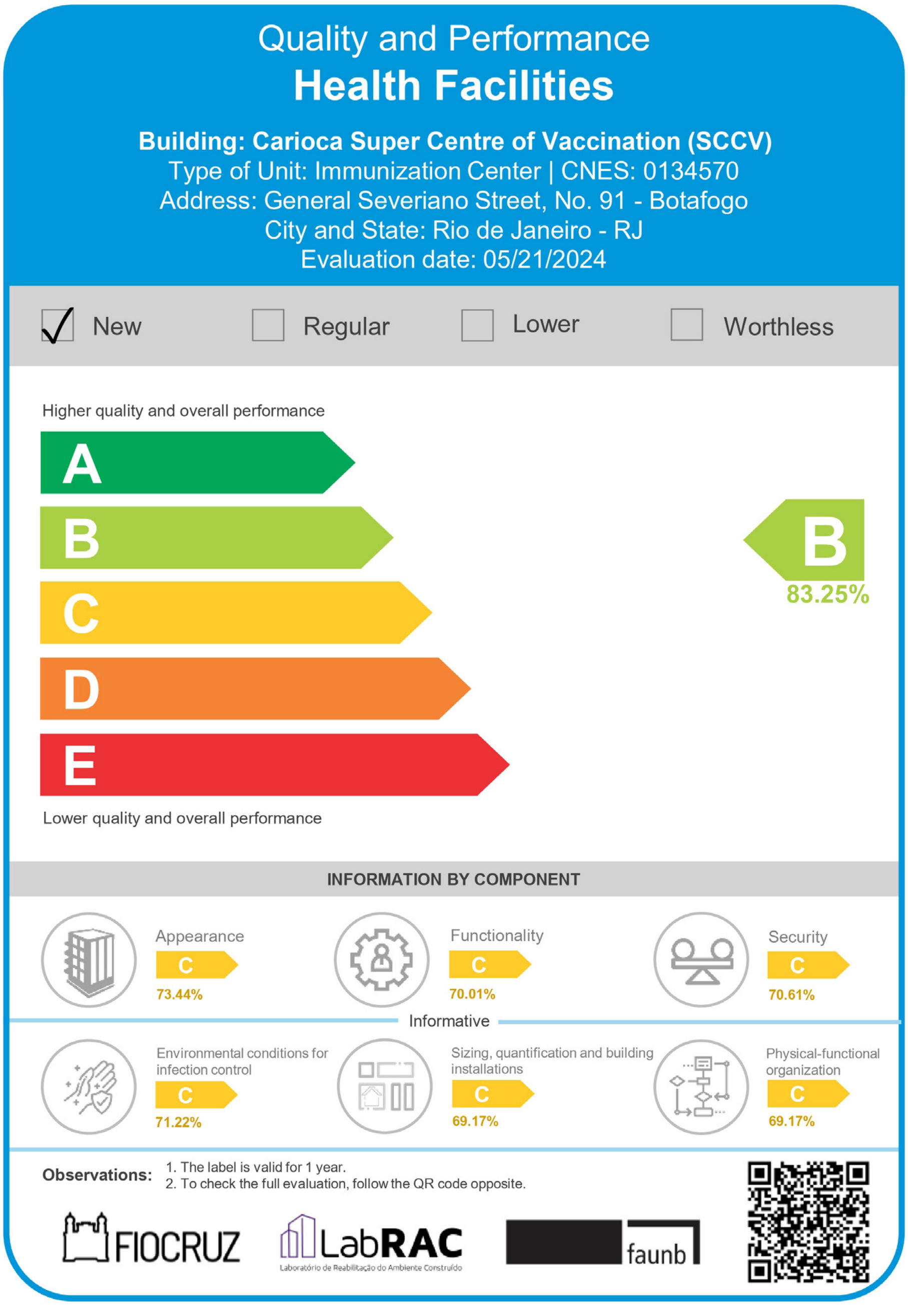


**Illustration 3.** SCCV's label of certification. Source: Designed by the author based on the model proposed by PBE Edifica (2024).

## Discussion of case study #1

The conservation status of SCCV shows low degradation of main and general elements (ID 12,21%) and meaningful performance factor (73,41%). Overall, it means that, although SCCV is operating in a 119-year-old building, the need for intervention and the level of urgency is low. The building possesses good cultural relevance and patrimonial importance ($I_{sc}$

de 5 e $I_p$ de 0,71), which requires special treatment concerning its historical valorization and preservation. Moreover, its estimated lifespan is high (1,728), reflecting a higher structural stability and lower need to carry out short-term corrective interventions. As to its certification, SCCV was ranked in the B range of general quality ($I_{QD}$ de 83,25%), suggesting that the facility is close to reaching standards of excellence.

SCCV highlights the importance of preserving the architectonic patrimony in the city of Rio de Janeiro. The building not only represents a landmark for Brazil's public health but also reflects the rich historical and cultural heritage that shapes Rio de Janeiro's identity. Preserving this space is a way to reaffirm the commitment with the valorization of the patrimony as a public asset, enhancing the bond of the population with its history, increasing the access to quality healthcare services.

In Rio de Janeiro, historical architecture is an indissociable part of the urban imaginary and landscape, hence the importance of initiatives that combine the preservation with the functionality of healthcare centers to ensure sustainable urban growth and social well-being.

## Case study #2

In 2016, Distrito Federal carried out the National Public Bid for Architecture and Complimentary Projects for the Basic Health Unit 5 of Riacho Fundo II (UBS-5), at Riacho Park Residential. Offered by Distrito Federal's Company for Living Development (Codhab – DF), the bid chose Preliminary Study #270 as winner, which resulted in UBS-5, chosen for this case study. Opened on January 1st, 2021, it was soon named the biggest in Brazil (DF, 2021), being recognized internationally for its modern and conceptual architectonic standards (Souza, 2017).

Built with modernist architectonic style, UBS-5's foundation and floor slab are made of reinforced concrete. The pillars and the structure that supports the roof are metallic. The indoor partition walls are made of thermoacoustic and waterproof compounds, coated with clay, when necessary, and the window frames are made of aluminum. The unit was designed and built within just one pavement, being organized into three modules comprised of rectangle blocks with indoor yards.

Illustration 4 shows the aerial view of the unit, where it is possible to see its three modules.

**Illustration 4.** Aerial view of UBS-5, from its left elevation (northeast)
Source: Saboia+Ruiz Architects

Among the general responsibilities and activities developed at UBS-5, according to RDC 50 classifications, there are: ambulatory elective appointments aimed at health promotion and assistance; activities concerning health promotion and surveillance, and prevention against diseases in the community, with scheduled patient appointments and follow-ups; human resources and research development; appointments related to health assistance and surveillance concerning both teaching and research; supporting activities for administrative management and operation; and logistics support.

## Results from case study #2

UBS-5 was classified as a *regular* building, according to Heidecke's conservation status. This classification results from the failures found in the building due to defective maintenance throughout its three years of usage since the opening.

Considering patrimonial values, the $I_{sc}$ was 2, since only the values of usage and artistic received scores. The following weights were as follows: façades = 0,30; structural systems = 0,35; architectonic design = 0,20; and implementation = 0,15. The $I_{sc}$ rate and the weight given to each system led to a building global Ip of 0,23, suggesting that the building has little patrimonial importance, being ranked in the range of classification 0,00 < $I_{sc} \leq 0,25$.

After assessing the criteria that granted values for A to G factors, the following values were given: Factor A = 1,0; Factor B = 1,2; Factor C = 1,0; Factor D = 1,0; Factor E = 1,0; Factor F = 1,2; and Factor G = 1,0. The result of the values leads to an ESL = 1,44.

The building inspection was carried out under the Term of Technical Responsibility CRT/ DF CFT2403672375; the place was visited on 7/16/2024. The building's final GUTC value was 0,1887, which corresponds to the arithmetic rate of the value of all elements assessed.

The value found for the damage of the main elements of the building equals 0,5555; and the value found for the damage of the general elements equals 0,0667. Therefore, the structure damage Indicator is 0,2690, or 26,90%, classifying the structure damage as inexistent or weak. Consequently, the value for the special performance of the structure is 0,5445, or 54,45%.

Employing the values found for performance, cultural relevance, patrimonial importance, estimated lifespan, GUTC evaluation and damage Indicator, it is possible to calculate UBS-5's quality and performance Indicator as 0,5360, or 53,60%.

On that ground, UBS-5 certification falls to category D for quality and performance.

Table 4 presents the values for each parameter assessed, the value of the quality and performance, and the corresponding range of certification.

<table>
<tr><th colspan="2">Element assessed/certified</th><th>UBS-5</th></tr>
<tr><td colspan="2">Heidecke's conservation status (C)</td><td>Regular (0,025)</td></tr>
<tr><td colspan="2">Building inspection using $GUT_C$ methodology (overall rate)</td><td>0,1887</td></tr>
<tr><td colspan="2">Cultural relevance ($I_{sc}$)</td><td>Some relevance (2)</td></tr>
<tr><td colspan="2">Patrimonial importance ($I_p$)</td><td>Small (0,23)</td></tr>
<tr><td colspan="2">Degradation of main elements (DM)</td><td>0,0227</td></tr>
<tr><td colspan="2">Degradation of general elements (DG)</td><td>0,5555</td></tr>
<tr><td colspan="2">Degradation indicator (ID)</td><td>0,0667</td></tr>
<tr><td colspan="2">Performance factor (D)</td><td>0,2690 or 26,90%</td></tr>
<tr><td colspan="2">Estimated lifespan of the building</td><td>0,5445 or 54,45%</td></tr>
<tr><td rowspan="7">Quality and performance indicator ($I_{QD}$)</td><td>Physical and functional organization</td><td>49,83%</td></tr>
<tr><td>Building dimensioning, quantification and facilities of spaces</td><td>48,83%</td></tr>
<tr><td>Aspect</td><td>49,35%</td></tr>
<tr><td>Functionality</td><td>49,07%</td></tr>
<tr><td>Safety</td><td>48,12%</td></tr>
<tr><td>Environmental conditions to control infection</td><td>48,96%</td></tr>
<tr><td>Overall</td><td>53,60%<br>D (40% < $I_{QD}$ < 60%)</td></tr>
</table>

**Table 4.** UBS-5's parameters assessed and certification ranges

Illustration 5 presents UBS-5's certification label in category D for quality and general performance.

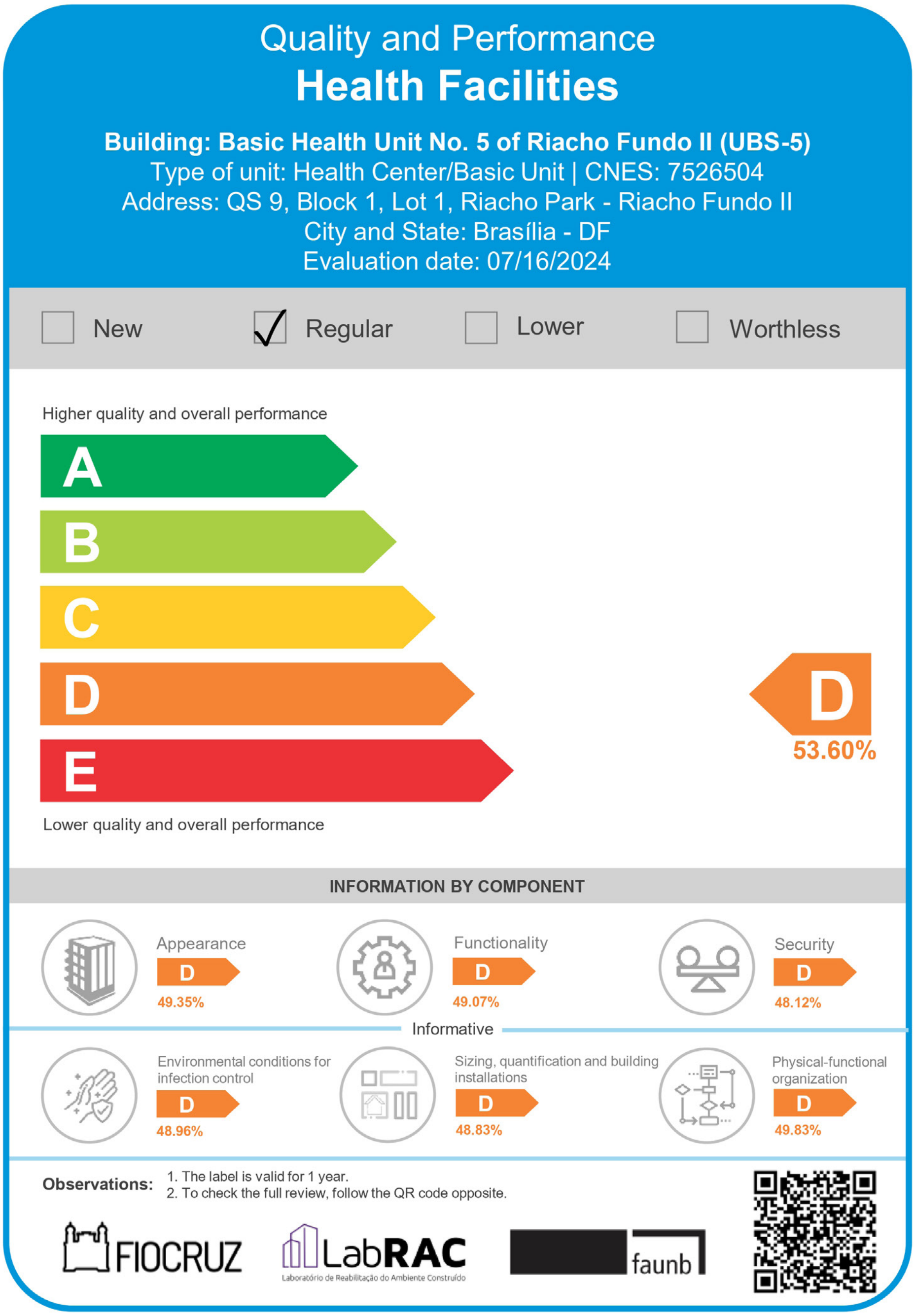


**Illustration 5.** UBS-5's label of certification. Source: Designed by the author based on the model proposed by PBE Edifica (2024).

## Discussion of case study #2

UBS-5 presented the status of conservation with damages on both main and general elements (ID de 26,90%), besides intermediate performance factor (54,45%), requiring low-urgency level interventions, possibly due to the lack of preventive maintenance. The cultural relevance and the patrimonial importance are low ($I_{sc}$ de 2 e $I_p$ de 0,23), and the estimated lifespan is high (1,44). As to its certification, UBS-5 was ranked in range D concerning general quality ($I_{QD}$ de 53,60%), indicating that the facility must undergo improvements to achieve the appropriate level of quality and performance.

The vulnerabilities in the conservation process of this health center defy the State commitment towards the valorization of patrimonies as public assets, besides failing in ensuring access to quality healthcare services.

Therefore, providing UBS-5 with excellent levels of maintenance concerning its quality and performance shows high regard towards the public health in Distrito Federal, besides highlighting the importance of preserving a built patrimony.

## Conclusions

The proposed method is a viable and efficient alternative to assess and certificate healthcare buildings, since it allows a comprehensive assessment of the conservation status, the performance and the sustainability of buildings, providing a solid basis for decision-making process concerning the management and maintenance of such spaces.

Besides treasuring the cultural patrimony, a high-quality and safe physical environment has a positive impact on how users engage with healthcare services, leading to more regular access to preventive care. This quality not only improves users' experience but reinforces the population commitment with their health, leading to prevention and ongoing care.

The impact of caring for the quality of the built environment translates into a more efficient healthcare service, boosting the system's response to the needs of users. Therefore, SUS benefits from a more resilient infrastructure and planning that gives thorough and ongoing support to the health of the population, aligned with the principles of universality and equity.

The research highlighted the relevance of carrying out preventive maintenance in these buildings, in accordance with normative standards and building inspection processes, aiming at increasing their lifespan. Consequently, a proper assessment of the shape of structures may avoid high costs in the future and might guarantee a safer environment for users and workers.

The building certification is intrinsically connected to the improvement of the services offered in such facilities, since it enables safer, more comfortable and more suitable spaces for users and professionals, impacting positively the quality of health assistance.

After analyzing the components individually and the system in general, it was possible to observe that, when working together, built systems perform better than their elements separately.

Upon applying the method to rather different buildings it was possible to see that it may be adapted to different typologies of healthcare facilities, enabling its use to the most diverse contexts with minimum adjustments, enlarging the applicability of the proposed methodology, hence enhancing its efficiency as a tool.

The results also emphasize the role of the method as a practical tool to guide sustainable and efficient interventions in healthcare facilities, contributing to the urban management and the valorization of the public patrimony.

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Article

# Hospital Architecture Responsive to Neurodiversity

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## Abstract

This study investigates neurodiversity in hospital environments, focusing on the specific needs of neurodivergent children, particularly those with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). An integrative literature review examines the influence of these conditions on the hospital experience and identifies inclusive design strategies to address them. Case studies of pediatric hospital projects are presented to demonstrate the practical application of such strategies. The findings propose recommendations for responsive design in pediatric healthcare, emphasizing environmental clarity, predictability, and user control to improve the experience of neurodivergent patients and their families. The study underscores the need for continuous evaluation and adaptation of these guidelines across diverse contexts, fostering design approaches that enhance effectiveness, empathy, and inclusivity in pediatric care.

## Keywords

Hospital environments, Design, Children, ASD, Neurodiversity

## Introduction

The pain caused by medical procedures gains a potentially traumatic dimension when experienced by children in healthcare contexts (Trottier *et al.*, 2019). Painful situations are recurrent in hospitals and ambulatory environments, which include diagnosis, vaccination, blood draw and surgical procedures of minor complexity (Stevens *et al*., 2011). Although vital for prevention and treatment situations, such techniques cause anxiety, pain and distress in children, their relatives and healthcare professionals (Dewan *et al*., 2023). To improve comfort and mitigate discomfort, healthcare professionals must be aware of the different needs, including those concerning neurodiversity among children and teenagers.

In the context of neurodiversity within hospital environments, it is fundamental to recognize the diversity of neurological conditions, which encompass 15% to 20% of all neurodivergent cases, according to the Centers for Disease Control and Prevention (2022). Among such conditions, there are the Attention-Deficit/Hyperactivity Disorder (ADHD), the Autistic Spectrum Disorder (ASD), dyspraxia, and dyslexia, whose varied impact may lead to different sensorial sensibilities (Doyle *et al*., 2020).

Neurodivergent children usually face additional health complexities that increase their length of stay at medical facilities. For instance, autistic children might present gastrointestinal disorders, epilepsy and chronic sleeping disorders, associated with severe risks of anxiety and depression, which particularly escalated during the pandemic. Therefore, to conceive inclusive healthcare environments, efficient design strategies focus on offering choices, reducing sensorial stimuli and simplifying the medical care experience, covering elements such as intelligibility, predictability, accessible orientation and contact with nature.

Moreover, allowing children more control over their immediate surroundings is essential to minimize their stress during medical appointments, which may be reached by enabling lighting control, suppressing noisy devices, providing individual control of temperature, and developing therapeutic ambiences with mobility and comfort options. For pediatric medical practices, physical design, operational strategies and technological innovations share major roles in providing positive experiences to neurodivergent patients and their families. This encompasses using mobile applications, spatial navigation guides, and virtual tours, as well as reducing interpersonal interactions whenever appropriate.

Thereby, an inclusive architecture not only benefits neurodivergent children but also offers gains for everyone, thus promoting more coherent, penetrable and flexible environments, which can be adapted to the different needs of patients under pediatric care.

### Neurodiversity: concepts, typologies and problems within hospital environments

Neurodiversity is a concept coined in 1999 by Australian sociologist Judy Singer to describe the different ways in which the human brain is connected, which result in unique skills, needs and capabilities (Armstrong, 2011). Such variations impact social dynamics, cognitive operations, motor abilities, attention, sensorial stimuli, speech, language and learning. The rationale behind the choice of this term was to resemble the word biodiversity, highlighting not just one specific subgroup of individuals but the numberless variations of the human brain.

As the concept evolved, as described by Feinstein (2018), neurodiversity began to classify individuals as neurodivergent or neurotypical. Neurotypical refers to those who present ways of thinking and behaving that fall within the typical standards expected from society, while neurodivergent people develop differently from those standards, as shown in Illustration 1. Such categorization enables a more refined understanding of the different ways in which a brain works, allowing a foundation to discuss and approach the neurological variabilities in a more thorough and inclusive manner.

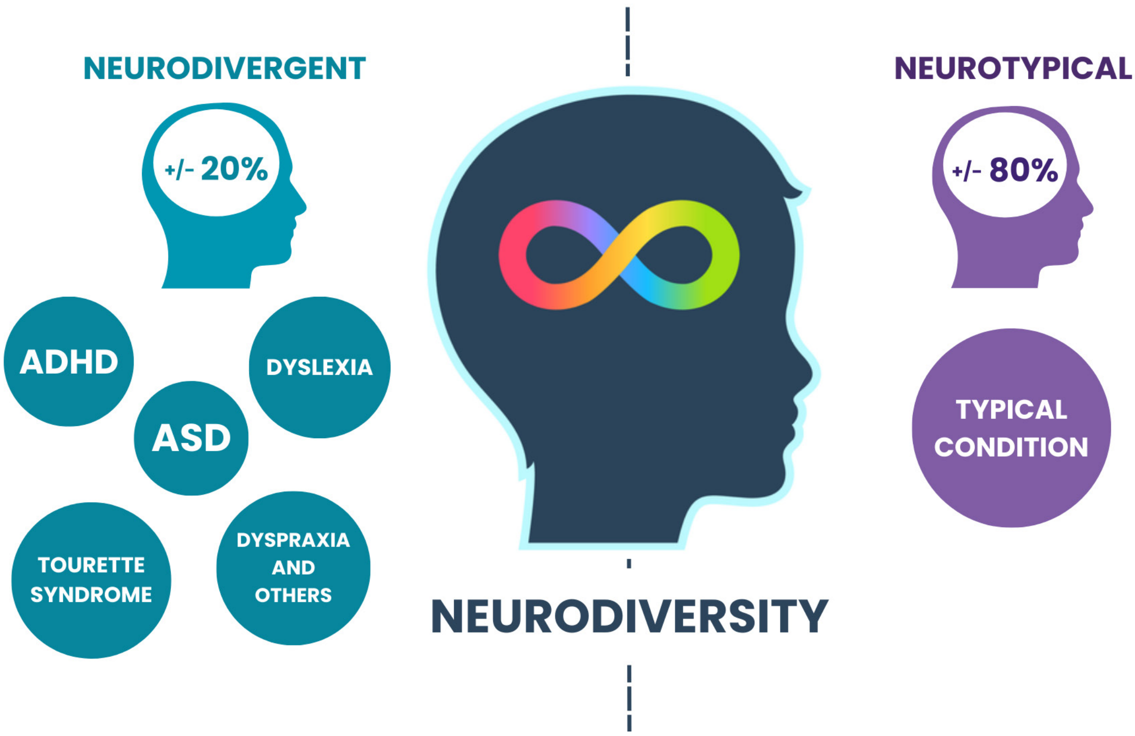


**Illustration 1.** Neurodiversity and its subgroups, neurotypical and neurodivergent.
Source: the author (2023).

Neurodivergent children present an atypical neurocognitive way of functioning, i.e., they function outside the expected rate, due to neurodevelopment disorders, genetic and environmental variables, among other likely causes. Even among those considered neurotypical, one out of four will face mental health problems, like depression or stress, at some point in life. Due to daily underdiagnosis cases, more than 50% of society is unaware of this neurological differentiation, undermining the respect and full integration of the neurodivergent population.

In the United States, progressive hospital directors are beginning to recognize that neurodiversity integration might significantly boost medical treatment, enabling hospitality and qualitative experiences within the healthcare facility, besides reducing the hospitalization time and the costs with painkillers. Such recognition is obvious at the Thompson Autism and Neurodevelopmental Center (CHOC) and the Medical University of South Carolina Shawn Jenkins Children's Hospital. It is noteworthy that this inclusive movement is boosting a series of more inclusive policies, programs and procedures, although the impact over the hospital architecture is still beginning.

In the chapter concerning anxiety, stress and depression in the hospital context, the COVID-19 Health Care Workers Study (HEROES) report, from 2022, revealed that between 14,7% and 22% of healthcare workers interviewed in 2020 showed symptoms that indicated one episode of depression, while between 5% and 15% had considered suicide. Additionally, the study indicates that, in some countries, just one third of professionals seek psychological help, even though they work in hospital facilities lacking inclusive infrastructure. In 2021, about 36% of Brazilian young population showed symptoms of depression and anxiety during the pandemic, according to a study carried out by the Medical School of University of São Paulo (FMUSP) with close to six thousand people ranging from 5 to 17 years old. According to the Pan American Health Organization (PAHO), depression is one of the main causes of disease and impairment among teenagers, in which suicide come as the third main cause of death between 15- and 19-year-olds. The consequences of not approaching mental health conditions during adolescence endure until adulthood, harming physical and mental health, besides limiting future opportunities. In this context, promoting mental health and preventing disorders are crucial so adolescents can blossom (OPAS, 2022).

Consequently, inclusive architecture must improve to welcome, treat and respect the biopsychosocial health of patients, healthcare professionals and other workers of hospital facilities. In that sense, the Design Based on Evidence (DBE), with emphasis on neuroscience applied to architecture, come as a promising project tool to develop hospital environments that are inclusive and suitable to its users.

The methodology used for this article is based on a comprehensive bibliographic review, approaching a wide range of academic and professional sources related to neurodiversity in hospital environments. Specific case studies from inclusive hospital projects were analyzed, including the Thompson Autism and Neurodevelopmental Center CHOC and the Medical University of South Carolina Shawn Jenkins Children's Hospital, which take into consideration the needs of neurodivergent children, as well as the design and operational strategies employed in such projects. Moreover, the method includes the proposition of practical guidelines for the employment of inclusive design principles in pediatric health environments, with the focus on enabling neurodivergent patients and their families to comprehend, predict and control the environment.

## Neuroscience applied to hospital architecture responsive to neurodiversity

According to Moser (1998), physical space has a major role in the influence over the behavior and development of neurodivergent people. In this context, the conception of a hospital environment must aim at creating pleasant feelings and adding to the progress of people facing several neurological conditions, as well as the well-being of their families.

To achieve this purpose, it is crucial to understand the impact of the built environment over neurodivergent sensorial processing. Therefore, it is necessary to know the importance of multisensorial architecture and its adjustments, specifically in therapeutic hospital centers. The ultimate goal is to develop responsive architectonic strategies supported by evidence and centered in the target population, which includes patients, relatives and healthcare professionals.

The environment aimed at the neurodivergent population demands an architecture project based on every user's sensorial processing needs. As emphasized by Mostardeiro (2019), individuals with diverse neurological conditions have their sensorial processing deeply affected. In *Designing for Autism Spectrum Disorders*, Ângela Bourne and other authors highlight that the neurodivergent population "shows different levels of environment sensibility, known as hypersensitivity and hyposensitivity, which encompass the five senses: hearing, sight, touch, smell and taste" (Bourne *et al*., 2016, p.4).

Within the context of sensorial perception, the differences in processing, as described by Grandin *et al.* (2015), indicate that such individuals interpret environmental stimuli differently, even though their senses operate normally. This difference in sensorial processing may lead to symptoms such as mental confusion, stress and discomfort.

Neurodivergent individuals interpret sensorial information from the external environment differently from neurotypical individuals – those with standard neurological development.

According to Gaines *et al.* (2016), sensorial integration, which comprises the perception of sensorial stimuli like touch, noise, smell, sight, movement (vestibular) and the position of the body in the space (proprioception), is key to understanding a situation and reacting efficiently. Such a skill enables the appropriate interpretation of the functionality of each environment within the built space (Illustration 2).

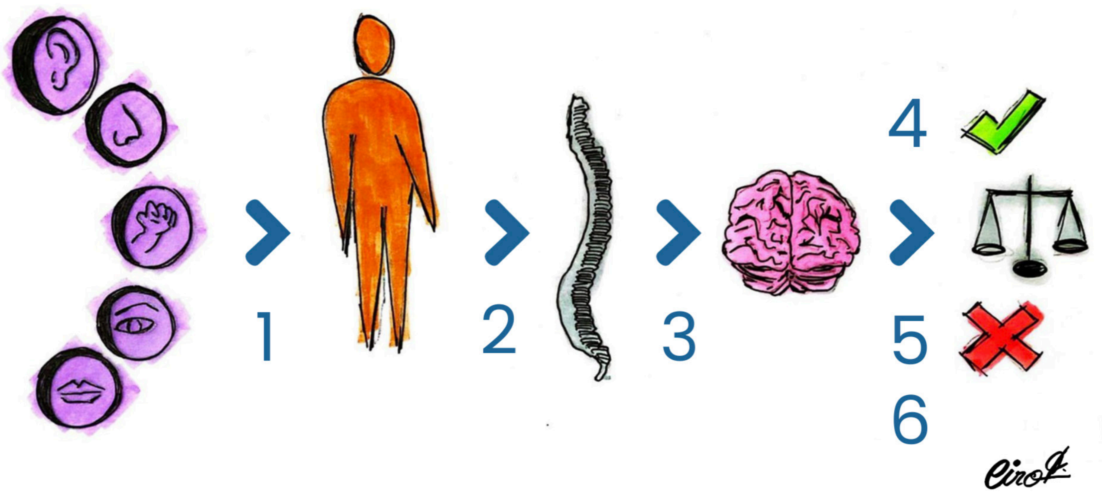


**Illustration 2.** Sensorial integration after combining the sensorial stimuli in the built environment. 1. The outside world (environment) interacts with the inner world (body, CNS) through sensorial receivers; 2. The peripheral nerves carry data to the spinal cord; 3. The information then goes to the brain through neural tracts present in the spinal cord; 4. Balanced level of sensorial information processed; 5. High level of excitement: superfluous sensorial information go through the brain "filter", causing excitement, confusion and distraction; 6. Low level of excitement: insufficient sensorial information are processed in the brain, causing distraction, delays and accidents. Source: the author (2023).

In neurodivergent individuals, the uniqueness of sensorial integration might be manifested as hypersensitivity or hyposensitivity, i.e., either an excessive or insufficient response to sensorial stimuli, respectively. For instance, a child might have an increased sensitivity to sounds (even the slightest noise may be disturbing) while being less sensitive to smells (sensing only strong smells). Consequently, Neumann *et al.* (2021), Aiochio and Queiroz (2020) and Mostafa (2010) describe some possible reactions concerning sensorial processing that the neurodivergent population may experience, as shown in Table 1.

| SENSORIAL PERCEPTION<br>CONCERNING THE DIFFERENT WAYS OF PROCESSING SENSES | | |
|---|---|---|
| SENSES | HYPOSENSITIVITY | HYPERSENSITIVITY |
| HEARING | They like resonant noises; might not answer when called; like to make loud and excessive noises. | They are sensitive to loud noises; can easily identify sounds; do not like background noises. |
| SIGHT | They do not perceive people and objects in the environment; only see contours of objects; like shiny colors or intense sunshine. | Shiny colors and intense sunshine bother them; they get easily distracted by spatial movements; stare at objects or people in certain situations. |
| TOUCH | They touch people and objects excessively and often unnecessarily (for those observing). | They are sensitive to certain fabrics; avoid touch and are bothered by them; they dislike being barefoot or wet. |
| TASTE + SMELL | They might ingest inedible objects; seek after strong smells; cannot perceive certain smells. | They are picky towards their food; choose textures before eating; like remarkable smells and temperatures. |
| PROPRIOCEPTIVE SYSTEM | They are unaware of their body's spatial position; might misunderstand different inner sensations as hunger. | They usually have a unique body posture; they might have difficulties in handling small objects. |
| VESTIBULAR SYSTEM | Their movements are usually excessive and unnecessary from the observer's perspective; they get excited with tasks that require movements. | They seem out of balance; it bothers them when their feet are not touching the ground or when they are upside down. |
| INTEROCEPTIVE SYSTEM | Their perception of body signs tends to be reduced, which might make it more difficult for them to recognize basic needs, such as hunger, tiredness or discomfort. The decreased perception might lead to the search for additional stimuli, to compensate for the lack of internal information. Therefore, their difficulty in identifying and responding to the needs of their own body might have a negative impact over emotional self-regulation, which will require specific strategies to enhance their sensorial | They usually show enhanced responses to internal stimuli, apprehending normal feelings in devastating ways. Their high responsiveness might lead to anxiety, irritability and avoidance behavior, since their body signs – like changes to their heartbeat or breath – are experienced disproportionately. Such difficulty in harmonizing the intensity of sensations may compromise their emotional regulation and hamper their adaptation to environments and daily situations. |

**Table 1.** Differences between hypersensitive and hyposensitive sensorial perception.
Source: Adapted from Neumann *et al.* (2021); Aiochio and Queiroz (2020); Mostafa (2010).

Exploring senses carefully and orderly through multisensorial architecture comes as a strategy to improve the treatment and social inclusion of neurodivergent individuals (Aiochio; Queiroz, 2020; Mostafa, 2010). Aesthetic, functionality and sensorial aspects must be properly harmonized to create a comfortable and cozy environment for the neurodivergent population, enabling pleasant interactions among patients, relatives, healthcare professionals and other workers inside the hospital.

In this context, the prevailing challenges found in hospital environments are channeled to the sensorial process of each user, i.e., it depends on how each user's central neural system manages the information received from the sensorial organs, such as visual, hearing, touch, taste, odor, proprioceptive, interoceptive, and vestibular stimuli (Machado *et al*., 2017). Neurodivergent patients are usually susceptible to either over or under stimulation depending on environmental factors, like lighting, sound, texture, smell, temperature, air quality or general feelings of safety. Any comprehensive approach to employing a neurodiverse design must consider such experience aspects within the hospital environment, mainly in pediatric units (Ozel *et al*., 2020).

Therefore, employing neuroarchitecture into hospital design enables spatial strategies capable of encompassing a wide range of neurological conditions found in healthcare facilities. Using an efficient approach to empower diversified uses in the place of assistance provides a feeling of control and autonomy through spatial choices (Bury *et al.*, 2020). Such freedom entitles both neurodivergent and neurotypical individuals to manage their own needs with dignity and autonomy. Versatile environments, which offer a range of preferences, highlight differences positively, fostering respect and integration. These environments also advance individual and operational adjustments, making it possible to reorganize the patient's space during his/her admission or therapeutic treatment, for example, as shown in Illustration 3.

**Illustration 3.** At Shawn Jenkins Children's Hospital, patient rooms were inspired by local beach houses, with wood floors, simple rugs and furniture. They are designed to encourage children to decorate their own rooms, with painted surfaces, shelves and desks. Source: perkinswill.com (2022)

Next, we highlight some concepts derived from neuroscience applied to architecture, also known as neuroarchitecture, which were identified as suitable for hospital units. Such concepts, taken from the literature review, concern the environmental variables: wayfinding and spatial organization, spatial choices, acoustic quality, thermal comfort, degree of stimulation, and lighting (Rosqvist *et al.*, 2020).

## Wayfinding and spatial organization

Wayfinding concerns the orientation and navigation around a built environment. An efficient wayfinding project must conceive an environmental design that enhances curiosity, reward, and exploration, while fostering pleasure upon discovery. Moreover, it must be intuitive, enabling visitors and regular residents to easily understand their location and find the desired way (Rosqvist *et al.*, 2020; Feinstein, 2018).

However, for individuals with neurodivergent conditions, such as ADHD and ASD, repetition, predictability and clear boundaries might offer a sense of safety. In this context, it is vital for the design to offer a legible spatial order. Efficient strategies for spatial design include creating spaces that trigger the memory through the rhythm of ordinary elements capable of causing a soothing feeling of order and, at the same time, avoiding the confusing repetition of spaces or identical features (O'Malley *et al.*, 2022).

Landmarks and focal points, like stairs or works of art, mezzanine floors and clear lines of sight, including outside views, are elements that can help users to find their way in the building (Illustration 4). Carrying out relevant variations in lighting in each environment may also be beneficial, since people have a natural tendency of going towards brighter areas (Illustration 5). The strategic use of materials, colors and signs also plays an important role in this context (Edelstein, 2005).

**Illustration 4.** The sensorial room at Shawn Jenkins Children's Hospital is aimed at the neurodivergent population. It presents different touch stimuli on the wall, with toys and shades of colors. Source: perkinswill.com (2022).

**Illustration 5.** At Shawn Jenkins Children's Hospital, the view to the main lobby was key for the design team to conceive a soothing space and reduce the environmental stress, besides providing natural lighting that varies throughout the day. Source: perkinswill.com (2022).

In complex environments, intelligible and consistent signs are imperative for some neurodivergent people. Concise messages, simple typography – sans serif – and information hierarchy are efficient strategies to alleviate visual overload. Consistent indications with messages with abundant colors, numbers and words provide multimodal assistance for a variety of users in the building while they head to their destinies (Illustration 6).


**Illustration 6.** At Shawn Jenkins Children's Hospital, the assistance sections are divided into colors, which are highlighted on the walls and on signs spread across corridors. Source: perkinswill.com (2022).

## Spatial choices

Hospital environments that provide a diversity of configurations offer their users the possibility to choose the most suitable space for their specific needs. Open and shared areas foster socialization, while smaller and closed spaces offer support and a sense of welcoming and individual refuge. Failing in providing such an opportunity in the management of spaces may result in a sensorial overload of sound and visual alerts, due to the noise from interactions and movements, adding to a stressful atmosphere for most users. Kaplan (1996) called this high demand for cognitive attention *mental fatigue*.

In this context, when patients' attention declines due to the overload of sensorial stimuli in the built environment, they tend to have more difficulty handling situations that trigger anxiety and stress. Studies emphasize that cognitive attention may be restored with direct or indirect resources from nature, like outside views, parks, gardens and forested pathways (Albuquerque *et al.*, 2016; Horn, 2016). This restoration process is explained in the *Attention Restoration Theory* (Kaplan, 1996).

By assessing restoring environments within neuroscience and environmental psychology, it is noteworthy that they present a series of sensorial aspects related to biophilia, i.e., the innate human being's need to be close to nature. The argument states that, once this contact with natural elements is carried out properly, it can foster qualitative cognitive, behavioral, emotional, and social experiences (Gressler, 2013). The restoring garden on the rooftop of Boston Children's Hospital, known as Longwood Rooftop Healing Garden (Illustration 7), stands out as an interesting example in hospital context.

**Illustration 7.** Aerial view of the Longwood Rooftop Healing Garden, the sensorial garden on the rooftop of Boston Children's Hospital. Source: Chi-athenaeum.org (2019).

Using technology in some spaces while keeping some tech-free zones gives additional options to enhance users' experience in the hospital environment. Besides enabling moments of breaks and reflection, such spaces offer relief from the several outside stimuli found in hospital corridors, as shown in Illustration 8. Such choices also allow people to find their own comfortable level of exhibition and social interaction (Horn, 2016).

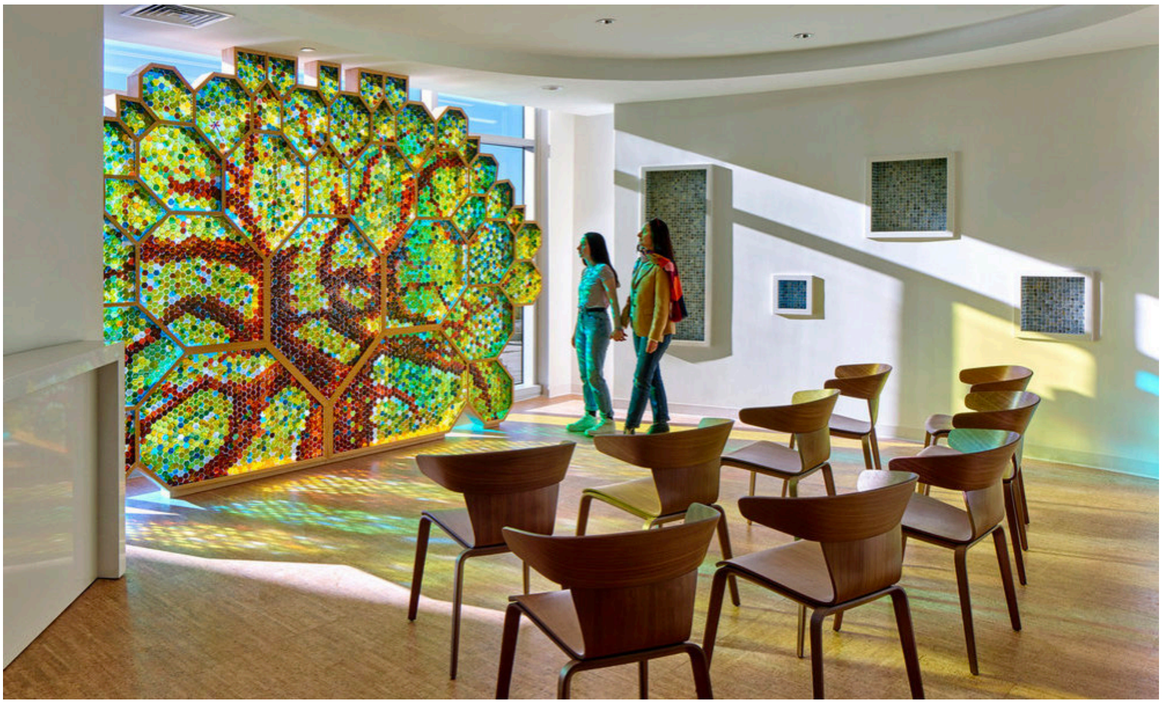

**Illustration 8.** Meditation room at Shawn Jenkins Children's Hospital. Source: perkinswill.com (2022).

## Acoustic quality and thermal comfort

The everyday noises found inside hospital environments, in their classic configuration, may not only impair professionals' focus but also extend patients' hospitalization or treatment. That happens due to increased levels of anxiety and stress among patients triggered by excessive noise (Dokmanic *et al.*, 2013). In this context, when there is no acoustic treatment in the built environment, even the slightest noise might become deafening for users who are especially sensitive or prone to distraction, such as those with Autistic Spectrum Disorder (ASD) and Attention-Deficit/Hyperactivity Disorder (ADHD) (Honeybourne, 2019; Tadeu *et al.*, 2011).

According to Emar, Smith and Coats (2022), an efficient acoustic project for the workplace must offer a variety of hearing configurations capable of handling several activities, being properly located at each work zone. Besides, the acoustic project may encompass the integration of sound masking[1] or white noise[2] systems to increase comfort (Illustration 9).

Alongside acoustics, thermal comfort is consistently mentioned in Work Wellbeing Scores as one of the main factors causing discomfort, which negatively affects patient treatments. Consequently, the lack of thermal comfort is linked to an increase in the hospitalization period of patients (Heerwagen *et al.*, 2011; Sundell *et al.*, 2011).

**1** Sound masking is the controlled addition of noises, usually a low-volume sound, to mask or disguise unwanted sounds in an environment (Awada *et al.*, 2022). The main goal of sound masking is to reduce the perception, or the annoyance caused by unwanted noises, offering a more uniform and less intrusive sound layer.

**2** White noise is a type of noise with a uniform frequency distribution, meaning that all the frequencies within one sound range have the same intensity. Studies, such as the one from Awada *et al.* (2022), highlight that a 45 dB white noise led to an improved cognitive performance concerning sustained attention, accuracy and performance speed, as well as to higher levels of creativity and lowers levels of stress. In practical terms, White noise is often used in contexts like sound masking, sound therapy or to create a "sound wall", which helps mask other unwanted sounds, enabling a calmer and more soothing environment.

Thermal comfort may vary according to personal factors, like clothes, level of activity and metabolism, as well as neurological factors. One solution for such a variation is to offer ways for individual control of temperature, such as an operable window or air diffusor, to enable patients and professionals to adjust their thermal environment according to their individual needs (Kapp, 2007; Frankenhauser, 1986).

Estimates indicate that individual control of temperature might be associated with up to 7% increase of productivity, depending on the medical treatment or the work carried out by the health professional (Heerwagen *et al.*, 2011; Sundell *et al.*, 2011). There are further efficient thermal design elements for the workplace, as follows:

**.** Perimeter insolation control, to avoid overheating people near windows.

**.** Improving the building's external coating performance, to ensure equal cooling for the entire area.

**.** Spaces with varied thermal solutions, like an atrium with natural ventilation or an outdoor yard, so people can choose a place that best fits their thermal needs.

**Illustration 9.** CHOC – Children's Hospital of Orange County offers shelter clusters along corridors. Such spaces might enable acoustic comfort to minimize stressful stimuli from the hospital environment. Source: healthcaresnapshots.com (2020).

## Lighting

More extensively, several studies, like the one from Boubekri *et al.* (2014, p.14), show that "[...] people working in sunny environments sleep better and smile more than those who spend their days in poorly lighted offices", enhancing sleep quality and reducing physical and mental issues. Kellert and Calabrese (2015) emphasize that the perception of changes in natural lighting may be reached by contrasting light and shadow (Illustration 10), influencing users' emotions in the built environment. Sunlight, combined with certain resources, like big windows, skylights, external areas, outside views, windows with openings (Kellert, 2012), balconies, decks, terraces, gardens (Huiberts, 2015), glass walls and clerestories (Paiva, 2021), plays a crucial role in this context.

**Illustration 10.** Outside area aimed at the healthcare team at Shawn Jenkins Children's Hospital. Source: perkinswill.com (2022).

Lighting contributes to the responsive design and is an additional opportunity to make the difference. Fluorescent lamps, due to their glow and buzz, might be distracting and only noticeable to neurodivergent people. Replacing them with high-quality LED lighting is promising (Kapp, 2020; Joye, 2007). Research carried out at Toronto University suggested that steep levels of lighting may intensify emotional valences, with either positive or negative influence, while reducing lighting glow might lead to more rational decisions (Kapp, 2020). Studies also indicate that adjusting the color and intensity of artificial lighting throughout the day to simulate nature changes can reduce stress.

Such benefits can affect both neurodivergent and neurotypical patients positively during hospitalization (Largo-WIGHT *et al.*, 2011). Technical standards of lighting, like the tunable white system, which simulate the intensity and the color of natural light in indoor environments (Illustration 11), offer guidelines concerning natural light within the workplace. Regarding hospital lighting, studies indicate that an inappropriate design can increase a patient's pain perception during hospitalization (Peccin, 2002).


**Illustration 11.** Tunable white system used in hospitals' patient rooms and corridors. Source: Adapted from lumicenteriluminacao.com.br (2020).

Finally, if the hospital staff can adapt lighting according to patients' preferences, drug therapy is likely to be more efficient, besides reducing patients' and relatives' stress and mental exhaustion, according to Maslin (2022) (Illustration 12). For the healthcare team, more efficient lighting systems can contribute to increased productivity and well-being in the workplace (Edelstein, 2005).


**Illustration 12.** Using technological devices to adjust variables of temperature, acoustic and lighting inside patient's room at Shawn Jenkins Children's Hospital. Source: perkinswill.com (2022).

## Degree of stimulation and operational systems

When considering adjustments in hospital environments to meet the needs of neurodivergent people, it is essential to consider their hyposensitivity or hypersensitivity towards specific sensorial experiences, a distinguishable characteristic of such a population. As stressed by Neumann *et al.* (2021), Aiochio and Queiroz (2020) and Mostafa (2010), different reactions connected to sensorial processing, classified as hyposensitivity or hypersensitivity, are common among neurodivergent people, as it happens with the Autistic Spectrum Disorder (ASD), shown in Table 1.

In situations where neurodivergent patients present specific neurological conditions concerning sensorial process, the presence of visual, auditory and odor stimuli might compromise the efficiency of hospital treatment, leading to irritability, in case of hypersensitive people. On the other hand, the lack of environmental stimuli may be a problem for those hyposensitive individuals, resulting in their inability to achieve a harmonious concentration in the environment (Maslin, 2022). Therefore, developing options that enable patients to control or choose the level of sensorial stimulation of their surroundings is key for the responsive design.

3 According to Kellert and Calabrese (2015), fractals refer to complex and recurring geometric figures that happen in nature and are incorporated to the built environment to create a visual and aesthetic connection with nature. They are mathematical patterns that are repeated in different scales. In the biophilic design context, the inclusion of fractals can be observed in architectural elements, interior design and landscapes, copying patterns found in nature, like leaves, flowers, clouds, mountains, among others. The idea is to create environments that evoke natural complexity and beauty.

4 Biophilic design was conceived by Kellert and Calabrese (2015). It is an architecture and design approach that aims at integrating natural elements and patterns found in nature into the built environment. Such an approach focuses on developing spaces that forward emotional and physical connections between people and nature, aiming at improving well-being, productivity and quality of life. Biophilic derives from biophilia, which refers to human beings' innate fondness towards nature.

Offering patients opportunities to choose from is a valid strategy in hospital environments (Maslin, 2022). Efficient strategies include reducing visual confusion to a minimum, creating silent and tech-free zones, and adding rest and relief clusters in areas of people flow, as appointed by Horn (2016).

The careful choice of colors plays a relevant role. Shades of blue and green tend to calm down and soothe, while yellow, orange and red tend to stimulate and excite. Unharmonious or conflicting colors, often ignored by neurotypical people, can deeply disturb those with increased sensitivity (Bury *et al.*, 2020).

Besides colors, patterns and textures also contribute to sensorial stimulation. Predictable patterns, symmetry or fractals[3] can help neurodivergent people to comprehend, manage and assess their cognitive conditions, while organic patterns and natural texture can be more comprehensible and soothing for this population (Armstrong, 2011; Mandelbrot, 1975).

According to Ben-Alon *et al.* (2019), for neurodivergent people, natural material is usually more intelligible, soothing and able to increase the mood when compared with synthetic material. In general, the principles of biophilic design[4], applied to neuroarchitecture, show overarching beneficial impacts for healthcare professionals' well-being and patient recovery, both neurotypical and neurodivergent (Illustration13).

**Illustration 13.** Biophilic design represented by aspects that refer to the ocean floor applied to an MRI suite at Shawn Jenkins Children's Hospital. Source: perkinswill.com (2022).

The discussion concerning responsive architecture in hospital environments, with focus on neurodiversity, reflects an increasing awareness over the importance of meeting the needs of neurodivergent people. Sensorial stimuli significantly affect the experience of neurodivergent patients, who can be either hypersensitive or hyposensitive. This group, especially children, tend to spend more time in healthcare facilities due to overlapping health issues, like gastrointestinal disorders, epilepsy, and sleeping disorders. Moreover, mental health issues, like anxiety and depression, also prevail in this group, which was aggravated after the pandemic.

Upon designing a hospital environment responsive to all, it is crucial to provide a variety of options to enable users to have a space that meets their specific needs for the required task (O'Haire, 2017). Every aspect of the space – color, lighting, furniture, elements within their visual reach and sensorial stimuli – must be designed with purpose and intention, as mentioned above.

For an efficient approach of the neurodivergent population, it is fundamental to apply responsive design, prioritizing, above all, intelligibility, repetition, predictability and patient's control over the environment. This implies developing spaces with little sensorial stimuli that enables adjustable lighting and removes noise devices and automatic equipment. Architectonic strategies that foster control over the environment, like the use of consistent colors and intuitive handling, are key to creating a soothing and able-to-control ambience for patients.

Besides physical design, operational and technological strategies, like mobile applications and alternative therapies, play an important role in improving neurodivergent patients' experience. Reducing interpersonal interactions and incorporating health-wise technological information might reduce anxiety and provide a platform that enables written communication, making the experience more comfortable.

An interesting example of how to apply technology in the hospital environment was employed at Thompson Autism and Neurodevelopmental Center – CHOC (Illustration 14). In the lobby of the new Bill Holmes Tower, an interactive show called *Turtle Talk with Crush* was installed, which was donated by Walt Disney Imagineering. In this case, technology, with the use of virtual reality, enables hospitalized patients to interact with characters from the movie *Finding Nemo* (Choc, 2020).

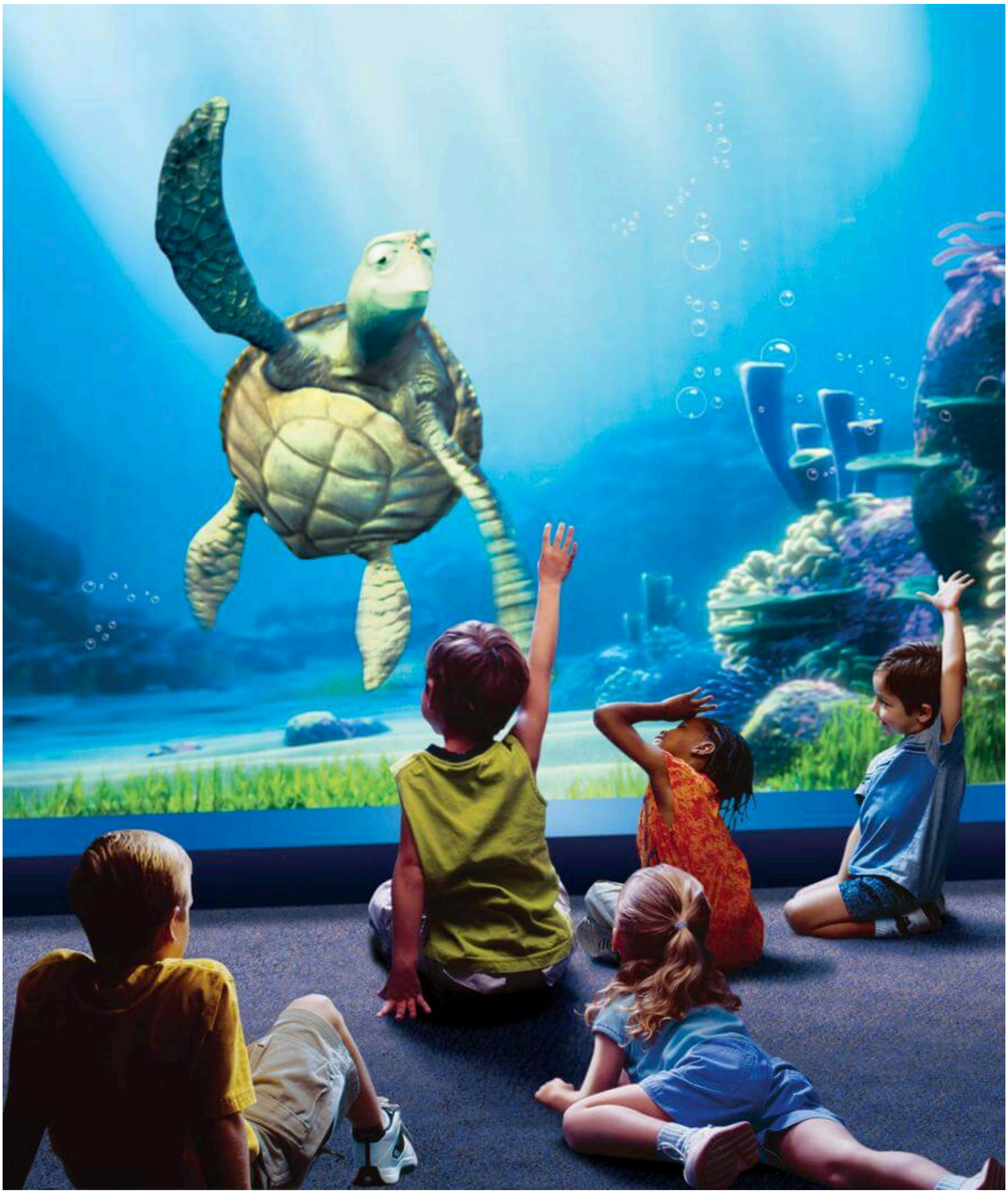

**Illustration 14.** The partnership between CHOC and Disneyland Resort has been magical from the beginning, enhancing the recovery of patients in the pediatric wing of the hospital. Source: choc.org (2021).

## Conclusions and recommendations

Architecture responsive to neurodiversity plays a key role in the promotion of well-being and in the development of inclusive environments. By following the guidelines, architects can significantly contribute to the improvement of neurodivergent patients' experience in hospital environments. Understanding the specific sensorial and cognitive needs of this population is vital for the development of spaces that not only fulfill clinical requirements but also further a sense of safety, comfort and autonomy. Upon investing in the implementation of these practices, healthcare facilities might become more accessible, cozier and efficient for all the diversity of users.

. **Wayfinding and spatial organization**: it must prioritize intuitive design, with clear wayfinding elements to ease spatial orientation; use distinguishable visual landmarks and focal points to help identify places and directions; avoid confusing repetitions of spaces or identical features, fostering a readable order.

. **Spatial choices**: it must provide a variety of configurations to enable users to choose appropriate environments to their needs; develop shared spaces to enhance socialization and smaller spaces for individual refuge; reduce overwhelming sensorial stimuli and offer options to control the environment.

. **Acoustic quality**: it must integrate efficient acoustic solutions to create a variety of auditory configurations; avoid the overload of noise, especially in sensitive areas, and consider sound masking technology; ensuring clear and consistent signs to facilitate wayfinding in complex environments.

. **Thermal comfort**: it must offer individual control of temperature to meet individual thermal preferences; control solar gains and improve external coating to ensure thermal comfort in the environment; design spaces with varied thermal characteristics so users can choose places aligned to their thermal needs.

. **Lighting and degree of stimulation**: it must use natural light whenever possible, with big windows and outdoor areas; adopt adjustable lighting systems that enable changes in the intensity and temperature of the light throughout the day; consider the use of high-quality LED technology to reduce glow and provide visual comfort.

. Operational systems: it must integrate operational strategies, like mobile applications, to reduce interpersonal interactions and allow patients to have control; explore alternative therapies and technologies, such as virtual reality, to improve the experience of the neurodivergent patient; implement systems that further individual choices, enabling a more customized environment.

Therefore, in a context where every user’s health and well-being are a priority, the architecture aimed at hospital environments responsive to neurodiversity comes across as crucial for a holistic and sympathetic approach. Neuroscience applied to hospital architecture can provide a solid foundation to guide such efforts, aiming at developing truly inclusive and beneficial environments. Although there is no single solution, the continuous implementation of these architectonic strategies can provide flexible, safe and welcoming spaces. To enable supportive and qualitative experience, further research is necessary to adapt the proposed guidelines to the several needs of the neurodivergent population. Committing to a responsive architecture in healthcare environments is essential to promote well-being and efficient treatment for the neurodivergent population, who is in constant evolution.

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Article

# Healthcare 4.0 and Lean Healthcare in Santa Catarina hospitals: mapping adoption and exploring integration

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## Abstract

Healthcare has been changing at a rapid pace, keeping up with significant global transformations resulting mainly from technological advances and medical and scientific knowledge. Given the growing demand for quality and optimization of hospital resources, this study aims to investigate the integration of healthcare 4.0 technologies and lean healthcare practices in hospitals in the state of Santa Catarina by conducting semi-structured interviews with managers of public and private institutions. Among the technologies incorporated, electronic medical records, telemedicine, artificial intelligence, robotics and advanced imaging exams stand out, bringing benefits such as agility, safety and process optimization, but also challenges such as cost and resistance to change. The results indicate that lean healthcare practices are not widely used, and many institutions are unaware of their application. The challenges in implementing new technologies and practices are similar in the institutions studied, highlighting common barriers in the hospital sector.

## Keywords

healthcare 4.0; lean healthcare; hospital management.

## Introduction

Health has been changing at a rapid speed, and the causes may be related to the progress of technology as well as of medical and scientific knowledge, changes in the epidemiologic dynamics, the growing number of chronic patients, population growth and increased lifespan (Mendonca; Rodrigues, 2023). Such transformations call for overarching changes in the organizational structures of hospitals, which depend on the engagement of managers to make long-term decisions aligned to the organization's goals and strategic planning.

The increasing demand for quality healthcare services and the need to optimize hospital resources have boosted the search for innovative solutions. Institutions have been dealing with significantly high costs and a skyrocketing rise in patient demands, leading to "higher costs and expensive assistance; by contrast, the investment in optimizing the area agility does not grow in the same proportion" (Chaves; Daú; Scavarda, 2024, p. 2). In this context, two concepts come as change enablers: healthcare 4.0 and lean healthcare.

The term healthcare 4.0 came from the Fourth Industrial Revolution as a structure to enable the connection, automatization and automation of healthcare services, increasing efficiency, efficacy, accessibility, quality and the customization of the services offered to the population (Al-Jaroodi *et al.*, 2022). Healthcare 4.0 "serves as a technologic catalyzer that enhances rapid growth, by integrating cutting-edge industrial technologies" (Gupta; Singh, 2023, p. 933), via the improved interconnection between physical and digital aspects and solutions provided by innovative information and communications technologies (Mukhopadhyay; Banerjee; Das Mukhopadhyay, 2024). The technological development forwarded by this concept had to resolve high expectations or at least minimize some of the issues pointed out in the beginning of this introduction (Mendonca; Rodrigues, 2023).

Lean healthcare practices, on the other hand, regard the implementation of the lean approach to hospital services, aiming at decreasing waste and improving processes. The basic principle is to "doing increasingly more with increasingly less resources – whether that resource is human, an equipment, time and/or space" (Souza Lima, 2022, p. 5). Therefore, it is "a set of tools and a management system, a method that advances ongoing improvements and the engagement of employees, an approach that enables us to handle really important problems" (Graban, 2013, p. 3).

Since the 90's, healthcare professionals began to seek inspiration in other areas, willing to face challenges concerning the quality and the costs of services (Shortell; Bennett; Byck, 2001). In this context, lean healthcare emerged as a strategy to decrease or eradicate waste and activities that do not add value to healthcare processes. Therefore, employing lean to enhance hospital assistance efficiency was recognized as a proficient approach to reduce expenses and improve results (Montesarchio *et al.*, 2012; Tlapa *et al.*, 2020).

Combining both approaches (healthcare 4.0 and lean healthcare) can represent relevant advancements in hospital management, causing impacts in quality and safety regarding patient, costs, waiting time, team disposition (Graban, 2013). Healthcare 4.0 plays a crucial role in the improvement of the entire healthcare system, making processes better, reducing medical errors, helping the decision-making process and refining patient care (Al-Jaroodi; Mohamed; Abukhousa, 2020), therefore it is a strong concept to help the country reach new standards in health policies (Valentim *et al.*, 2018). Such integration, however, is also associated with challenges, especially in developing countries, like Brazil, where budget and infrastructure restrictions might hamper implementation. Moreover, technologies are evolving faster than organizational cultures, which contributes to the increasing difficulties concerning human resources, finances, physical implementations and patient safety (Thimbleby, 2013).

Considering the above matters, understanding how healthcare 4.0 and lean healthcare can help hospitals is crucial to propose guidelines that foster institutions modernization and improvement. Therefore, this study aims at investigating the integration of healthcare 4.0 technologies and lean healthcare practices in the operational efficiency and quality of the assistance provided at hospitals in the state of Santa Catarina, Brazil.

Santa Catarina was chosen for its outstanding hospital network, which includes institutions that are a reference in innovation and health management, providing the ideal scenario to investigate the proposed concepts. Moreover, it was necessary to limit the sample in order to carry out a more comprehensive and contextualized analysis, which could help to understand the concepts being study, considering that Santa Catarina has socio-economical and hospital characteristics that enable an assessment concerning the incorporation of healthcare 4.0 technologies and lean healthcare practices in a specific local scenario, favoring the collection and analysis of data regarding local singularities.

## Methodology

This is applied research consisting of field data collection, aiming at practical solutions for specific matters. With a qualitative approach, this research is classified as exploratory with the purpose of advancing the comprehension of the issue being studied, forwarding its explanation and enabling hypotheses (Gil, 2002).

The methodology was structured into three main phases: (1) contextualization; (2) semi-structured interviews; (3) data analysis and interpretation of results.

**Phase 1: Contextualization**

Literature review was carried out through overarching research in papers published on a national and international academic and scientific basis, besides thesis, dissertations and books. The purpose was to deepen the knowledge concerning the main concepts of this study: healthcare 4.0 and lean healthcare. The review helped mapping healthcare 4.0 emerging technologies already implemented or in process of employment in hospitals, as well as analyzing the state of art of lean practices within the hospital context. Therefore, it was possible to identify gaps, benefits and challenges of such technologies and practices, providing the base for the development of this research and the discussion of the results obtained.

**Phase 2: Semi-structured interviews**

Interviews are the main method of primary data gathering and offer important flexibility to the work, as interviewers can repeat or explain questions, framing them accordingly, clarifying definitions to guarantee their intelligibility. Mostly, interviews offer the opportunity to obtain data that cannot be found in theoretical sources, although those are equally relevant to the research, besides making it possible to assess interviewees' attitudes, observing what they say and how. The semi-structured approach also allows flexibility concerning the answers, since interviewees might share information that was not primarily envisaged in the script, hence enrichening data analysis (Gil, 2002).

For this research, twelve hospital managers working in public and private institutions of Santa Catarina were interviewed; the interviews were carried out via videoconference and followed a pre-established script (Table 1). The interviews were framed to explore, in depth, the employment of healthcare 4.0 technologies and lean healthcare practices in hospitals.

| Part I: Social and demographic data | |
|---|---|
| 1 | Education |
| 2 | Work experience |
| 3 | Institution (public or private) |
| 4 | Position |
| 5 | Time in position |
| Part II: Specific data | |
| 1 | What emerging technologies have been implemented in your hospital? |
| 2 | What were the benefits and challenges linked to this implementation? |
| 3 | Have lean healthcare practices already been implemented in your hospital? |
| 4 | What were the benefits and challenges linked to this implementation? |
| 5 | Have emerging technologies being integrated with lean healthcare practices? |
| 6 | If so: how has this integration been carried out in your hospital, can you give concrete examples? What were the benefits and challenges identified? |
| 7 | If not: how could such an integration contribute to your hospital? |

**Table 1.** Script for the semi-structured interviews. Source: Authors, 2025.

Participants were recruited in September and October 2024, through a simple random sample, which consists in randomly choosing participants from the target determined in the research (Gil, 2002). Hospitals were mapped from the Healthcare Facility National Register (CNES), regarding the state of Santa Catarina. The contact with the target was directly via hospitals, addressing their managers with an invitation to participate voluntarily, anonymously and confidentially in the research.

According to data from 2024, provided by the Hospital Policy and Management Observatory (OPGH), from Oswaldo Cruz Foundation (FIOCRUZ), gathered from CNES, in Santa Catarina there are 306 hospitals, divided into isolated day hospital, specialized hospital, general hospital, policlinic/specialty center/natural birth centers and emergency rooms/ emergency services. Additionally, those categories were further divided into profitable private institutions, non-profitable private institutions, public institutions, and teaching institutions. The sample of 12 hospital managers in the research corresponds to 3,92% of all hospitals.

**Phase 3: Data analysis**

The answers from the interviews were analyzed as proposed by Bardin (2016). The purpose of such analysis is to transform the gross data from the answers through a process that cuts, gathers and lists information to present a clear representation of the content, highlighting the main characteristics from the text.

There are three phases to data analysis: (i) pre-analysis; (ii) exploration of material; (iii) result processing, inference and interpretation (Bardin, 2016). The pre-analysis phase consists of primary organizing, transcribing and reading documents, as well as conceiving indicators to underpin the final interpretation. Material exploration means to codify, decompose or list data, transforming the gross information into units for analysis via patterns, repetitions and meanings that were identified in the material studied. Finally, during the result processing, inference and interpretation phase, results are processed, interpreted and analyzed. Then, based on the answers obtained in the interviews and on the theory adopted, inferences, i.e., logical deductions, are carried out.

## Results e discussions

The research results present a panorama of Santa Catarina hospitals regarding the integration of healthcare 4.0 technologies and lean healthcare practices, which count on the participation of twelve hospital managers from different institutions and locations, as shown in Illustration 1.


**Illustration 1.** Geographic distribution of participants. Source: Authors, 2025.

The geographic distribution encompassed by the research refines the results and enables a panorama that is true to the reality of Santa Catarina across its different regions.

Regarding the social and demographic data of participants, it is possible to define their profile: 58,3% come from public institutions and 41,7% from private ones. Professional education was varied, with nurses prevailing, with varied professional experience. Illustration 2 presents a social and demographic infographic of the participants, with the main category data of the sample.

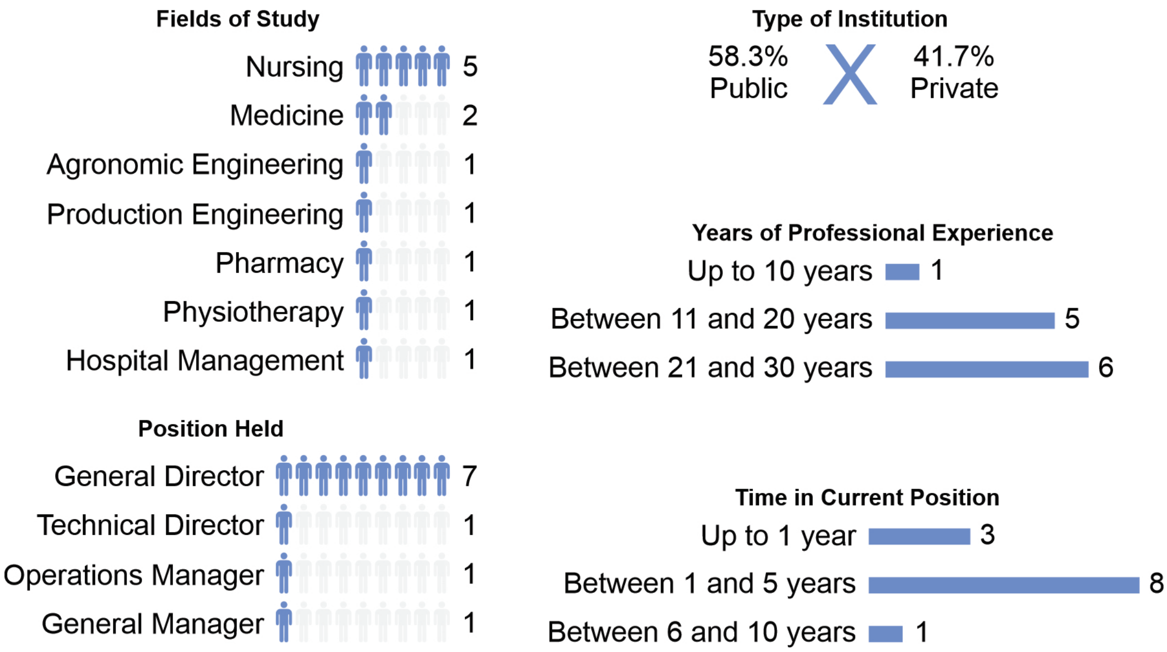


**Illustration 2.** Social and demographic infographic of participants. Source: Authors, 2025.

First, participants were asked: "What emerging technologies have been implemented in your hospital?". Their answers resulted in the categorization presented in Table 2.

| Category | Subcategory | Recurrence |
|---|---|---|
| Electronic medical records | Fully implemented | 9 |
| | Partially implemented | 1 |
| | Implementation in progress | 1 |
| Telemedicine | Fully implemented | 4 |
| | Partially implemented | 1 |
| | Implementation in progress | 1 |
| Artificial intelligence | Partially implemented | 5 |
| Robotics | Partially implemented | 2 |
| Advanced imaging exams | Fully implemented | 4 |
| | Partially implemented | 2 |

**Table 2.** Categorization of emerging technologies implemented. Source: Authors, 2025.

Most hospitals confirmed the use of electronic medical records, which is currently considered the main technological tool for the optimal functioning of hospital units. One of the interviewees (E4), however, emphasized the partial implementation of the system, whereas hybrid (written and digital) documents are used for medical record; another one (E7) said that the system is in phase of implementation, via the digitalization of hospital processes.

Telemedicine was boosted during the COVID-19 pandemic; however, its use is still limited within tertiary healthcare system (Lima *et al.*, 2022). Some managers said its use is aimed at remote diagnosis; however, there is a noteworthy preference for not using it in hospitals. E11 explains that telemedicine makes it easier to remotely handle imaging exams, like tomography, ultrasound, R-ray and electrocardiogram, advancing the efficacy of the radiology services. Therefore, exams are carried out in the hospital, but the report can be done remotely. That is beneficial for both doctors, who do not need to be present, and patients, who can access their exams remotely. In E9's hospital, telemedicine was implemented in 2014, mainly focusing on the journey of oncologic patients. Nowadays, E9's hospital is a reference to 52 municipalities, employing telemedicine to optimize the assistance and forward these patients' follow-ups. On the other hand, E8's hospital does not employ telemedicine, but E8 believes that it is an important tool to resolve several existing problems.

Regarding artificial intelligence (AI), it is noteworthy that its use has been widely spread, especially in tomography and MRI, advancing the issue of reports, clinical pharmacy and Diagnostic Imaging Center (DIC), as well as administrative/management processes.

AI has become an essential tool in medicine, being broadly used in several areas, like diagnosis and treatment, thanks to its capacity to reproduce human thought and store great amount of information (Leite, 2019). This technology is already applied to several areas of expertise to prevent and analyze medical images, enhancing patient health (Arias, 2019). Moreover, AI helps to identify diseases and provide more accurate diagnosis, with the advantage of detecting patterns that human beings often cannot (Santos, 2021). AI also allows real-time data update, which improves hospital management and the prevention of complication, therefore avoiding a collapse in the healthcare system (Tomás, 2020).

Robotics is still restricted to a few hospitals, being mentioned only by two interviewees (E4, E6) as partially implemented. It is emphasized that its use is mainly limited to surgical processes. Regarding advanced imaging exams, interviewees reported full or partial implementation, highlighting mainly tomography, MRI, ultrasound and X-ray.

Regarding the comprehension of emerging technologies, participants answered the following question, "What were the benefits and challenges linked to this implementation?". Table 3 presents the categorization of the answers, showing the viewpoint of the managers interviewed.

| Category | Subcategory | Answer |
|---|---|---|
| Benefits | Promptness | Reduced duration of exams |
| | | Possibility to access data from different hospitals |
| | | Faster information transmission |
| | | Fast access to electronic medical records |
| | | Faster and more economic processes |
| | Safety | Integration with AI to support decisions |
| | | Better understanding of patient record |
| | | Better cost control |
| | | Reduced human risks |
| | | Increased safety via digitalization |
| | Paperless systems | Information integration |
| | | Cost reduction via digital tools |
| | Service quality | Telemedicine avoids patient displacement |
| | | Improved service quality |
| | | Reduced human cost and more safety |
| | | Digital tools provide better assistance |
| | Process optimization | Process automation |
| | | Process standardization and optimization |
| | | Improved information flow |
| | | Real-time internal control |
| Challenges | Cost | Limited financial resources |
| | | High cost of implementation |
| | | Difficult to measure financial return |
| | Reluctance to change | Professionals are reluctant |
| | | Difficult to choose what adds value |
| | | Cultural reluctance to technology |
| | Specialized knowledge | Professionals must evolve |
| | | Difficult to find the right tools |
| | | Qualified workforce |
| | System integration | Need for standardization among all hospitals in Santa Catarina |
| | | System expansion for primary and secondary levels |

**Table 3.** Categorization of benefits and challenges regarding the incorporation of emerging technologies. Source: Authors, 2025.

It is noteworthy that the benefits are strongly connected with enhancing the efficiency of processes and the quality of assistance, while the challenges usually involve financial, cultural and knowledge barriers.

Among the main benefits, speeding up processes is widely recognized. E2 affirms that in his/her hospital, for example, replacing an old CT scan with a more modern one has significantly reduced the duration of the exam, which directly reflects on the hospital's assistance capability and operational efficiency. An additional recurring benefit is the safety enabled by new technologies, whether in data and medical report protection, as reported by E7, whether in the optimization in the use of antibiotics and infection control, as exemplified by E8. Those tools not only improve the quality of assistance but are also money-savings, by avoiding unnecessary costs with procedures and reducing treatment response time.

However, the challenges are sweeping, especially in institutions that rely on public resources. The matter of the cost was massively mentioned by some managers, like E3, E5 and E6, who said that the lack of resources limits the standardization and development of such technologies in every hospital in Santa Catarina. Besides, it is still very hard to measure the financial return on many of those investments, posing a risk for hospitals facing financial difficulties.

Reluctance to change is also a significant challenge. E3 mentions how difficult it is to convince professionals to use digital tools, such as electronic medical records, a barrier that compromises the efficiency of the process.

Another issue mentioned was the lack of workforce. According to E8, there is a lack of professionals with the necessary knowledge to operate the new tools and technologies, limiting the full employment and usage of such innovations. That was emphasized by E6, who pointed out the difficulty in choosing which technologies truly add value and reduce costs, considering the vast possibilities available in the market and the lack of expertise in carrying out a cost-benefit assessment.

Afterwards, participants were asked, "Have lean healthcare practices already been implemented in your hospital". Table 4 shows the analysis of the answers obtained, presenting in detail which practices were incorporated or not.

| Interviewee | Incorporation | Details |
|---|---|---|
| E1 | Partial | Implementation of internal control and ongoing processes within emergencies and other operational areas. |
| E2 | Yes | Participation in several programs offered by the federal government and partnerships with renowned institutions (Albert Einstein Israeli Hospital, Sirio-Lebanese Hospital and Moinhos de Vento Hospital). |
| E3 | In process | Gradual implementation of lean. |
| E4 | No | Cannot remember clear examples of lean practices but mentioned a "zero-paper" guideline and system integration. |
| E5 | No | - |
| E6 | Yes | Lean implementation in emergency rooms and surgery center with the consultancy from Sirio-Lebanese Hospital. There were noteworthy results in reducing overcrowding. |
| E7 | Yes | Involved with several programs aimed at continuous improvement process optimization, including accreditation and the use of Diagnosis Related Groups (DRG). |
| E8 | No | - |
| E9 | Yes | Lean is implemented in emergency rooms, surgery center and oncology, helped by specific consultancies from major hospitals [did not mentioned names]. |
| E10 | In process | Participation in the program to implement lean practices in emergency rooms; now they will participate in the second phase: lean in the surgery center. |
| E11 | No | - |
| E12 | Yes | The hospital received a level 1 certification by the National Accreditation Organization (ONA), which requires the implementation of process optimization and time management, for example. |

**Table 4.** Incorporation of lean healthcare practices. Source: Authors, 2025.

The incorporation of lean healthcare practices in hospitals shows a rather diversified scenario, as observed from the answers given by the managers. While some hospitals are ahead in the implementation of such practices, others are still in the beginning or haven't even started the process yet.

Among hospitals with lean practices, there were some successful examples, like the one mentioned by E2, whose hospital participated in several national programs teamed up with renowned institutions, like Albert Einstein Israeli Hospital, Sirio-Lebanese Hospital and Moinhos de Vento Hospital. Such an involvement has enabled significant improvements in areas like infectious diseases and cost management. E6 said that a consultancy from Sirio-Lebanese Hospital advanced the employment of lean in emergencies and the surgery center, leading to the decrease of overcrowding and the optimization of process in the ER. E9 mentions the implementation of lean in emergencies, surgery and oncology, with positive results: the average length of patient hospitalization was reduced from 6,6 days to 3,2 days, while the number of monthly surgeries in the surgery center has doubled, from 700 to 1,400. The interviewee explained that this progress was achieved thanks to the eradication of waste and the implementation of lean methodology, which has been successfully employed in the hospital for four years in a row.

The project "Lean in Emergencies" aims primarily at reducing overcrowding and improving the duration of the assistance in urgencies and emergencies rooms of public and non-profitable hospitals in Brazil. Started in 2017, by Sirio-Lebanese hospital, it is an initiative proposed by the Ministry of Health via its Assistance Program for the Institutional Development of Unified Health System (PROADI-SUS), which proposes the employment of lean to optimize assistance flows and improve the quality of services. Lean methodology focuses on identifying and eradicating waste, offering tools that enable a best understanding of processes and increase organizational efficiency. The team in charge of the project is interdisciplinary and combines on-site and remote activities, using DMAIC methodology (Define, Measure, Analize, Implement, Control) to train professionals and ensure the continuous improvement of healthcare services. Therefore, "Lean in Emergencies" not only fosters operational efficiency but also enhances the value of the services offered to patients (PROADI-SUS, 2023). Phase II of the program encompasses the implementation of lean practices in the surgery center, with the same goals and purposes as Phase I.

Other hospitals are in the initial stages of the implementation. As explained by E3: "*lean practices are being gradually implemented with focus on ongoing improvements*". E7 said that "*we are involved in accreditation programs and protocols to optimize processes*", especially in health assistance and administrative areas. The use of tools like Diagnosis Related Groups (DRG) is an example of how these practices can positively impact hospital management.

DRG is an assessment system used in hospitals to classify hospitalized patients based on similar medical conditions and similar levels of required resources during hospitalization. Developed between the decades of 1960 and 1970, by Yale University, in the United States, DRG was conceived to facilitate the management of hospital costs, corelating types of patients according to their treatment and the resources available (Mullin, 1986 *apud* Noronha *et al.*, 1991). This system is crucial for the financial management of healthcare institutions since it allow hospitals to classify severe cases – whose average length of stay does not exceed 30 days – in homogenous groups. This system considers variables like age, main diagnosis, comorbidities, complications and procedures carried out. Therefore, DRG not only helps allocating resources but also enables a comparison of hospital performance, being widely used in several countries, with changes and improvements to suit local needs (Silva, 2019; Noronha, 2004).

On the other hand, there are hospitals where lean practices have not been employed yet or their use is still in early stages. E4, for example, does not remember specific practices, but highlighted the hospital's effort to eradicate the use of paper and integrate exams and medical prescription systems, a strategy that, although not officially lean, shares its principles of efficiency and waste eradication.

These changes found in the degree of lean practices employed might refer to several factors, like the availability of a specialized consultancy, the participation in government programs and the hospital organizational culture. When they were asked, "What were the benefits and challenges linked to this implementation?", most interviewees mention the optimization of process and the improvement of the services provided as key advantages. Such practices forward more efficient adjustments to the workflow, which will consequently lead to better patient care and safer assistance processes.

However, challenges are equally emphasized. Change reluctance is a common topic, since it is difficult for many professionals to adapt their usual practices to new methodologies. It is essential to invest in technical qualifications and training to guarantee that all professionals are aligned with lean practices' purposes. Moreover, system integration and information connection are critical matters that must be approached to enhance the benefits of digitalization and automation.

Financial challenges were also mentioned, especially in public institutions, where the operational cost and the need to make the best out of resources are usual. The lack of qualified professionals, especially in lower levels, poses an additional obstacle.

The last question inquired participants if emerging technologies and lean healthcare practices were integrated. The answers revealed a diversity of experiences and perspectives, highlighting both the benefits and the challenges associated with this integration.

Most answers (7 out of 12) indicate that there has not been an effective integration between emerging technologies and lean healthcare practices, especially due to the lack of financial resources and cultural resistance. However, there is a clear understanding (6 positive answers) regarding the benefits that would result from the integration, like improving organizational efficiency and patient safety. However, in most hospitals, such benefits are not yet fully evident.

On one side, some hospitals are advancing, through the installation and calibration of hospital management systems. This type of system has the potential to make process integration easier and improve organizational efficiency, minimizing waste and optimizing the use of resources. Others mentioned the importance of integrating vital sign monitors with hospital management systems, emphasizing that this automation could significantly improve healthcare quality.

However, most hospitals have faced financial difficulties over the last years, especially after the COVID-19 pandemic, which has deprived them of the investments in technologies that would be necessary to carry out the integration (ANAHP, 2024). Many interviewees highlighted the importance of changing the culture inside organizations. The reluctance of professionals in adopting new processes and their difficulty in understanding the importance of intersectoral collaboration were the critical points mentioned.

Additionally, not connecting hospital systems may result in errors and flaws in communication, which harms efficiency and patient safety. Managing data and developing informative dashboards are important steps towards the right direction, but many hospitals are still not able to fully carry out such an implementation.

## Final considerations

Global transformations are boosting changes in healthcare structures, leading to the incorporation of new technologies and practices that enable the increase in productivity and waste reduction. Therefore, the purpose of this research was to investigate the integration of healthcare 4.0 technologies and lean healthcare practices in the operational efficiency and assistance quality in Santa Catarina's hospitals.

It became clear that while emerging technologies offer promising advancements for the hospital sector, its full potential will only be achieved when challenges regarding cost, training and reluctance to change are properly overcome. Healthcare institutions must work on strategies that encompass professional ongoing training, efficient resource management and team awareness, so they are more open to innovation. This will allow hospitals to make the best out of available technologies, ensuring safer, swifter and better assistance to patients.

Lean healthcare practices are a reality only in a few hospitals. Despite the efforts, many institutions still lack knowledge or do not even know how to implement them. When the implementation happens, it is limited to certain hospital sectors and results in significant improvements, as mentioned by managers interviewed.

The integration between emerging technologies of healthcare 4.0 and lean healthcare practices has great potential to transform the operational efficiency and the quality of the services. However, it faces relevant challenges, like lack of financial resources and cultural resistance. Overcoming these limitations is crucial so hospitals can receive the expected benefits and therefore contribute to a more efficient and patient-driven healthcare system.

This research offers support for hospitals and managers willing to incorporate emerging Technologies or lean healthcare practices, enabling the development of a culture that prizes for the reduction of waste and the improvement of patient assistance. In Santa Catarina, hospitals share a very similar reality. Although private hospitals have more financial resources, the challenges are the same, highlighting the barriers for the implementation of new technologies or practices.

For future research, it is recommended to broaden the study to other Brazilian states, enabling a panorama of healthcare 4.0 and lean healthcare practices that enlarges the geographic approach and better represents the national reality.

## Ethical considerations

This research was submitted to the Ethics Committee in Research with Human Participants (CEPSH) of the Federal University of Santa Catarina (UFSC) (CAAE 81424924.0.0000.0121), which issued its approval via report number 7.157.381. The participants signed the Free and Informed Consent Term (TCLE), agreeing with their voluntary, anonymous and confidential participation.

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# Book “Jarbas Karman, architect”

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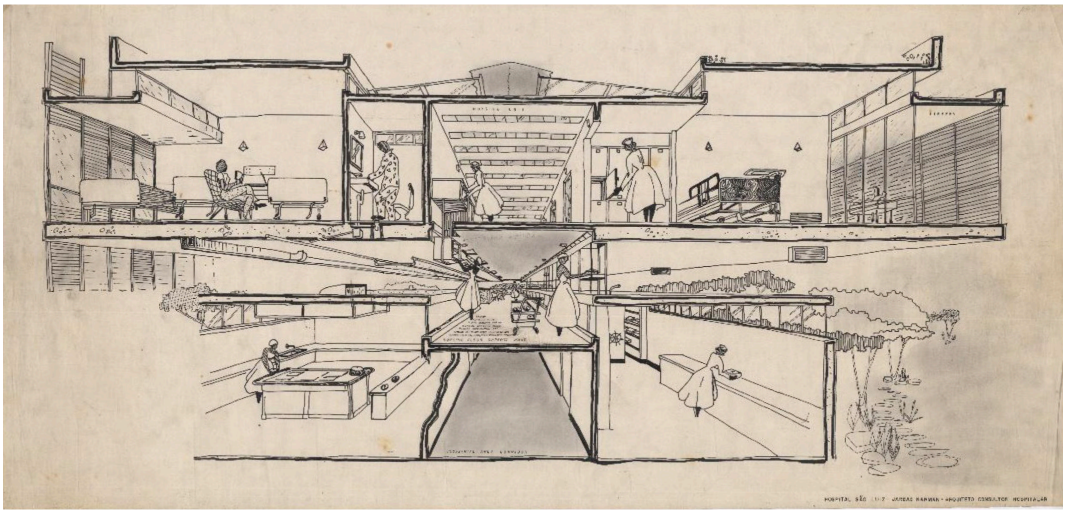

The book *Jarbas Karman, architect*, scheduled to be launched in 2026, is going to fulfil part of the gap in the historiography and review work concerning hospital building architecture, mainly for research whose focus lies on project analysis. Written by myself and researcher Monica Musatti Cytrynowicz, the book was organized by IPH – Instituto de Pesquisas Hospitalares Arquiteto Jarbas Karman and will be published by the Romano Guerra Publishing House.

In 1958, Karman wrote that only a few people knew how to “see” a hospital[1]. Indeed, it is not an easy task to identify which aspects are the most relevant to pay attention to in a hospital project. Such perception is linked to a critical interpretation of the subject, which must be based on technical and theoretical foundations.

Most publications that deal with the transformations of hospital buildings do not enable an analogy between textual descriptions and spatial, formal and material characteristics of the projects. That happens because they fail to present architectonic plans (blueprints, cuts, elevations, extensions, and so on) or even drawings that could clearly

**1** Karman wrote this statement in his article *Só é bem planejado o hospital com decisivo desenvolvimento horizontal*, for *Folha da Manhã newspaper*, on August 24, 1958. It was his reply to an article published on May 25 of the same year regarding the private context to build Albert Einstein Israeli Hospital’s first tower, which was won by Rino Levi, Roberto Cerqueira Cesar and Luís R. de Carvalho Franco. The author of the article, identified as I.J., criticized the rival projects without getting into the complexity of hospital planning. Jarbas Karman disagreed with I.J. ‘s statements and the newspaper’s editors granted him the right to reply.

illustrate certain characteristics of the project that support the importance of phenomena. This also makes it harder to compare different project solutions.

To build a theoretical reference and carry out an architecture review concerning the project of buildings and, more specifically, hospitals, it is necessary to have an archive of analysis of projects from different authors, places and periods. Consequently, that depends on a thorough interpretation of plans, since the composition of the matrix of needs, functional requirements, organization of flows and the correspondence between biological paradigms and environmental compartmentalization are key to the formal, spatial and material result of buildings.

In this sense, the book *Anatomia dos edifícios hospitalares*, written by Lauro Miquelin, stands out. It is deservedly one of the most referenced books in Brazil in the field of hospital architecture since it provides at least one plan (implementation, blueprint or cut) or one isometric perspective of each project presented. By illustrating the architectonic solutions through blueprints, cuts, implementations, schematic plans or isometric perspectives, which are all hand drawn and rich in details, the author has significantly contributed to the building of a theoretical basis and a handful of reviews, not just concerning the changes that hospital buildings have undergone throughout time but also the relevant elements of the project.

To enhance the review output and to enter the list of publications that advance the understanding of architecture through the analogy between text and drawing, this book about Karman's work presents his production with emphasis on his rich collection of works, including digital redrawing of blueprints and cuts of some of his main projects. The book is divided into four main parts (besides a list of his works): biography; contextualization of his work in time; ideas; and main projects, including both built and not built buildings.

The first part expounds on the origins and professional life of Jarbas Karman. Born into a family of Hungarian immigrants, he got his bachelor's degree in civil engineering, in 1941, from the Polytechnic School at the University of São Paulo (Poli-USP), in Brazil. Three years later, he got his architecture degree after concluding a postgraduation course in the same institution. His interest in hospitals arose while developing his academic work concerning this topic, during his specialization course, which used to be mandatory for architect training back then. The text approaches his experience at SESP – Special Service for Public Health; his master's studies at Yale University, in the USA; his course concerning Hospital Planning; his friendship with architect Rino Levi; his partnership with architect Alfred Willer; and some of his most important professional experiences, among which, his participation in designing and building Albert Einstein Israeli Hospital, in São Paulo, Brazil.

The second and third parts address his architecture work. First, to contextualize Karman's work in time, the book presents a panorama of the transformations that hospital buildings went through in the 19th and 20th centuries. The text suggests three paradigmatic changes: the emergence of pavilion-designed hospitals, the verticalization of hospital buildings, and the criticism around pre-established models. Jarbas Karman's production belongs to a time when the almost involuntary adoption of certain designs and building models were questioned. The increased demand for new hospitals, due to the creation of IAPs (Institutes for Retirements and Pensions) and the development of the private healthcare system, coincided with the increased interest of modern architects in the subject. His intensified studies on issues regarding function and biological safety led him to new interpretations on how to organize the space according to its function and how architecture could add to the definition of more rational operational processes. Therefore, the second half of the 20th century saw the dawn of more diversified projects, as we can see, for instance, in Irineu Breitman's, João Filgueiras Lima's and, obviously, Karman's works.

The third part addresses project strategies more objectively. It is important to highlight that "project strategy" is understood here as recurring architectural solutions employed in different projects and periods that usually concern the same problem or matter. Therefore, there is an investigation on how Karman solved issues regarding functional design, people access and flow, biological safety, and physical and psychological comfort. Such an investigation is presented by connecting text and drawing, including blueprints, cuts and architectonic diagrams.

The fourth and last part presents 15 of his main projects, carried out between 1956 and 1999, through detailed journals, original drawings and documents, and, to help the understanding of architecture, through redesigned and standardized blueprints and cuts. Such a strategy will allow readers to identify from the original images and redesigned drawings the issues discussed in the text, fostering their graphic (scale) understanding of the solutions implemented for the projects and the construction work. Moreover, it also enables readers to compare Karman's projects with those from other authors, from different places and periods.

Overall, this book was intended to, on one side, increase the technical repertoire and qualify professional practices, and, on the other, expand the range of theoretical structures and forward the review output concerning hospital architecture.

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