REVISTA | MAGAZINE

IPH

20

INSTITUTO DE PESQUISAS HOSPITALARES ARQUITETO JARBAS KARMAN

REVISTA IPH

EDIÇÃO Nº 20 DEZEMBRO DE 2023

ENGLISH

december 2023
IPH Magazine

VERSION

IPH Magazine
20th edition
December 2023

Graphic Design
Nathalia Duran

Translation
Spanish Martin y Claudia Cadillo
English Marina Jarouche

Cover Image
Shaare Zedek Medical Centre - SZMC
Architects: Farrow Partners e Rubinstein Ofer Architects.
Photographer: Harel Gilboa.

ISSN 2358-3630

Mailing address
IPH - Instituto de Pesquisas Hospitalares Arquiteto Jarbas Karman
74 Vargem do Cedro Street, São Paulo - SP
Zip Code 01252-050
Phone number (+55 11) 3868-4830
e-mail revista@iph.org.br
website www.iph.org.br/revista

Summary

Editorial

It is with great satisfaction that I greet all the readers of the Magazine of the Institute of Hospital Research Jarbas Karman (IPH) and thank you for being with us on this special occasion: our twentieth edition.

In this significant milestone, we would like to express our pride in the recognition of IPH Magazine by the scientific community, from which it stands out as one of the most well-regarded in Brazil, with the A2 grade in the last Capes/Qualis evaluation, reserved for journals of international excellence. This achievement is certainly the result of the commitment of our entire editorial team, authors, collaborators, translators, and reviewers, who have contributed to the construction and consolidation of the IPH Magazine over the last two decades.

The importance of research and science in contemporary society cannot be underestimated. Through scientific research, we can understand, explain, and solve a wide range of complex challenges in areas such as architecture and urbanism, engineering, planning, management, and maintenance of healthcare buildings. Throughout these more than 20 years of existence, IPH Magazine has been dedicated to the mission of spreading out scientific knowledge, serving as a fundamental vehicle for the dissemination of national and international research and studies. By providing this space, the Institute founded by Jarbas Karman shows that it remains firm in its purpose of promoting the advancement of scientific knowledge.

In this issue, we present four unpublished articles, which address different issues related to the hospital area and health architecture. The first article, entitled “Health care buildings, design and use of diagrams”, presents reflections by the authors Luciana and Renato de Medeiros, researchers of the Federal University of Rio Grande do Norte – UFRN, about the importance of the use of diagrams in the design-process of healthcare buildings. The authors argue about the application of diagrams as valuable tools in the development phase of complex projects, highlighting its relevance for the creative process, in the search for environments with greater resolution and quality.

The second article, “Performance indicators as a management tool in building maintenance”, presents a case study of a university hospital located in the city of Curitiba. In this article, engineer Washington Souza, a server at the Hospital de Clínicas of the Federal University of Paraná – UFPR, investigates the use of tools in the management of building maintenance in a large hospital, highlighting the importance of monitoring five indicators related to building maintenance to support the decision-making process.

In the third article, “Evaluation of the allocation of activities applied to an adult hospital emergency room: an analysis compared with the findings of post-occupation evaluation”, the authors Lucas Pereira and Sheila Ornstein, members of the Research Group Quality and Performance in the Built Environment of the School of Architecture and Urbanism of the University of São Paulo – FAU-USP, offer an analysis of the practices of activity allocation in hospital emergency rooms, with the help of a methodology that involves the mapping and post-occupation evaluation of a sector of within the University Hospital – HU-USP. The authors thus seek to contribute to the management and planning of health spaces, providing a clearer understanding of the challenges and opportunities arising from this type of research.

The last article, “Hospital architecture sensitive to dementia”, presents the findings of research concerning the aspects related to dementia-sensitive architectural design for the qualification of the experience of the elderly in hospital settings. Researcher Ciro Férrer, from the Federal University of Ceará (UFC), presents part of a more comprehensive research to identify the possibilities of using neuroscience applied to architecture in health centers and also to residential projects for the elderly.

In addition to the scientific articles, this edition also includes a review of the book Constructing Health, the first publication by the Canadian architect Tye Farrow, which deals with the application of neuro-architecture and other practices and concepts related to the design of health spaces, offering reflections on trends and innovations in health architecture and their influence on the well-being of patients and the effectiveness of services. As a bonus, we present an interview with the renowned architect, conducted a few days before the release of the book.

We encourage all our readers to explore the articles and other texts presented in this issue with attention and interest. We also invite researchers and professionals to contribute to the next editions of IPH Magazine by submitting their work and research, which will help to further enrich our journal and promote continuous advances in the health area.

On behalf of the entire IPH Magazine team, I wish you all a good read!

Prof. Arch. Marcio Nascimento de Oliveira, MSc.

Editor – IPH Magazine

Article

Healthcare buildings, design, and use of diagrams

Authors

Luciana de Medeiros holds a master's degree in Psychology, and a PhD in Architecture, working in the field of architectural design and Environmental Psychology. She is an adjunct professor at the Architecture and Urbanism program, as well as at the undergraduate program in Architecture, Design and Environment at the Federal University of Rio Grande do Norte.

Renato de Medeiros holds a master's degree and a PhD in Architecture, working in the area of design and its relationship with teaching and technological content. He is an adjunct professor at the Architecture and Urbanism program, as well as at the undergraduate program in Architecture, Design and Environment at the Federal University of Rio Grande do Norte.

Abstract

The purpose of this article is to present some reflections on the field of architectural design, more specifically on complex projects and potentialities of the use of diagrams in the design processes of buildings that provide healthcare services. To this end, a literature review was carried out on the theme and its related subjects, exemplifying, through illustrations extracted from the literature around hospital architecture, the use of functional diagrams in the initial stages of the project. It is considered that diagrams are essential tools for the creative process and the systematization of the quantity and diversity of variables involved in the design of healthcare facilities.

Keywords

architectural design, healthcare facilities, diagrams.

1. Introduction

The debate about architectural design in the face of the new challenges of contemporaneity has been a recurring topic in the studies carried out in recent years, especially due to new concepts and methodologies that influence its practice. As a process or product, the project has multiple faces and development possibilities, intrinsic to its own configuration. Thus, the greater its complexity, the greater the number of variables involved in the stages of conception and elaboration of the corresponding graphic material, requiring certain artifices for its implementation.

In this sense, the purpose of this article is to examine the theme of design complexity and the potential use of diagrams in the design processes of buildings that provide healthcare services. As these settings can be classified in the category of complex buildings due to their own physical and functional requirements and characteristics, it is considered that diagrams are fundamental tools both for the creative process and for the systematization of the quantity and diversity of information related to the project's demands.

The present study was carried out via a literature review about the main theme and its related subjects, along with an analysis of the illustrations done by J. C. Bross (2013) to exemplify the use of functional diagrams in the initial stages of a complex project. The main objective of this investigation, which is part of wider research on the subject, is to demonstrate the importance of architectural diagrams for the conception of the most complex and current projects.

2. Design, processes, and complexity in architecture

A project can be understood as the result of an effort, carried out in a certain period and with pre-established objectives, whether to create a product, a service, or a process (PMI, 2017). In the field of architecture, while some researchers develop or carry out investigations focused on the final product, delivered through a series of documents (mostly graphic), seeking to evaluate different aspects such as formal, functional and/or representative solutions (BAKER, 2002; TAGLIARI, 2009), others focus on the stages of development of architectural design and its parts, strategies, tools, and methods (LAWSON, 2011), in order to unveil what goes on beneath the veil of design (BOUDON, et. al., 2001).

According to Andrade et al. (2011), there are several ways to describe the architectural design process and how it interferes with the production of the building. As pointed out by Vries and Wagter (1991) and Lawson (2011), this happens because there are characteristics that should be considered in investigations regarding design processes. In summary, these authors convey the inherent complexity of the processes, emphasizing their poor structure and their open configuration that allows for several starting points or referrals (VRIES and WAGTER, 1991). These aspects are related to the definition elaborated by Rittel and Webber (1973), who classified the problems found in projects as *wicked problems*[1], as a clear reference to the characteristics of the architectural problem, a situation different from what happens in more exact fields of knowledge.

In view of this understanding, the architectural project gains a multidimensionality inherent to its own configuration, i.e., it invariably presents some degree of complexity, which also requires that its resolution be the result of highly sophisticated reflections. In addition, we know that there are various types of architectural problems, resulting from complex demands and that are related to functional, economic, technological, and social aspects. In the case of architectural projects that are considered complex, we usually associate them with buildings whose programs are extensive or that are subject to specific restrictions, such as the incidence of special legislation. This is the case, for example, of projects for healthcare facilities, airports, schools, bus stations or intermodal stations.

What we see is that complex projects have varied conceptualizations and delimitations according to investigations in different areas of knowledge, although they include similar variables in their characterization. In general, the most recurrent definition is that complex projects are systems composed of many variables, an increase in high technology, many standards and regulatory bodies, multiple objectives and several actors involved in the decision-making process (BACCARINI, 1996; REMINGTON, et. al., 2009; CARVALHO, 2011; 2014; CAIXETA; FABRÍCIO, 2011; KOWALTOWSKI, 2011; SALGADO, et. al., 2012; NETO; PISCOPO, 2015; LUKOSEVICIUS, et.al., 2018).

In architecture, all these dimensions act in the project at different scales, from urban planning to building. When associated with hospital architecture, they are also connected to issues related to the safety and health of the establishment's users, including patients, companions, and staff. At the same time, factors related to the level of service and the profile of the building also influence the number of variables involved in the project.

Therefore, as Bross (2013) and Carvalho (2014) point out, the complexity of healthcare facility projects lies mainly in the coexistence of the following assumptions: requirements arising from health planning and regional demands; norms and constraints of different natures; specificities of physical arrangement; interdisciplinary work; environmental requirements; interface with complementary projects; and architectural attributes linked to humanization in health.

1 *Wicked problems* are those with multiple formulations, to which, therefore, there are no right or wrong solution, but rather solutions considered to be good or bad. Moreover, for Rittel and Webber (1973) they are unique problems whose solution is determined by the choice of one, from many, point of view around that issue.

It is observed, therefore, that the multiplicity of elements that make up each variable or characteristic dimension of the project should be worked on and/or analyzed in different ways by architects and other professionals involved in the project design in search of an integrated solution.

To accomplish this goal, we cannot fail to consider the central role that drawings play in the practice of architectural design. Authors such as Ortega (2001, p.37) argue that "drawing is, therefore, the essence of architectural activity. It is the immediate method of expression of all that is thought." This value was also pointed out by Schön (2000), when he characterized the reflective practice in the design process and called the designer as that person who talk to the drawings. Thus, from the understanding of all this potential to express and communicate ideas, and observing contemporary methods and tools applied in various phases of the project and involving actions of analysis and synthesis, it is seen that the use of diagrams has been configured as one of the several possibilities to face design issues, especially in situations involving architectural problems considered complex.

3. Diagrams and projects of healthcare facilities

In general, architectural diagrams can be understood as graphic schemes used to synthesize ideas – together with information – referring to concepts, design constraints or details necessary for the project. Although it is not a new artifice within the field of architecture, its application nowadays takes on a broader meaning.

As Munari and Izar (2013) point out, since the 18th century, diagrams have been used as visualization tools. As in physics, for example, with the representation of mechanical movements or in astronomy studies developed by Isaac Newton, Kepler, among others. The origin of the term, which dates to the 17th century, relates to geometric representation[2]. Used by various fields of science, diagrams were initially presented as static figures, i.e., expressing information about certain processes, procedures, or models that, through design, are characterized in a direct way. A way of imparting information that does not leave room for other interpretations or analyses.

According to Montaner (2017), from the mid-twentieth century onwards, architectural diagrams began to receive a more dynamic use and interpretation, connected to the design process. Thus, they were conceptualized as an abstraction, which went from an initial instrument "capable of interpreting vectors, phenomena and desires of reality" (MONTANER, 2017, p. 08) to a means of proposing and projecting. For the author, the diagram is a graphical tool that enables the visualization of phenomena or flows, both of reality and of the project. It does not have a

2 The Latin term originates from the Greek word meaning "everything that is described by drawing or by writing and figure geometry": "day" (through) and "gramma" (written thing) (MONTANER, 2017).

precise shape or figure, “it is a possibility, a geometric means that allows us to move from the unspeakable to words” (MONTANER, 2017, p.23).

In short, diagrams are lines of force that have the ability to self-organize and the possibility of being transmitted. The diagram is the smallest graphic element capable of representing an idea in progress (...). In architecture, the diagram is not yet the architectural fact; it is pre-architectural. (MONTANER, 2017, p.23).

Montaner (2017) has conceived a classification for the diagrams used today, dividing them into two main categories: analysis diagrams and project diagrams (Table 1). This organization proposal seeks to systematize the types of diagrams without, however, calling it definitive, considering the progressive character of the instrument.

DIAGRAMS	
ANALYSIS DIAGRAMS	PROJECT DIAGRAMS
Legibility analysis	Classic typologies
Requirement analysis	Structural and lines of force
Strictly analytic	Methodological
Formal analysis	Procedural
Symbolic analysis	Functional
Proportion analysis	Formal or iconic

Table 1 . Types of diagrams according to Montaner (2017). Source: Prepared by the authors, adapted from Montaner (2017).

According to the author’s considerations, analytical diagrams examine architectural, urban, or territorial characteristics or phenomena, but they are also used for design, since diagnosis and action can occur simultaneously. Project diagrams, on the other hand, fall within the field of architectural design, highlighting design reasoning. Although they differ from sketches by the way they explain and communicate certain relationships, helping the architect’s analytical or propositional work, this difference between the two still has divergent interpretations in the literature. Both are drawings, graphic representations that must communicate. But while sketches express information, sometimes with a high level of detail, diagrams act through an abstract representation, without providing detailed descriptions of scale or other architectural elements, even indicating spatial relationships through undefined shapes (DULIC´; ALADŽIĆ, 2016).

This new interpretation, according to Somol (2007), originates from the 1960s, when the idea of diagram was changed to a tool of architectural production and a primordial element to reinforce its discourse. From that moment on, the diagram was introduced into architectural practice not only as a representational means, but also as a design tool, capable of adding stages of analysis and diagnosis, as well as propositions. After the 1990s, it took on a more dynamic character to assist in the analysis and resolution of multifaceted and imprecise everyday problems (LACOMBE, 2005; BARKI, 2009; DUARTE, 2012; ROCHA; MOREIRA, 2014; MIRANDA, 2015; MONTANER, 2017; SILVA, 2017).

The use of functional diagrams in the initial phases of the project

In the area of hospital architecture, diagrams have often been used during the design phases of the project, especially in the initial phases, in which the architect deals with a large amount of data and must spatialize both the ideas and the project constraints. That said, the diagram can be seen as a device with numerous functions, among which the following can be mentioned:

. Analysis of the existing relationships in the scenario of implantation of the building (relationship between lot and surroundings, environmental comfort, accesses, among others).

. Development of architectural programming.

. Study of sectorization.

. Understanding and definition of flows (of people and materials).

. Reflection on flexibility and/or expandability solutions.

. Evaluation of construction systems (structure, materials, and installations).

Although several types of diagrams can accompany the creative process and discussions about the project with the team of professionals, and even with the participation of future users, some types are among the design methods employed by architects in the area. Bubble diagrams, for example, a derivation of the functional diagrams already indicated in the previous section, generally fulfills the role of simulating spaces and their relationships, predicting connections, as well as organizing flows of people and materials.

To better illustrate this subject, we refer to the work Compreendendo o edifício de saúde (understanding the healthcare building) by Brazilian architect João Carlos Bross, and the many examples given throughout his discussions on healthcare facility projects (BROSS, 2013). According to the author, the elaboration of the physical program – preceded by the operational program – requires the construction of bubble diagrams to organize the intersectoral relationship network (determining proximity or distance between compartments of a sector), flow sequences (indicating routes of greater demand), or even events of the processes related to the sector being worked on (see Illustrations 1, 2, and 3). These diagrams also have the purpose of involving project consultants in the debate about the planned activities and services, with the aim of defining details of the site to be built/occupied.

In fact, functional diagrams derive from the architectural program and often generate floor plan schematics (BORGES; NAVARRO, 2001). Although it is an artifice widely used in an analog and spontaneous way, free of rules, it can act together with various types of information, including matrices that generate relationships between environments. Currently, as suggested by Veloso (2014), diagrams have acquired new possibilities of presentation and application, using digital technologies to support the project.

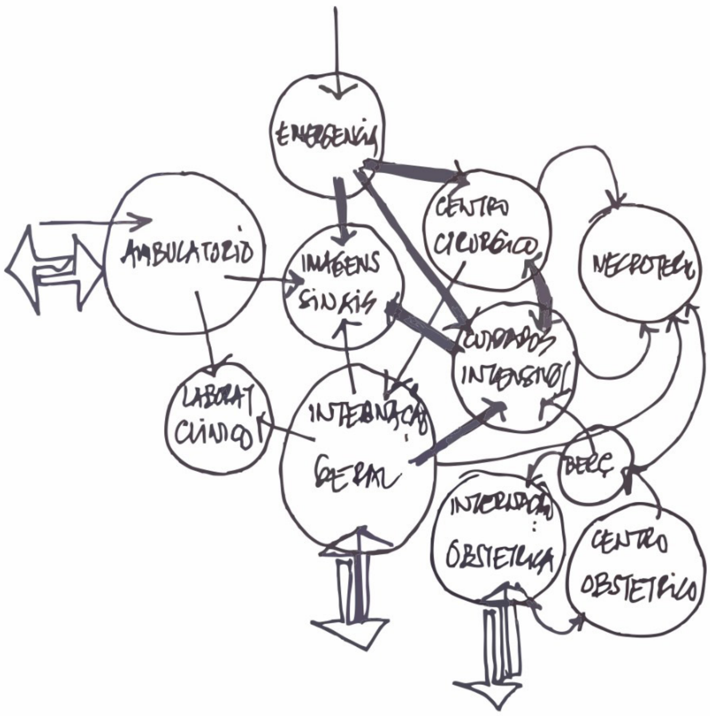


Illustration 1 . Example of a bubble diagram with intersectoral and flow connections within the hospital. Source: Bross (2013, p. 204)

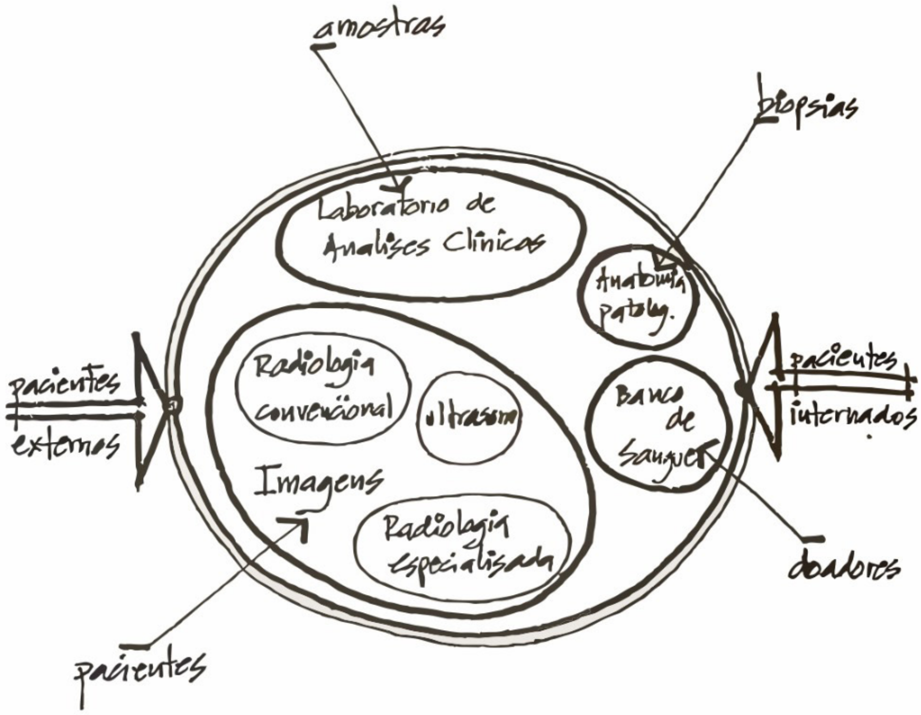


Illustration 2 . Example of a bubble diagram of a clinical support unity. Source: Bross (2013, p.214)

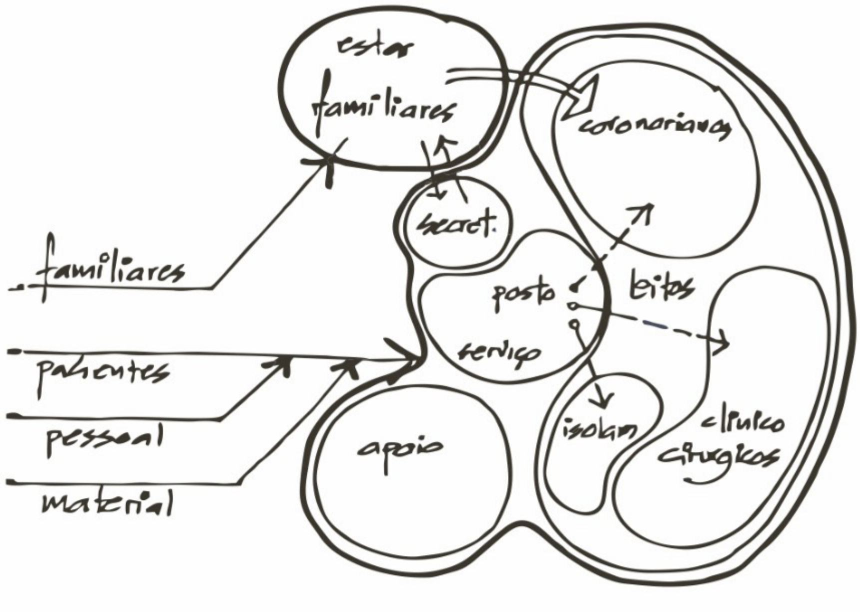


Illustration 3 . Example of a bubble diagram of an intensive care unity. Source: Bross (2013, p. 215)

4. Final considerations

The development of the present research revealed the complexity existing in the conception of the architectural project, especially of healthcare buildings, due to the expressive number of uncertainties and variables that are characteristic of them. The importance of systematizing the process is also observed by the use of certain graphic resources that assist in the search for solutions and their registration throughout the various stages of the project, as is the case of diagrams.

As visualized in the examples of bubble diagrams, its use in the early stages of the project helps to fast-track the analysis and synthesis of the different elements and variables present in the problem that is intended to be solved. Therefore, for complex projects, these diagrams have excellent applicability.

However, even though they are well-known design and representation tools, diagrams have been acquiring a new meaning in the face of the challenges to which architecture needs to respond. Currently, its use is expanded, with greater abstraction and possibilities of linking with software and digital technologies. In addition, the variety of applications in the field of activity of several Brazilian professionals is highlighted, especially in the most complex projects, pointing to the need and opportunities for more in-depth future research on the subject.

5. Bibliography

ANDRADE, M.L.V.X., RUSCHEL, R.C., MOREIRA, D.C. **O processo e os métodos**. In: KOWALTOWSKI, D. et al. **O processo de projeto em arquitetura: da teoria à tecnologia**. São Paulo: Oficina de textos, 2011.

BACCARINI, D. **The concept of project complexity: a review**. International Journal of Project Management, v. 14, n. 4, pp. 201-204, 1996. Disponível em: https://www.sciencedirect.com/science/article/pii/0263786395000933. Acesso em: set 2018.

BAKER, G. H. **Le Corbusier: uma análise da forma**. São Paulo: Martins Fontes, 2002.

BARKI, J. **Diagrama como discurso visual: uma velha técnica para novos desafios**. In: 8º DoCoMoMo BRASIL. 2009. Disponível em: https://docomomobrasil.com/course/8-seminario-docomomo-brasil-rio-de-janeiro/ Acesso em: 6 jun 2021.

BORGES, M. M.; NAVEIRO, R. M. **Considerações Acerca das Formas Tradicionais e Recursos Computacionais para a Representação do Projeto**. Revista da Escola de Minas, Ouro Preto, v. 54, n.1, pp. 19-23, 2001. Disponível em: https://doi.org/10.1590/S0370-44672001000100004. Acesso em: 7 set 2022.

BOUDON, P., DESHAYES, P., POUSIN, F., SCHATZ, F. **Enseigner la conception architecturale**. Cours d'architecturologie. 2 ed. Paris: Éditions de la Villette, 2001.

BROSS, J. C. **Compreendendo o edifício da saúde**. São Paulo: Editora Atheneu, 2013.

CAIXETA, M. C. B. F.; FABRÍCIO, M.M. **Gestão de projetos complexos: edifícios de saúde**. In KOWALTOWSKI, D. C. C.; MOREIRA, D. C.; PETRECHE, J. R. D.; FABRICIO, M. M. (Orgs). **O processo de projeto em arquitetura: da teoria à tecnologia**. São Paulo: Oficina de Textos, 2011.

CARVALHO, A. P. **Gestão de Projetos Complexos e Transdisciplinaridade**. In: II SBQP, Anais... Rio de Janeiro, 2011.

CARVALHO, A. P. **Introdução à arquitetura hospitalar**. Salvador: Quarteto; FAUFBA, 2014.

DUARTE, R. B. **Radicalizando por diagramas. Por favor, devagar no mar agitado das novidades**. Arquitextos, São Paulo, ano 12, n. 143.06, Vitruvius, abr. 2012 Disponível em: https://vitruvius.com.br/revistas/read/arquitextos/12.143/4275. Acesso em: 16 ago 2022.

DULIĆ, O. ; ALADŽIĆ, V. A. **Note on Graphical Representations in Architecture - Diagrams over Sketches**. In: 4th International Conference Contemporary Achievements in Civil Engineering 2016, 2016, pp. 835-844 Disponível em: http://www.gf.uns.ac.rs/~zbornik/doc/NS2016.084.pdf. Acesso em: 12 mar 2019.

KOWALTOWSKI, D. C. C. **Arquitetura escolar: o projeto do ambiente de ensino**. São Paulo: Oficina de Textos, 2011.

LACOMBE, O. L. M. **O projeto como descoberta: analogia, diagrama e experimentação**. In PROJETAR, II, 2005, Rio de Janeiro. Anais... Rio de Janeiro: Universidade Federal do Rio de Janeiro, 2015. CD-ROM

LAWSON, B. **Como arquitetos e designers pensam**. São Paulo: Oficina de textos, 2011.

LUKOSEVICIUS, A. P.; SOARES, C. A. P.; JOIA, L. A. **Caracterização da complexidade em projetos de Engenharia**. Gest. Prod., São Carlos, v. 25, n. 2, p. 331-342, 2018. Disponível em: http://dx.doi.org/10.1590/0104-530X2957-16. Acesso em: 2 set 2018.

MIRANDA, J. T.; CAETANO, D. C. T.; LAGES, L. B. **Procedimentos diagramáticos no projetar: duas experiências de TCC na UFMG**. In PROJETAR, VII 2015. Anais... Natal: Universidade Federal do Rio Grande do Norte, 2015. CD-ROM

MONTANER, J. M. **Do diagrama às experiências, rumo a uma arquitetura de ação**. São Paulo: Gustavo Gili, 2017.

MUNARI, L.; IZAR, G. **Diagrama, arquitetura e autonomia**. Pós. Revista do Programa de Pós-Graduação em Arquitetura e Urbanismo da FAUUSP, v. 20, n. 33, p. 160-180, 2013. Disponível em: https://www.revistas.usp.br/posfau/article/view/80926. Acesso em: jun 2021.

NETO, F. S.; PISCOPO, M. R. **Evolução do conhecimento sobre projetos complexos: uma análise da produção científica**. Revista de Gestão e Secretariado - GeSec, São Paulo, v. 6, n. 3, pp. 91-116, Set./Dez. 2015. Disponível em https://www.revistagesec.org.br/secretariado/article/view/434. Acesso em: 2 set 2018.

ORTEGA, A. R. **O projeto e o desenho no olhar do arquiteto**. 2001. Dissertação (mestrado) Universidade de São Paulo, São Paulo, 2001.

PMI. **Um guia do conhecimento em gerenciamento de projetos**. Guia PMBOK® 6a. ed. – Pensilvânia: Project Management Institute, 2017.

REMINGTON, K.; ZOLIN, R.; TURNER, R. **A model of project complexity : distinguishing dimensions of complexity from severity**. In: Proceedings of the 9th International Research Network of Project Management Conference, Berlin, 2009. Disponível em: https://eprints.qut.edu.au/29011/1/c29011.pdf . Acesso em: 2 set 2018.

RITTEL, H. W. I.; WEBBER, M. M. **Dilemmas in a general theory of planning.** Policy Sciences v. 4, n. 2 1973, pp.155–169. Disponível em: https://link.springer.com/article/10.1007/BF01405730. Acesso em: 7 set 2022.

ROCHA, A. P.; MOREIRA, D. C. **O Diagrama e o design da informação na arquitetura contemporânea**. Arcos Design. Rio de Janeiro, v. 8 n. 1, 2014, pp. 49-61 ISSN: 1984-5596. Disponível em: http://www.e-publicacoes.uerj.br/index.php/arcosdesign. Acesso em: 16 ago 2022.

SALGADO, M.S.; RHEINGANTZ, P.A.; AZEVEDO, G.A.N.; SIVOSO, M.M. **Projetos complexos e seus impactos na cidade e na paisagem**. Rio de Janeiro: UFRJ/FAU/PROARQ; ANTAC, 2012.

SCHÖN, D. **Educando o profissional reflexivo - um novo design para o ensino e a aprendizagem**. Porto Alegre, Artmed, 2000

SILVA, A. M. **Entre diagramas e processos - notas sobre discursos, enunciados e práticas contemporâneas**. Revista Projetar - Projeto e Percepção do Ambiente, [S. l.], v. 2, n. 2, p. 36–51, 2017. DOI: 10.21680/2448-296X.2017v2n2ID16578. Disponível em: https://periodicos.ufrn.br/revprojetar/article/view/16578. Acesso em: 16 ago 2022.

SOMOL, R. E. **Dummy Text, or The Diagrammatic Basis of Contemporary Architecture.** Risco, São Carlos, n. 5, p.168-178, 2007. Disponível em: https://www.revistas.usp.br/risco/article/view/44700. Acesso em: 7 set 2022.

TAGLIARI, A. **Análise da forma e espaço pelo método gráfico residências usonian de Frank Lloyd Wright.** In: IV Projetar 2009. São Paulo. Anais... São Paulo, Universidade Presbiteriana Mackenzie, 2009. Disponível em: http://projedata.grupoprojetar.ct.ufrn.br/dspace/handle/123456789/488. Acesso em: 2 set 2018.

VRIES, M.; WAGTER, H. **A CAAD model for use in early design phases**. In: The Electronic Design Studio: Architectural Knowledge and Media in the Computer Era - CAAD Futures '89 Conference Proceedings, ISBN 0-262-13254-0, 1989, pp. 215-228. Disponível em: http://papers.cumincad.org/cgi-bin/works/Show?c2ed. Acesso em: 7 set 2022.

VELOSO, P. L. A. **Explorando o diagrama de bolhas**. In: Proceedings of the XVIII Conference of the Iberoamerican Society of Digital Graphics: Design in Freedom - Blucher Design Proceedings, v.1, n.8, São Paulo: Blucher, 2014, p. 115-119, ISSN 2318-6968, DOI 10.5151/despro-sigradi2014-001. Disponível em: http://papers.cumincad.org/data/works/att/sigradi2014_128.content.pdf. Acesso em: 7 set 2022.

Article

Performance indicators as a management tool in building maintenance – a case study of a public hospital

Authors

Washington Batista de Souza Civil Engineer with a degree on Architectural Design and a Master´s degree in Civil Construction. Federal Technical University of Paraná, Curitiba, PR, Brazil.

Adalberto Matoski Civil Engineer with a PhD in Wood Technology, Full Professor at the Federal Technical University of Paraná, Curitiba, PR, Brazil.

Abstract

The objective of this study is to present the results of the monitoring of five maintenance indicators of a large hospital in the city of Curitiba. The synthesis of this work is the result of nine years of monitoring of the hospital engineering service of the building maintenance of the Hospital de Clínicas belonging to the Federal University of Paraná, through five performance indicators, using as a basis a control tool called physical schedule. The methodology used in this work was the creation of a tool in Microsoft Excel, called physical schedule, which allowed the monitoring of the performance of four categories of building maintenance: masonry and hydraulics, locksmithing, electrical and refrigeration, and carpentry, which cover practically all the building maintenance services necessary to maintain in conditions of use the 60 thousand m2 of the buildings of the Hospital de Clínicas belonging to the Federal University of Paraná. This tool made it possible to evaluate the services performed vs. services procrastinated, labor employed, labor cost, labor cost per service performed, and the characteristics of the services performed. It was found that the average number of services performed in the four areas is 47% of the total demanded, thus performing an average of 541 tasks per year. The average number of employees used to perform these tasks was 45, with an average monthly cost of US$ 46,597.60, and an average cost per position of US$ 76.44, and the cost of one man-hour worked in 2021 was, on average, US$ 4.88.

Keywords

hospital building maintenance, performance, cost, hospital engineering.

1. Introduction

The well-being of patients is correlated with the quality and performance of the hospital building. In this context, for construction to achieve its objectives and provide services compatible with its activities, users and administrators, building maintenance becomes a key element (OLANREWAJU, FANG and TAN, 2018).

According to Karman (2011), the hospital is a company designed to assist people, prevent diseases, treat, and rehabilitate patients, raise the standard of health professionals, and conduct research. Therefore, they require special facilities. Karman also states that hospitals are the most complex enterprises from an architectural, engineering, facilities and building maintenance point of view, as they operate 24 hours a day, 365 days a year, mentioning that foresight and early detection of failures or defects curb interruptions and interdictions, as well as unnecessary mobilizations and resources.

Machado (2013) comments that, because of the level of operability required in a hospital environment, the unavailability of spaces, facilities or equipment can have negative impacts on clinical activity, including risk to human lives.

In the hospital environment, each sector has its own maintenance needs, the failure of which, if not circumvented, can compromise the local service and the delivery of its service, directly influencing patient care (SILVA, 2018).

Boeger (2009) comments on the importance of the structural conditions offered by the hospital environment to patients during their stay, emphasizing that they can even affect their recovery. In turn, the durability of a building is directly linked to the maintenance routine imposed on it and the available costs (GUIMARÃES, 2020).

2. Literature review

2.1 Building maintenance

According to European Standards (EN 13306, 2017), building maintenance can be defined as the combination of all manageable technical and administrative efforts aimed at maintaining or restoring the conditions of use of any good or any asset during its useful life.

Building maintenance can be defined as a tool composed of several items in which technical and administrative activities take place simultaneously (SANTOS, ALVES and PINHEIRO, 2021). For Donas (2004), maintenance is the correction and prevention of failures, and, depending on the application environment or the criticality of the failure, maintenance becomes more relevant, as it involves economic elements such as: production, preservation of the environment, availability of equipment, lives, and safety of users.

Building maintenance can also be defined as the set of all activities related to the operations of conservation, adaptation, restoration, replacement, and prevention of the physical conditions of buildings (PINTO and XAVIER, 2001).

According to Cabral (2009), building maintenance is basically divided into three modalities: preventive, corrective, and improvement. Preventive maintenance is carried out with the aim of avoiding breakdowns, losses, or malfunction. Corrective maintenance is performed following a breakdown or loss of function. Finally, the improvement maintains the conditions of use of the asset or compliance with current legal standards.

In recent years, according to research conducted by Burgardt (2002), with the recent evolutionary increments, in most companies, the maintenance area is no longer just a routine activity and has become a strategic activity, being a competitive differential between organizations.

Alner and Fellows (1990) summarize that the main building maintenance strategy should be focused on the safety of users and that the other strategies derive from this.

The building maintenance strategy adopted by organizations must be efficient and add value to existing assets. To this end, it must be effective to such an extent that it can extend the useful life of the building and its equipment as much as possible (HORNER et al. 1997).

Building maintenance policy and strategy are the main aspects to be considered in the building maintenance operation management process (LEE and SCOTT, 2008).

The three essential elements for this policy are: the choice of maintenance strategy, the standard of maintenance, and the allocation of resources (LEE, 2008).

Lee and Worsworth (2001) observe that, without a well-defined maintenance policy, all efforts in this direction will be random. To avoid such a situation, the authors list five basic principles: (i) the appropriate interval for carrying out a maintenance operation; (ii) the useful life of the equipment and elements of the building; (iii) the standard of services to be maintained; (iv) the required response time between the occurrence of the defect and its repair; and (v) the legal requirements to be observed.

On the other hand, the acceptable standard of maintenance in organizations depends a lot on the availability of resources and factors common to both users and property managers (EL-HARAM and HORNER, 2002).

Another important aspect mentioned by Pitt (1997) is the fact that the operational maintenance team argues that the budget allocated to this activity is always below its needs. On the other hand, senior management criticizes the inefficiency of maintenance regarding the use of allocated resources.

On the other hand, Amaratunga et al. (2000) mentions that maintenance has become an important focus to ensure the useful life of the assets of the buildings constructed, requiring considerations that must already be considered in the design of the project.

Another similar aspect was addressed by Arditi and Nawakorawit (1999). In a survey conducted in the United States, the authors found that most owners of 230 buildings surveyed were not only investing resources in reactive maintenance, but also, especially, in the efficient planning and management of building maintenance, as well as in any corporate activity.

In the same study, the authors noted a 16% increase in the number of building maintenance employees during the five years of research.

When considering sustainable development, it is very important to take into account life cycle (maintenance) costs, especially since it is estimated that buildings are responsible for 40% of all energy consumed in the European Union (BORKOVIĆ, 2005, cited by MARENJAK and KRSTIĆ, 2012).

According to Shohet and Lebiovich (2003), the performance of hospital buildings depends largely on the efficiency of maintenance execution.

Chanter and Swallow (2007) mention that among the main elements to be evaluated in the management of building maintenance there is people management.

Viana and Ribeiro (2017) conducted a survey on the factors that contribute to the success of maintenance management in mining companies. The third item most mentioned by the interviewees – managers, supervisors, and engineers – was people management.

In a personal research model, Al Zubadi and Christer (1997) analyzed the main maintenance problems and the average number of employees to meet such demands, perceiving a large deficit of employees to solve them.

2.2 The importance of building maintenance in the hospital environment

Precarious building maintenance services or services with few investments are risk factors for patients, given that the number of defects in the facilities tends to increase as the repair response time rises, which often disqualifies adequate care, if not completely makes it impossible (ABISUGA et al., 2016).

To cite a few examples, it was found that, in Palestinian hospitals in the Gaza Strip, there was only corrective maintenance of the water and sewage systems, often putting the health of patients at risk due to the lack of preventive inspection of these systems (ENSHASSI et al., 2015).

In a hospital located in southwestern Nigeria, the low efficiency of the vertical fire transport system was found, in addition to several failures in the electricity supply system (ADENUGA and IBIYEMI, 2009).

An audit carried out in Cuban hospitals concluded that the root cause of many pathological manifestations in buildings was linked to poor management of building maintenance activities (GALÁN and EDITH, 2017).

According to Joshi and Murthy (2011), building maintenance activities in hospitals should not focus on adding value to the building as happens in commercial buildings and residences, but rather on reducing the time of execution of services as much as possible and with the least possible impact on routine hospital activities.

The Malaysian government, for example, began privatizing the management of hospital maintenance in the country's 144 public hospitals in 1996 through five different consortia. Even so, after several years of services provided, these consortia, for various reasons, have not yet been able to present satisfactory results in terms of service quality before the country's public opinion (WONG et al., 2021).

Another important aspect that should not be neglected in hospital maintenance operations is the environmental management of air and ventilation through air conditioning and refrigeration systems, which are responsible for being the major spreaders of infectious diseases, such as aspergillosis and legioneliosis (STREIFEL, 2005).

Also in Malaysia, Pallis and Misnan (2018) listed the main factors that affect maintenance costs: resource allocation by management, user behavior, climatic factors, complexity of use, and quality of materials and components used.

Such authors also give the example of the faulty air-conditioning systems at Tengku Ampuah Rahimah Hospital, causing several fungal infections in patients, among other occurrences recorded in Malaysia due to lack of maintenance.

According to a survey conducted in 61 health units in the state of Minas Gerais, only 3.3% fully meet the operational and infrastructure conditions for the execution of their activities, considering the complexity profile, and 96.7% partially meet (AMORIM et al., 2013).

Also in the same study, the authors found that only two health units have a quantity compatible with their needs; 57 have a quantity that partially meets the needs, and two have a totally insufficient quantity.

2.3 Building maintenance costs

In a study conducted in the United Kingdom, Chanter and Swallow (2007) mention that total expenses with building maintenance grew by about 90% between 1993 and 2003, a very significant figure that deserves due attention from maintenance managers.

A study by Neely and Neathemer (1991) found that in 34 different types of buildings (including hospitals), it was found that maintenance budgets were spent as follows: finishing and construction (34%); heating and air (29%); electrical installations (16%); plumbing installations (10%); and external façades (13%).

At the University of Barcelona, another study was carried out on the costs of a building during its lifetime. It was found that 5% of the costs regard the project; 20%, construction; 65%, maintenance and operation; and 10%, replacement or demolition. However, in health institutions, the operating costs are higher, mainly due to intense use (LOUSTAUNAU and BEGUERÍA, 1992), (CALCEDO, 2014).

In a study carried out with 700 hospital buildings in Israel, it was concluded that in 80,000 m2, with a rate of 8.25 beds per 1,000 m2, the average annual cost of maintenance was US$ 37.2/m2, of which 51.60% was spent on personnel, 11.7% on material, and the rest on water, light, and fuel expenses (SHOHET and LEIBOVICH, 2003).

In a study conducted in the public hospitals of Malaysia, it was found that many problems related to lack of maintenance in hospitals are directly linked to the lack of government investments in healthcare. It was found that while England invests on average US$ 3,867.00 per patient, Singapore spends US$ 1,148.00, and Brazil, US$ 723.00, in Malaysia, this investment is in the order of US$ 437.00 (OLANREWAJU, FANG and TAN, 2018).

In 2002, the total investment in building maintenance in Malaysia was US$ 117,943.99, a sum equivalent to 6% of the country's total investment in civil construction, according to the Malaysian Construction Industry Council (OLANREWAJU, 2008).

According to Barylka (2016), cited by Plebankiewicz and Gracki (2013), one of the components of a building's life cycle costs that is difficult to determine is the costs incurred during the operation of the building, in particular maintenance.

In a survey conducted in five public hospitals in Syria, Hassan and Haddad (2011) concluded that 50.5% of maintenance expenses were with architectural elements, 23.16% with electricity, 14.67% with mechanical installations, and 12.5% with other elements.

From the point of view of management, besides the expenses that generate economic costs, the costs of shutdowns, energy consumption, atmospheric emissions and the premature aging of equipment and systems due to inefficient maintenance must also be considered (KAPLAN and NORTON, 2004).

2.4 Hospital maintenance indicators

To measure whether the maintenance of a given institution is efficient, enough indicators must be created and monitored, in order to predict or anticipate actions to achieve excellence in the services provided with building maintenance (VERRI, 2007).

Branco Filho (2008) suggests the following items as indicators of building maintenance, among others:

a Equipment performance

b Maintenance costs

c Efficiency of maintenance programs

d Maintenance efficiency

Two other interesting indicators are proposed by Pinto and Xavier (2001), one of which measures the fulfillment of maintenance plans and is defined by the following equation:

MP = Task performed in the Maintenance Program x 100% (1)

Scheduled tasks in the Maintenance Program

The desirable value of this indicator is close to 100%.

The other indicator is related to the monitoring of labor costs in relation to the total cost of services and is defined by the following equation:

MO = Total cost of labor force employed on the task x 100%

Total cost of task maintenance

The lower the percentage, the more efficient the labor cost will be, except in cases where maintenance only involves the use of labor force and does not have any inputs.

In a survey conducted in a medium-sized hospital in the west of Santa Catarina State, in the southern region of Brazil, which serves about 114 beds, it was found that, between January and May 2017, the MP was 81.44% (QUADRI, 2017).

Heineck and Pazzenter (1989) state that large services consume large amounts of labor and have more power to dilute mobilization and demobilization times for the execution of tasks. The authors assume as a general assessment of the level of uncertainty that real labor consumption is distributed around average values according to a coefficient of variation between 10% and 20%.

Regarding the coefficient of variation, some studies indicate that for a sample to present an acceptable value the value of the coefficient of variation cannot be high. Thus, according to Nanni (1981), cited by Hirota (1987), values equal to or lower than 25% are considered acceptable.

In a study carried out in the city of Florianópolis (Santa Catarina), which analyzed the construction of an 8,916.93 m2 building, Parissoto (2003) noticed that the average production of most labor services in the execution presented coefficients of variation between 13% and 18%.

In a study carried out at the Hospital de Extremadura, in Spain, it was found that, by increasing the total time spent on preventive maintenance by 6% over a five-year period, the demand for corrective maintenance was reduced by 20%, with an average annual saving of 500 MWh in total electricity consumption (CALCEDO and CHAPARRO, 2017).

In the hospital mentioned above, maintenance operations are carried out by nine employees who work in shifts, covering 24 hours a day, all year round. The annual cost of this service is € 335,417.00, and this hospital has 75 beds, distributed in an area of 8,507.00 m2 (CALCEDO and CHAPARRO, 2017).

During the research, between 2010 and 2015, the authors mentioned above obtained an average annual cost of € 252.55 per service performed and € 167.97 per hour of maintenance worked.

Sezer et al. (2018) also stresses the importance of data collection throughout the maintenance process for predicting trends, behaviors, and decision-making in the continuous improvement of predictive maintenance.

3. Purpose and methodology

The main purpose of this study was to identify the costs related to hospital maintenance, as well as to the production and percentage of demand fulfillment, using a maintenance management tool developed in Microsoft Excel software, where we compiled data from nine years of research to monitor the execution of maintenance services in four different areas of the hospital environment.

The research methodology adopted for this study was exploratory, with analysis of data collected in the field (GIL, 2007). The research was carried out in a public hospital in the state of Paraná, Brazil, with an area of 59,541.60 m2 and an average occupancy of 400 beds, with an average rate of 6.71 beds per thousand square meters.

3.1 Management tool – physical schedule

The search management tool was developed in an Excel file, from the Microsoft package, which was divided into rows and columns where the following information was recorded:

a Requester control number

b Requester sector

c Date (when the demand was received)

d Service specification

e Service classification

f Observations

Table 1 shows an example of the use of this tool:

Control number	Sector	Date	Service	Classification			Obs.
				S	R	L	
015250/21	Operating Room	Feb 2	Renovation of 5 rooms			X	Starts in March
017289/21	Pharmacy	Feb 15	Painting	X			Scheduled to May
018555/21	Hospitality	Feb 18	Floor replacement in 2 rooms		X		Scheduled to June

Table 1 . Physical schedule of the hospital maintenance management. Source: Authors.

To carry out this research, four distinct maintenance sections were chosen, namely:

a Masonry: all painting services, replacement of ceilings, floors, doors, also including all services carried out on hydraulic and plumbing installations of the building. It is worth noting that most of the services performed by this section (95%) are done in different locations, which increases the execution time of the tasks, since the horizontal displacement of each floor is approximately 50-meter-long, and the vertical can vary between 17, 7, 5 and 4 floors.

b Metal work: all services related to repairs, recovery, painting of all stretchers, beds, chairs, railings, doors, and metal gates. In addition to the repair of hydraulic pumps, steam network, and medical gases of the building. About 90% of the tasks are performed in the section itself.

c Electrical work: all services related to electrical installations, panels, replacement of light bulbs, lamps, sockets, circuit breakers and all installation, repair, maintenance services of the building's air conditioning and refrigeration equipment. About 80% of the tasks are performed in the section itself.

d Woodwork: all services related to making, maintaining, adjusting, and installing wooden furniture, as well as all upholstery services (recovery and replacement) existing in the complex. About 90% of the tasks are performed in the section itself.

To make monitoring easier, we used different colors to identify the status of the required service: white, on hold; blue, in progress; red, delayed; and green, completed.

3.2 Data collection – Service order

All hospital maintenance services are addressed through an official service order to the administrative management. Then, they are requested to the infrastructure sector, where they carry out a service screening following these parameters:

a Emergency: services that cause interruption or may interrupt patient's care or life support.

b Critical areas: Intensive Care Unit (ICUs), Semi-Intensive Care Unit (CTSIs), Operating Rooms, Transplant Services, Chemotherapy Compounding Pharmacy, Tomography, Hemodynamics, and Information Service.

c Outpatient areas: offices, pharmacy, laboratories, kitchen, and wards.

d Administrative areas and other locations.

Table 2 illustrates the average number of requests the hospital Infrastructure Sector received and carried out during our nine-year research.

Section	Work		
	Total	Carried out	Not carried out
Masonry	382	181	201
Metal work	195	97	98
Electrical work	202	98	104
Woodwork	313	165	148
Total	1.092	541	551

Table 2 . Demands per work addressed to Infrastructure, annual average over nine years. Between 2013 and 2021. Source: Authors.

We can also observe on Table 2 shows that the Infrastructure Sector received an average of 1,092 demands every year, managing to resolve almost 50% of them. The demands are classified into three groups:

a Large – complex services that use at least two workstations at a time and require more than five business days to perform; on average, they represent 4% of the total.

b Regular – services whose complexity requires at least more than one workstation and 2 to 5 working days of execution; on average, they represent 18% of the total.

c Small – services whose complexity requires, at most, one workstation and up to two working days of execution; On average, they account for 78% of the total.

It is worth noticing that the Infrastructure Sector also receives about 14 maintenance orders to carry out every year with the same staff. Most of them are easily resolved within one hour of work.

Building maintenance services are distributed in seven different buildings ranging from 17 floors, the largest, to three floors, the smallest, often depending on the availability of vertical transport, which is not always available, increasing the time of execution of tasks.

In addition, the Hospital Complex has eight external houses, an archive shed located 15 km away and a building located 6 km away, which require similar services.

Table 3 monitors the percentage regarding the amount of work carried out by section over nine years of research:

	Works per section			
Year	**Masonry**	**Metal work**	**Electrical work**	**Woodwork**
2013	39,00%	45,00%	30,00%	20,00%
2014	44,00%	36,00%	49,00%	33,00%
2015	35,00%	44,00%	46,00%	52,00%
2016	59,00%	65,00%	84,00%	53,00%
2017	45,00%	44,00%	63,00%	40,00%
2018	45,00%	42,00%	50,00%	53,00%
2019	48,00%	47,00%	47,00%	64,00%
2020	35,00%	32,00%	39,00%	60,00%
2021	46,00%	53,00%	58,00%	71,00%
Average	44,00%	45,33%	51,78%	49,56%
Standard deviation	6,94%	8,99%	14,56%	15,08%
Coefficient of variation	15,78%	19,84%	28,12%	30,43%

Table 3 . Demands per work addressed to the Infrastructure Sector, percentage of works carried out per year. Source: Authors.

By stipulating the maximum limit of the coefficient of variation of 15%, as recommended by some authors, the mean values of the attendances per section, as well as of the other items studied, began to present new values, more consistent with the reality of the day-to-day of hospital maintenance, as will be shown below.

3.3 Data collection – Work positions

Throughout our nine years of research, there were changes in the number of positions to be hired, either due to financial constraints or administrative decisions. To illustrate that we can see that 2015 was the year with the largest contingent, with about 52 positions, and 2016, with the lowest, with about 35 positions. Box 3 shows the total average and the value per section.

Section	Total
Masonry	20
Metal work	7
Electrical work	11
Woodwork	7
Total	45

Table 4 . Work positions hired by Infrastructure, annual average. Source: Authors.

As we can see in Table 4, the average number of jobs for hospital maintenance during nine years was 45 jobs/year.

Percebe-se que, apesar de a equipe da alvenaria ser a maior em número, devido à complexidade de algumas atividades, o percentual de conclusão de ofícios é um pouco menor que o da seção de marcenaria ou serralheria, conforme visto na Tabela 1.

Although the masonry team is the largest in number, due to the complexity of some activities, the percentage of works completed is lower than that of woodwork or metal work, as seen in Table 1.

After gathering the data regarding the works carried out and the amount of work positions used during the period of research, we will analyze the total costs of hospital maintenance, per sector and per work position.

We will also carry out a statistical treatment of the data, using the average values, the standard deviation, and the coefficient of variation, excluding the samples used for the composition of the average value, and those that range outside the 20% of the coefficient of variation.

Another aspect to be considered is that this research only evaluated the cost and performance with the labor force; therefore, it is not the object of this study to present data such as the cost of inputs, electricity and water expenses, or the fuel used to produce steam and water heating.

4 RESULTS

4.1 Maintenance costs

Total maintenance costs vary depending on the allocation of resources by management, weather conditions, variations in input prices, and other factors that must be weighed.

This study evaluated only the performance and costs with the workforce, not considering the costs related to inputs, electricity and water expenses, or the fuel used to produce steam and water heating, as presented below in Table 5, which shows only the average cost with employees, during the nine years studied, for each section of the hospital maintenance service.

Section	Total
Masonry	US$ 19.344,67
Metal work	US$ 8.105,12
Electrical work	US$ 11.639,77
Woodwork	US$ 7.508,05
Total	US$ 46.597,60

Table 5 . Total cost with maintenance work positions, average per month . Source: Authors.

As shown in Table 5, on average, hospital maintenance spends about US$ 46,597.60 per month to meet its demands, i.e., an average annual cost of US$ 559,171.30.

It is important to highlight that the costs of the work positions are not the same: masonry professionals cost US$ 967.23 on average; metal work professionals, about US$ 1,157.87; electrical work professionals, about US$ 1,058.16; and woodwork professionals, about US$ 1,072.58. Thus, the average cost per man-hour worked is around US$ 4.88.

These wage differences are due to the specialties of each sector, different extra fees due to insalubrious or dangerous work, and the minimum wage determined by each professional union in the region.

4.2 Production per position

The following data are presented regarding the average production per station, considering the demand for jobs carried out performed per year, on average, during the entire period studied.

This indicator is used so that building maintenance management can evaluate possible adjustments and control the performance of its teams in the coming years.

Table 6 compiles this data, showing the number of jobs carried out per hired position, on average, per year.

Section	Average/year	Employees	Total
Masonry	09	20	181
Metal work	14	7	97
Electrical work	09	11	98
Woodwork	25	7	165
Total	57	45	541

Table 6 . Production per position, on average, per year. Source: Authors.

In this survey, it is noticed that within 12 months, 45 jobs are required on average to be able to perform about 541 tasks per year, with 20 employees in masonry, 7 in metal work, 11 in electrical work/air conditioning, and 7 in woodwork, accounting for 541 tasks per year.

4.3. Average cost per task carried out

Next, we gathered the production data regarding the cost of each section and the average cost per task carried out, as shown in Table 4.

Section	Total
Masonry	US$ 78,23
Metal work	US$ 68,36
Electrical work	US$ 97,41
Woodwork	US$ 61,80

Table 7 . Average cost per work carried out. Source: Authors.

With this survey, it is possible to state that the average cost with labor force to carry out a hospital maintenance demand varies between US$ 61.80 and US$ 97.41.

This variation occurs mainly due to the diversity of tasks performed, for example: replacing a leaky pipe requires more time than changing a light bulb; rebuilding a tile floor takes more time than repairing a drawer on a piece of furniture or hanging a metal bracket on the wall, and so on. These situations generate differences in the average cost per section, in addition, the cost of an electrician is higher than that of the carpenter or mason, also reflecting in the average cost of each task to be performed.

Another aspect that directly interferes with the cost of each section is the displacement within the hospital complex. Electrical and masonry works are usually carried out outside the workshops. On the other hand, wood and metal works are mostly carried out within their own offices, i.e., not requiring extra displacements and stoppages during the execution of tasks.

Under the current contract for in-house maintenance personnel, a work position of bricklayers, painters, woodworker, and metal worker, costs US$ 1,073.58 per month; the position of electrician costs US$ 1,214.40, and the refrigeration mechanic, US$ 1,314.75.

5 Discussions

Although the results found show a lower performance in the execution of the tasks demanded compared to the research carried out by Quadri (2017) in a hospital in the city of Chapecó, it should be considered that the number of beds in this hospital is 114, which is equivalent to 28.5% of the number of beds in the hospital surveyed.

The services of the masonry team are generally carried out outside the section itself, that is, outside its work base, unlike the other sections, which carry out much of their work in their own offices; the yield of this section is lower than that of the others, as shown in Box 1 and Table 2.

Considering the Brazilian reality in the public sphere regarding the allocation of resources for all areas, including health, we notice an investment five times lower than that made in England, 58% lower than in Singapore and 65% higher than in Malaysia, as cited by Olarnewaju, Fang and Tan (2018) in a study carried out in Malaysia on hospital maintenance.

According to the parameters presented, the hospital maintenance service is able to meet about 50% of all its demands, i.e., on average, of the 1,041 services requested, 541 are carried out. As can be seen in the results presented in Box 2, it can be deduced that the service is satisfactory, considering the number of resources made available to health services in Brazil.

Based on the results of this research, it is estimated that the minimum maintenance team to be maintained for a vertical hospital with 400 beds is approximately 45 work positions, divided into masonry, metal work, electrical work, and woodwork sections. This index was estimated based on the survey of nine years of monitoring, using the average of this period, excluding data that were outside the 20% coefficient of variation.

The hospital where the data collection was carried out has several outpatient clinics, a surgical center with more than 14 operating rooms, an obstetric center with eight rooms, laboratories of various specialties, compounding and distribution pharmacies, a research center and other environments that occupy the physical area and are not intended for hospital beds.

Comparatively, in a survey carried out in Israel with 34 hospitals, by Shohet and Leibovich (2003), a rate of 8.25 beds per 1,000 m2 was found, while in Hospital de Clínicas Complex surveyed there are currently 400 active beds and an area of 59,541.60 m2. This results in a rate of 6.71 per 1,000 m2, i.e., an occupancy rate very similar to the occupancy rate found in Israel.

6. Conclusions

The use of the data collection and compilation tool called physical schedule to carry out this research presented three quantitative indicators related to the monitoring and control of the activities developed in the scope of hospital maintenance, which can serve as a basis for the future planning of building maintenance, namely: average monthly cost with allocated labor force, average cost of labor force per task carried out, and average number of jobs used per year.

Based on the research carried out, it is concluded that the average cost consumed per labor force during the year per task carried out is US$ 76.44. This is the amount spent by the hospital to perform a task that takes one to five days to perform. Taking into account the daily cost of a bricklayer, US$ 35.78, it can be said that tasks performed up to 2.4 days are economically customized, above that, the cost becomes higher than the amount budgeted for the post.

With this tool, it was possible to verify that, over the period studied, there were variations ranging from 15.78% to 30.43%, both in costs and in the amount of labor employed and, as well as in the performance achieved, a fact that is mainly due to changes of contracts during the period studied, which covered three different companies.

It is also important to note that, during the nine years studied, there was variation in the allocation of maintenance supplies in the hospital, in addition to changes in its administrative management, with the presence of four different managers, aspects that caused oscillations in demand and allocation of resources for hospital maintenance.

Despite all the variations mentioned above, the average of demands that were carried out was 50%, with a team of 45 workstations distributed in all areas of the Hospital Complex surveyed.

It is observed that the average Maintenance Plan (MP) during the nine years of research was 50%, a percentage lower than that found, for example, in a private hospital in Santa Catarina, which was 81.44%.

Finally, by way of comparison, while in some countries the average cost raised for hospital maintenance labor was US$ 19.19/m2, in the survey carried out we got the average value of US$ 9.39/m2, considering the exchange rate of the American currency at R$ 5.35, this demonstrates that the costs of maintenance in the researched hospital are equivalent to 48.93% of the Israeli costs with maintenance labor services.

In a way, it can be said that the cost of the labor force in this study was lower than that researched in Israel, but it should be noted that there are variables that can affect this conclusion, such as the exchange rate and the value of wages paid for labor force in a more developed country, as well as the cost of € 252.55 per task carried out presented by Spanish researchers.

Bibliography

ABISUGA, A.O.; FAMAKIN, I.O.; OSHODI, O.S. **Educational building conditions and the health of users**. Constr. Econ. Build. 16, p: 19–34, 2016.

ADENUGA, O.; IBIYEMI, A. **An Assessment of the State of Maintenance of Public Hospital Buildings in Southwest Nigeria.** Constr. Econ. Build, 9, p:.51–60, Nigéria, 2009.

AL-ZUBAIDI, H. e CHRISTER, A. H. **Maintenance Manpower modeling for a hospital building complex**, European Journal of Operational Research, 99, p: 603-18, Londres, Inglaterra, 1997.

ALNER, G. R. e FELLOWS, R. F. **Maintenance of local authority school building in UK: A Case Study in C.I.B**. W-70. Proceedings of International Symposium on Property Maintenance Management and Modernization, p: 90-99, Singapura, 1990.

AMARATUNGA, D., SARSHAR, M. e BALDRY, D. **Process improvement in facilities management, The SPICEFM approach**. Proceedings of CIBW70 International Symposium on Facilities and Maintenance, p: 161-70, Brisbane, Australia, 2000.

AMORIM, G. M., QUINTÃO, E. C. V., JÚNIOR, H. M. e BONAN, P. R. F. **Prestação de Serviços de Manutenção Predial em Estabelecimentos Assistenciais de Saúde**, Revista Ciência e Saúde Coletiva, Vol. 18, Ed. 1, Rio de Janeiro, Brasil, 2013.

ARDITI, D. e NAWAKORAWIT, M. **Issues in Building Maintenance: Property Managers Perspective, Journal of Architectural Engineering**, December, p: 117-132, Vancouver, Canadá, 1999.

BOEGER, M. A. **Hotelaria Hospitalar: gestão em hospitalidade e humanização**, SENAC, São Paulo, Brasil, 2009.

BRANCO FILHO, G. **A organização, o planejamento e o controle da manutenção**, Ed. Ciência Moderna, Rio de Janeiro, Brasil, 2008.

BURGARDT, O. A. **Desenvolvimento de um sistema para a gestão da manutenção de equipamentos militares**, Dissertação, Escola de Engenharia, UFRGS, Porto Alegre, Brasil, 2002.

CABRAL, J. P. S. **Gestão da Manutenção de Edifícios**, Navaltik Management, Lisboa, Portugal, 2009.

CALCEDO, J. G. **Mantenimiento eficiente de edificios: Agência Extremeña de la Energia**, Barcelona, Espanha, 2014.

CALCEDO, J. G. e CHAPARRO, M. G. **Quantitative analysis of the impact of maintenance on the energy consumption of a hospital in Extremadura**, Journal Sustainable Cities and Society, 30 p: 217-222, Switzerland, 2017.

CHANTER, B. e SWALLOW, P. **Building Maintenance Management**, 2º Ed. Blackwell Publishing, Oxford, UK, 2007.

DONAS, M. L. M. A. **Gestão da manutenção de equipamentos em uma instituição pública de C & T em saúde**, Dissertação, Escola Nacional de Saúde Sérgio Arouca, Fiocruz, Rio de Janeiro, Brasil, 2004.

ENSHASSI, A.; FARIDA, E.S.; SUHAIR, A. **Assessment of Operational Maintenance in Public Hospitals Buildings in the Gaza Strip**. Int. J. Sustain. Constr. Eng. Technol., 6, p: 2180–3242, 2015.

EL-HARAM, M. A. e HORNER, M. W. **Factors affecting housing maintenance cost. Journal of Quality in maintenance Engineering** 8 (2) p: 115-123, 2002.

EN 13306/2017 (European Standard) **Maintenance Key Performance Indicators**, Londres, Inglaterra, 2017.

GALÁN, M. H. e EDITH, M. D. **Management Audit Applied to the Maintenance Department in Hospital Facilities**. Ing. Mec. 20, p: 152–159, 2017.

GIL, A. C. **Como elaborar projetos de pesquisas**, 4ª Edição, Ed. Atlas, São Paulo, 2007.

GUIMARÃES, J. M. **Manutenção nos edifícios hospitalares: o que é preciso fazer?** Artigo, 2020, Disponível em https://portalhospitaisbrasil.com.br/artigo-manutenção-nos-edificios-hospitalares-o-que-e-preciso-fazer/. Acesso em: 15 dez 2022.

HASSAN, B. e HADDAD, R. **Methodology of analyzing factors that affect maintenance cost in public hospitals**, Journal for research and scientific studies, Tishreen University, vol. 33. Inglaterra, 2011.

HEINECK, L. F. e PANZENTER, A. A., **Estimativa de custos na construção civil: um estudo de caso de obtenção de constantes unitárias de consumo de mão de obra.** In IX – Encontro Nacional de Engenharia de Produção, Porto Alegre, p: 128-150, 1989.

HIROTA, E. H. **Estudo exploratório sobre a tipificação de projetos de edificações**, visando a reformulação da Norma Brasileira NB-140/65, 151p. Dissertação – Curso de Pós-Graduação em Engenharia Civil. Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil, 1987.

HORNER, R. M. W., EL-HARAM, M. A. and MUNNS, A. K. **Building Maintenance strategy: A new management approach**, Journal of Quality in Maintenance Engineering 3 (4): p: 273-280, Inglaterra, 1997.

JOSHI, K.P.; MURTHY, C. **Determining Value Co-Creation Opportunity in B2B Services**, In Proceedings of the 2011 Annual SRII Global Conference (SRII 2011), 29 March–2 April p: 674–684, San Jose, California, Estados Unidos, 2011.

KAPLAN, R. S. e NORTON, D. P. **Strategy maps: converting intangible assets into tangible outcomes**. p: 1-457, Harvard Business Press, Cambridge, Estados Unidos. 2004.

KARMANN, J. **Manutenção e Segurança Hospitalar Preditivas**, IPH, São Paulo, Brasil, 2011.

LEE, R. e WORSWORTH P. **Lee´s Building Maintenance Management**, Ed. Blackwell Publishing, Londres, Inglaterra, 2001.

LEE, H. H.Y. **Overview of maintenance strategy, acceptable maintenance standard and resources form a building maintenance operations perspective**, Journal of Building Appraisal, Vol 4-4 p: 269-278. Suíça, 2008.

LEE, H.H.Y. e SCOTT, D. **Idenfication of main aspects in the management of building maintenance operation process**, Surveys Times, Hong Kong Institute of Surveyors, 17 (6): p: 37-41, Hong Kong, China, 2008.

LOUSTAUNAU, S., e BEGUERÍA, P. **Mantenimiento de edificios: centros sanitários**, Ministerio de Sanidad y Consumo. Madri, Espanha, 1992.

MACHADO, M. P. N. M. **Manutenção Preventiva de um Edifício Hospitalar**, Dissertação de Mestrado, Instituto Superior de Engenharia de Lisboa, Lisboa, Portugal, 2013.

MARENJAK, S. e KRISTĆ, H. **Analysis of buildings operation and maintenance costs**, vol. 4, p: 293-304, Gradevinar, Croácia, 2012.

OLANREWAJU, A. L., FANG, W. W. e TAN, S. Y. **Hospital Building Maintenance Management**, Internacional Journal of Engineering and Techonology, 2018.

OLANREWAJU, A. L. **Building maintenance management in Malaysia**, Journal of Building Appraisal, vol. 4, nº 03, Suíça, 2008.

PALLIS, P. e MISNAN, M. S. **A review of key factors, that affect University buildings maintenance costs,** International Journal of Engineering & Technology, Vol. 7. P: 32-34, 2018.

PARISSOTO, J. A. **Análise de estimativas paramétricas para formular um modelo de quantificação de serviços, consumo de mão de obra e custos de uma edificação residencial: estudo de caso de uma empresa construtora**, Dissertação de Mestrado, UFSC, Florianópolis, 2003.

PINTO, A. K. e XAVIER, J. N. **Manutenção: Função estratégica**, Ed. Quality Mark, Rio de Janeiro, Brasil, 2001.

PITT, T. J. **Data requirements for the prioritization of predective building maintenance**, Facilities 15 (3/4): 97-104, Inglaterra, 1997.

PLEBANKIEWICZ, E. e GRACKI, J. **Analysis of the impact of input data on the planned costs of building maintenance**, Sustainability Journal MDPI, Ed. 13, Switzerland, 2013.

QUADRI, G. M. **Estudos e processos do setor de manutenção na área hospitalar**, Trabalho de Conclusão de Curso em Administração, UFFS, Chapecó, Brasil, 2017.

NEELY, E. S. e NEATHAMMER, R. **Life-cycle maintenance costs by facility use**.Journal of Construction Engineering and Management, 117, 1991.

SANTOS, G. C., ALVES, R. B. e PINHEIRO, E. C. N. M. **Manutenção Predial Hospitalar em uma Sala de Raio-X, Brazilian Journal of Development**, ISSN-2525-8761, Rio de Janeiro, Brasil, 2021.

SEZER, E., ROMERO, D., GUEDEA, F., MACCHI, M. e EMMANOUILIDIS, C. **An Industry 4.0-enabled low-cost predictive maintenance approach for SMEs**, IEEE, International conference on engineering, technology and innovation, pp. 1-8, Stuttgart, Alemanha, 2018.

SILVA, L. **Normas ABNT na Manutenção Predial Hospitalar**, 2018, Disponível em: https//www.google.com/amp/s/laurivalsilva.adm.br/blog/administracao-hospitalar/normas-abnt-na-manutenção-predial-hospitalar/amp/. Acesso em: 15 dez 2022.

SHOHET, I. M. e LEIBOVICH, S. L. **Integrated Maintenance Monitoring of Hospital Buildings**, Construction Management and Economics, Taylor & Francis, Londres, Inglaterra, 2003.

STREIFEL, A. J. **Infection Control Factors in Hospital Building Maintenance and Operations**, Business Briefing: Hospital and Engineering & Facilities Management, USA, 2005.

VERRI, L. A. **Gerenciamento pela qualidade total na manutenção industrial**: aplicação prática, Ed. Qualitymark, Rio de Janeiro, 2007.

VIANA, H. R. G. e RIBEIRO, J. L. D. **Fatores de Sucesso na gestão da manutenção em empresas mineradoras**, Artigo, Revista Gestão Industrial, 2017, UTFPR, Ponta Grossa, Paraná, Brasil, 2017.

WONG, W. F., OLANREWAJU, A. L, LIM, P. I. **Value-Based Building Maintenance Practices for Public Hospitals in Malaysia**, Journal Sustainability, v. 13, 2021.

Article

Evaluation of the allocation of activities applied to an adult hospital emergency room: an analysis compared with the findings of post-occupancy evaluation

Authors

Lucas Melchiori Pereira PhD in Architecture and Urbanism from the School of Architecture and Urbanism of the University of São Paulo (FAU-USP). Fapesp scholarship holder, process nº 2020/15909-8. Architecture and Urbanism PhD from the Institute of Architecture and Urbanism of the University of São Paulo (IAU-USP). Master's degree from the graduate program in Building and Sanitation Engineering (ENGES) of the Department of Civil Construction, Center for Technology and Urbanism (CTU), State University of Londrina (UEL). Lato sensu postgraduate degree in Building Construction Management from SENAI-SC. Architecture and Urbanism degree from UEL.

Sheila Walbe Ornstein PhD in Architecture and Urbanism from the School of Architecture and Urbanism of the University of São Paulo (FAU-USP). Full professor at FAU-USP, where she also served as deputy director and head of the Department of Architectural Technology. Co-leader of the research group included in the CNPq directory, entitled Quality and Performance in the Built Environment, and CNPq level 1B scholarship holder (process 304131/2020-2). Head of USP's Paulista Museum (Ipiranga Museum), between 2012 and 2016.

Abstract

The response to the pandemic emergency in healthcare facilities fostered a discussion about the impact of health facility conditions on hospital emergency services. This question highlighted the importance of developing means to understand and improve the relationship between the activities performed by health agents and the environments that accommodate them. The present study discusses a comparative analysis between the results obtained with a method of mapping the allocation of activities of a work organization where it is headquartered, called Mapping Activity Environment Allocation (MAEA), and the results of a Post-occupancy Evaluation (POE), both applied to the emergency room service of the University Hospital of the University of São Paulo (HU-USP). The MAEA was developed in postdoctoral research at the School of Architecture and Urbanism of the University of São Paulo (FAU-USP) and considered that the POE has consolidated measurement procedures. The article presents examples of how the map obtained with the MAEA was compared by the researchers with the findings of the POE, empirically demonstrating how to interpret the evidence processed by the method under development. The occurrence of correlations mapped by the method and by the POE was confirmed, which indicates that the map of relationships between processes and environments of a resulting organization offers a subsidy to designers and building managers to decide on the maintenance of a situation, a punctual spatial rearrangement, or the realization of a project for new facilities.

Keywords

organizational congruence, healthcare facilities, pre-design evaluation.

Introduction

The need to adapt the built environment (BE) to healthcare is not a recent problem (Elf et al., 2020). It is a recurring theme in studies of evaluation of the functionality of the building associated with the post-occupancy evaluation (POE). However, the 2020 pandemic reinforced the importance of quickly establishing new health parameters for healthcare (Lesan et al., 2021). This highlighted the importance of developing expeditious evaluation methods (Watkins; Keller, 2008) to support decision-making on the allocation of activities in healthcare facilities with evidence.

The representations of the activities of a complex process, such as emergency care in hospital emergency rooms and other health services, usually use abstractions such as organizational charts and flowcharts (Gayer et al., 2020). In practice, however, these activities depend on the interactions between agents and the environments where they occur. Thus, it is advantageous to align the flow of activities to the environments where they are allocated (Brambilla et al., 2022; Sasanfar; Bagherpour; Moatari-Kazerouni, 202). This alignment is identified as a type of organizational congruence, in which the correspondence between two domains of the organization linked to the process and the environment is evaluated (Pear et al., 2023).

The formulation of a congruent organizational arrangement depends on evaluation methods that support an evidence-based design (EBD) (Watkins; Keller, 2008). The objective of this study, developed in a postdoctoral study at the Faculty of Architecture and Urbanism of the University of São Paulo (FAU-USP), is to discuss the results of a programming-based pre-design evaluation method (PDE), called Mapping Activity Environment Allocation (MAEA), comparing them to the results of POE procedures applied to the same case: the organization of the emergency room (ER) of the University Hospital of the University of São Paulo (HU-USP), located at the Butantã Campus, in the city of São Paulo, SP, Brazil. The results of this study offer three significant contributions: (1) they demonstrate the application of the method in a real case, analyzing its potential and limitations; (2) provide a structured and traceable assessment of an existing environment and the activities carried out in it; and (3) allow for the improvement of the program of needs (pre-design) of complex environments such as those observed in the health field.

Concept and contextualization of the relationship between EBD and PDE

Over the past two decades, the adoption of EBD practices has intensified in healthcare facility developments (Pereira; Ornstein, 2023). This movement is based on successful experiences in the health area, which was the inspiration to use research evidence in the decision-making process (Phiri; Chen, 2014). Evidence-based medicine aims to reduce the uncertainty and decision-making burden that physicians experience (Vischer, 2009). Such an approach was quickly incorporated by other areas that deal with multivariable decisions, with an impact on people's living conditions and the economics of work organizations and other forms of social organization.

An analysis of EBD experiences showed that a significant part of the evidence used in these cases originates from POEs (Pereira; Ornstein, 2023). This is due to the consolidated POE process, carried out in a systematic and rigorous manner in buildings built and occupied for at least six months (Cranz et al., 2021). In Brazil, a period of 12 months was agreed to include the four seasons of the year and the consolidation of the enterprise and the neighborhood by the users (Ono et al., 2018). It is strong evidence about the social performance of a building, linked to the perception of the people who use it about functional requirements, such as thermal and light comfort, ventilation, air quality, flexibility, operating and maintenance conditions, etc. (Cranz et al., 2021; Ornstein; Ono, 2010; Shin et al., 2017).

In addition to methodological reasons, the POE results use is related to the volume of cumulative data, since the first international POEs are from the late 1960s and, from the 1980s onwards, their findings began to support decision-making in the design process and in building management. Since then, three criticisms of the results achieved with POEs have been highlighted: (1) excessive focus on user experience and perception, neglecting objective evidence with predetermined performance criteria (Vischer, 2009); (2) difficulty in assimilating the evaluations of buildings in use in other research, projects and acquisitions, due to the subjectivity of the findings linked to the users of a specific context (Hadjri; Crozier, 2009; Joseph et al., 2014); (3) the evaluation occurs too late to impact the reality of the case analyzed (Shin et al., 2017).

These criticisms have been answered in two ways: the first has been the development of a building performance evaluation (BPE) methods, which employ more objective, comparable and auditable criteria on building facilities (Preiser; Hardy; Schramm, 2018; Watkins; Keller, 2008); the second approach sought to meet the demand for pre-occupancy evaluations (PrOE), carried out quickly before occupation (Davoodi et al., 2017; Shin et al., 2017). Both PrOE and BPE studies have shown the importance of carrying out an assessment prior to construction, i.e., before and during the project (Pereira; Ornstein, 2023; Shin et al., 2017). It is in this context that the evaluation of performance-based design (PBD) and the pre-design evaluation (PDE) methods are developed.

Pre-Design Evaluation strategies

In addition to the normative and legal parameters that guide and determine expected attributes in an healthcare facilities, there is a need for additional resources to contextualize and individually evaluate the planning of a project (Saha; Haymaker; Shelden, 2020; Welch, 2012). Such assessments can be based on key indicators and employ analytical techniques, simulations, and statistical modeling (Vanbrabant et al., 2019).

The choice of one of these approaches depends on the complexity of the analyzed model and the processing capacity, as well as the skill of the professionals involved in the evaluation (Welch, 2012). Thus, although simulation models are more reliable when emulating real systems by incorporating discrete and dynamic events (Mohiuddin et al., 2017), its use requires computational resources and skills that are still scarce for most enterprises in Brazil. Something similar happens with statistical models of the flow and allocation of healthcare activities (Pereira; Ornstein, 2023), where the lack of detailed data makes it difficult to model statistically valid and useful scenarios (Demirdöğen; Işık; Arayici, 2022).

Analytical models are methods that offer simple and efficient solutions to simulate well-determined systems, even with little data (Vanbrabant et al., 2019). They are useful in situations such as the one in the present study, in which it is necessary to quickly evaluate an arrangement of activities in an environment. An analytical model widely used in analyses such as this is the dependency structure matrix (DSM) (Sinha et al., 2012). DSMs allow mathematically describing in a matrix the relationships between entities in a system. For example, they allow you to describe whether the relationships between activities in a process are serial, parallel, or circular/iterative (Unger; Eppinger, 2011). It has already been used to assess the conditions of adaptability (Schmidt; Vibaek; Austin, 2014), extend the life of buildings (Dog et al., 2018) and improve the flow of information (Pektaş; Pultar, 2006). In situations where more than one system is mapped, it is possible to relate the different domains described in each DSM in a Domain Mapping Matrix (DMM) (Sosa, 2007). It is a matrix that relates entities from different domains, i.e., from DSMs that treat two distinct and dependent systems. This multi-matrix arrangement (Pear et al., 2023) is the basis of the method/software evaluated in the present study.

Methodology

The development of a PBD allows for the improvement of design decisions for both environments in design and for those existing and in use (Elf et al., 2020). Such a strategy is not tied to the early stage of the building life cycle (Bueno; Pereira; Fabricio, 2018; Pereira; Ornstein, 2023), and yes it is a resource to be employed throughout the cycle when it is necessary or desired to find solutions to problems or improvements to an existing situation (Pereira; Ornstein, 2023).

The MAEA method was developed to support the decision of building management and the beginning of the project, framing itself as a PDE method. The data gathered are complemented with document analysis, on-site observations, interviews, and measurements. The multi-method approach is employed to confirm and complement the congruence data mapped with MAEA, as outlined in Illustration 1.

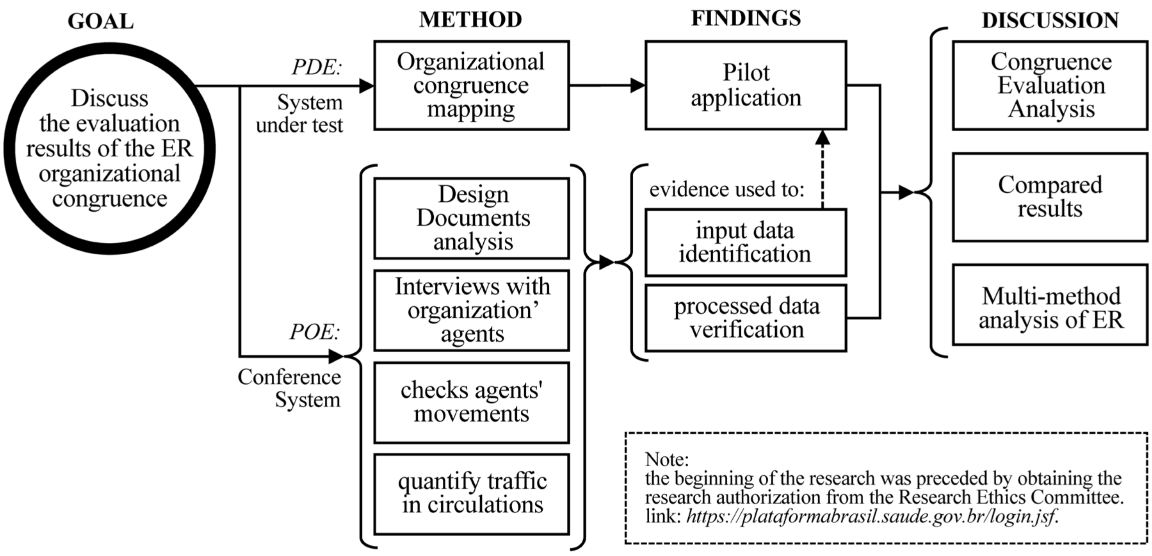


Illustration 1 . Research design. Source: Authors.

The activities foreseen when conceiving the research (Illustration 1) involving human beings were approved on March 26, 2021, by the Research Ethics Committee of the UH/USP (Registration number 05.508-000), identified by the Certificate of Presentation of Ethical Appreciation (CAAE) No. 44679021.0.0000.0076. The procedures employed are described below. All records produced are in the possession of the researchers responsible for the research and preserved to ensure the traceability of the analyses. However, access to records obtained directly from third parties involved in the collection of information is restricted to researchers, in order to preserve the impersonality of the data used in the discussion.

Mapping Activity Environment Allocation tool

Mapping Activity Environment Allocation, identified as MAEA, is a method of identifying the relationships between two domains of an organization to evidence the correspondence between them. In the present study, the allocation of adult emergency room (AER) activities in the environments of a healthcare facility was mapped to provide evidence on the conditions of workflows. The application of the method is based on a software of the same name which is currently in advanced development. The fundamentals of the processing carried out in the software are detailed in the article by Pereira et al. (2023).

Essentially, the software asks you to enter basic information about the structure of the organization, the process, and the environment, such as the names of the roles, activities, and environments, and what are the known relationships between the items reported. Each entry is considered an entity from an organization domain. The method allows you to relate entities from the same domain or from different domains. Relationships between entities can be binary or numeric. For example, the relationships between activities are binary: two activities, A and B, are parallel and independent if there is no relationship between them (Illustration 2, a); if B depends on some result of A (Illustration 2, b) there is a sequential relationship; if there is mutual dependence between A and B, they have a cyclical relationship (Illustration 2, c). These relationships merely indicate the existence of an influence, without assigning weight to it.

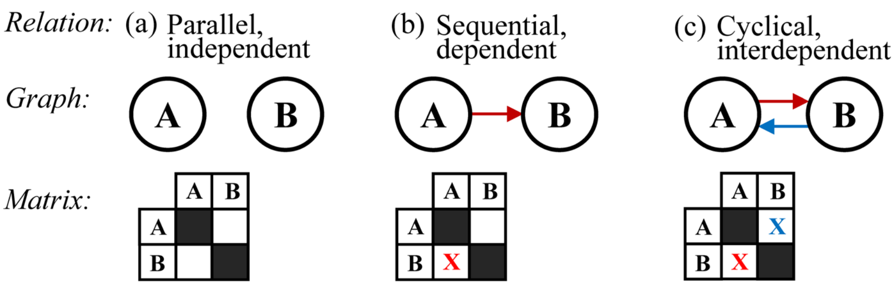


Illustration 2 . Example of relationships between process entities. Source: adapted from Eppinger, Browning (2012).

The relationships between process and environment entities are numeric, in which weight is assigned to different situations (Illustration 3). In this case, three weights were defined: "3" indicates that environment X is the place of the final action of activity A; "2" indicates that environment Y is the place where some action occurs as a means to make activity A viable; "1" indicates the path taken by the person responsible for activity A.

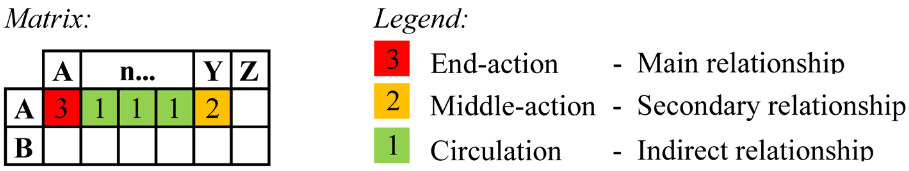


Illustration 3 . Example of relationships between process and environment entities. Source: Authors.

Another structure of relationships that can employ weights is the relationships between environments, with the variable indication of size and distances. Manually entering such indications can be quite costly and exhausting. To solve this, environment recognition resources were implemented through images of architectural floor plans. However, the outcome of that appeal has not yet been tested and is therefore not included in the present case. Therefore, the relationships between environments are binary in this study.

After data entry and processing, the results show a matrix that indicates the congruent points, the points at which the congruence condition was not met, and the points at which the relationship recorded between two entities was not recognized by the processing. The closer it is to the complexity of the actual relationships, the more the condition of congruence of the data matches the congruence of the actual organization. With such evidence, there was a work of analysis and complementation of the data, addressed in the discussion of the results.

Document analysis

DWG and PDF files, containing the drawings of the original architectural and complementary projects of the establishment, dated 1975, as well as the records of punctual interventions and an as-built of the building's situation that was carried out in 2005, were provided by the Superintendence of Physical Space (SEF -USP). These documents were analyzed to recognize the progression of the spatial changes of the building in use. To this end, technical visits were carried out to confirm the adequacy of the most recent existing records and to update the plans with undocumented physical and occupation changes.

The files received were processed to prepare the graphic resources used in the other research procedures and in the dissemination of the results.

Semi-structured interviews

The semi-structured interviews were prepared with the purpose of directing the collection of information on the functions and activities related to the emergency services of healthcare facilities. Three interview scripts were written for different types of functions related to the AER: healthcare, service support, maintenance, and administration/reception of the public. Each roadmap addresses the five topics indicated in Box 1.

	Topic	Resources
1	Indicate which activities are carried out in the emergency room spaces and which activities happen beforehand.	Table of activities, containing the columns: *code*, *list of activities, position in charge,* and *previous activities.*
2	The activities indicated in item 1 focus on which construction elements, equipment, and spaces of the emergency room?	Floor plans with identified environments; table of relationships between activity and elements of the building, containing the columns: *activity code*, *element code* and *type of use/impact.*
3	Indicate the presence of conflicts between activities that occur in the emergency room.	Notepad
4	Were there any changes in how you carry out your work due to the pandemic? Explain.	Notepad
5	Is there anything else you would like to add?	Notepad

Box 1 . Topics covered during semi-structered interviews. Source: Authors.

The interviews used to collect information took place between June and October 2022. The results of 13 interviews describing the activities directly and indirectly linked to the AER were used, and at this stage the interviews related to other sectors of the UH were not analyzed. Professionals who held a management position directly responsible for the operationalization of the activities were interviewed (Box 2). Therefore, it was possible to articulate the assignment of different employees in a sector without the need to interview the entire professional body involved.

	Process	Position
1	Healthcare	Nursing
2		Medicine
3		Consumable Management
4	Pharmacy	Analysis of drug interactions
5		Drug distribution
6	Front desk	Reception of the external public
7		Clinical records
8	Hospitality	Linen
9		Cleaning
10		Nutrition and meals
11		Safety
12	Building management	Building Maintenance
13		Specialized maintenance

Box 1 . Topics covered during semi-structered interviews. Source: Authors.

The interviews were conducted in person and remotely. In the face-to-face interviews, the health safety protocols were followed within healthcare facilities. The resources from Box 1 were used to record the reported information. The audio of the interviews was recorded and preserved under the researcher's custody. Remote interviews were conducted through recorded videoconferences, during which the interviewer shared his/her screen with the interviewee and filled out the tables and maps directly in the appropriate software, following the interviewee's instructions.

The data related to the registration of the processes were documented in lists and tables that fed the MAEA database. The plant records were also post-processed in order to provide a graphic record to the researchers for checking the results and complementary analyses.

Walkthrough

To confirm the records made in interviews and to broaden the understanding of the dynamics of the functioning of the HU-USP ER, the researchers carried out some walkthroughs in the building.

Walking through the hospital different areas with people from different job positions, aimed to observe the options of path and access to the ER, although it does not correspond to a sample quantity of the flows, but to a direct observation of the field researchers. The paths were documented in a printed plan, during the completion of the routes, with the aid of A3 drawing boards (size 297 x 420 mm). Two walks were also carried out with a professional manager, documented with photos and videos that illustrated the observations made by the professionals who accompanied the researchers. Such recordings avoided facial recognition of passers-by.

Quantification of flows in circulations

Two researchers carried out a sample survey of the flow of people who transit through the nearby corridors and accesses to the AER to quantify the flow in the circulations of the healthcare facility. The coming and going of people alone or on stretchers, wheelchairs, among other types of machinery, material and waste were computed.

Characterization of the case study

The ER is a vital and complex sector for any healthcare facility (Brambilla et al., 2022), as it corresponds to a "gateway" to primary care, through which many of the patients who are admitted to a hospital enter (Morgareidge; FALLS; JIA, 2014). Problems of inadequate flow of agents, patients and companions within the ER can impact the functions of the entire healthcare facility and hinder the provision of health services (Sasanfar; Bagherpour; Moatari-Kazerouni, 2021).

The University Hospital of the University of São Paulo (HU-USP) is located at the Butantã campus, in the city of São Paulo. It was conceived in 1966 and today brings together teaching and research activities in different areas of health, related to medicine, nursing, dentistry, nutrition, psychology, physiotherapy, occupational therapy, speech therapy, pharmaceutical sciences and social work (Margarido, 2021). The institution belongs to the Brazilian National Health System (Sistema Único de Saúde, SUS) as a tertiary healthcare center (BRAZIL, MINISTRY OF HEALTH, 2006) that assists the university community and the population of the city (Illustration 4). It has an AER and a children's emergency room (CER), both of which are often overcrowded (Roman, 2010).

Illustration 4 . Access to the administrative floor and to the public. Source: Authors.

The building consists of a service floor, identified as the second basement; a floor that accommodates the ERs, outpatient clinics and exams, identified as the first basement; and an administrative floor on the ground floor (Illustration 5), in addition to other pavements not addressed in this study, since the focus of the mapping carried out in the AER activities is only the three floors of the basement.

Illustration 5 . Schematic plans of the 1st, 2nd and 3rd floors, AER plan. Source: adapted from the archives provided by SEF HU-USP.

Discussion

The mapping indicated low congruence between the allocation of AER and the support services regarding emergency care. Conflicts were identified between the occupations of contiguous spaces within the AER sector. The cases indicated on the map were analyzed one by one, comparing them with the findings using the POE methods used in the same case. Some of them are presented below to demonstrate the development of the conference analysis of the results.

Organizational congruence of the AER environment

A point of environmental incongruence mapped, and confirmed by the observations, is in the location of the observation room next to the main access to the AER. The tool indicated that this relationship was not justified (Illustration 6, a) and the interviews, flow quantification and direct observation confirmed that this location causes flow conflicts and exposure of patients to the dynamics of emergency maneuvers, increasing their stress and feeling of insecurity.

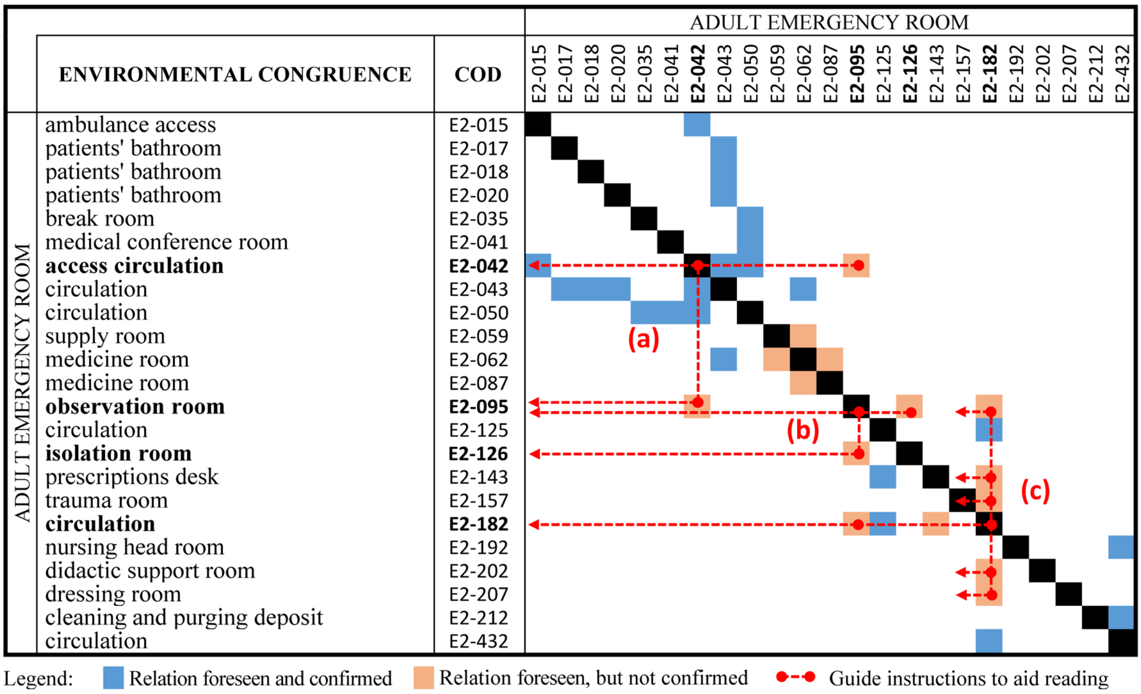


Illustration 6 . Excerpt of a congruence map between the environment and the process. Source: Authors.

Another issue that the processing evidenced is the access to the isolation room through the observation room (Illustration 6, b). This spatial arrangement is a constant concern (AER plant, Illustration 5), as it increases the risk of contamination even in a situation where negative pressure works. Some relationships between environments and access circulation have not been recognized (Illustration 6, c), possibly because the survey does not record all the steps of an activity. A solution to this situation is addressed in the indication of future development afterwards.

Organizational congruence of the process

Another conference is associated with the congruence of the process with the environment, in which a matrix that relates the activities shows the occurrence of interactions resulting from the environment in which they are allocated. The cases highlighted focus on the nursing services of the AER and its main interactions with other services (Illustration 7).

Nursing services are performed by the head nurse, nurses, and nursing assistants. The first activities are predominantly sequential and have little impact on the other AER activities (Illustration 7, a). At the beginning, there was a small circular relationship between the AER staff meeting and their shift management. Three activities stand out (Illustration 7, b) for impacting the activities of other services. The supervision of the AER nursing care involves intense circulation between the observation, medication and supply rooms, medical prescription counter and circulations; the clinical evaluation of the patient welcomed in the AER begins at the access to the AER, crosses the observation room and is completed in front of the prescription counter (AER plant, Illustration 5), when at least one nurse and one physician classify and transfer the patient accordingly.

Another point highlighted in the excerpt made from the matrix is the activity of cleaning AER environments, which does not have a direct relationship of precedence with nursing activities but impacts all activities that take place in the AER (Illustration 7, c, d). Activities not marked in this column occur in other sectors, such as employee access and waiting room (healthcare facility plan, Illustration 5). In the end, we highlighted the set of activities with cyclical relationships not mentioned in the interviews but that were detected on the map and confirmed by the other instruments of the POE (Illustration 7, e). It is noteworthy the medication distribution and distribution of consumables, permanent and sterile, both activities require dislocations through the environments to verify consumption and replenish stocks so the activities dependable on them are supplied.

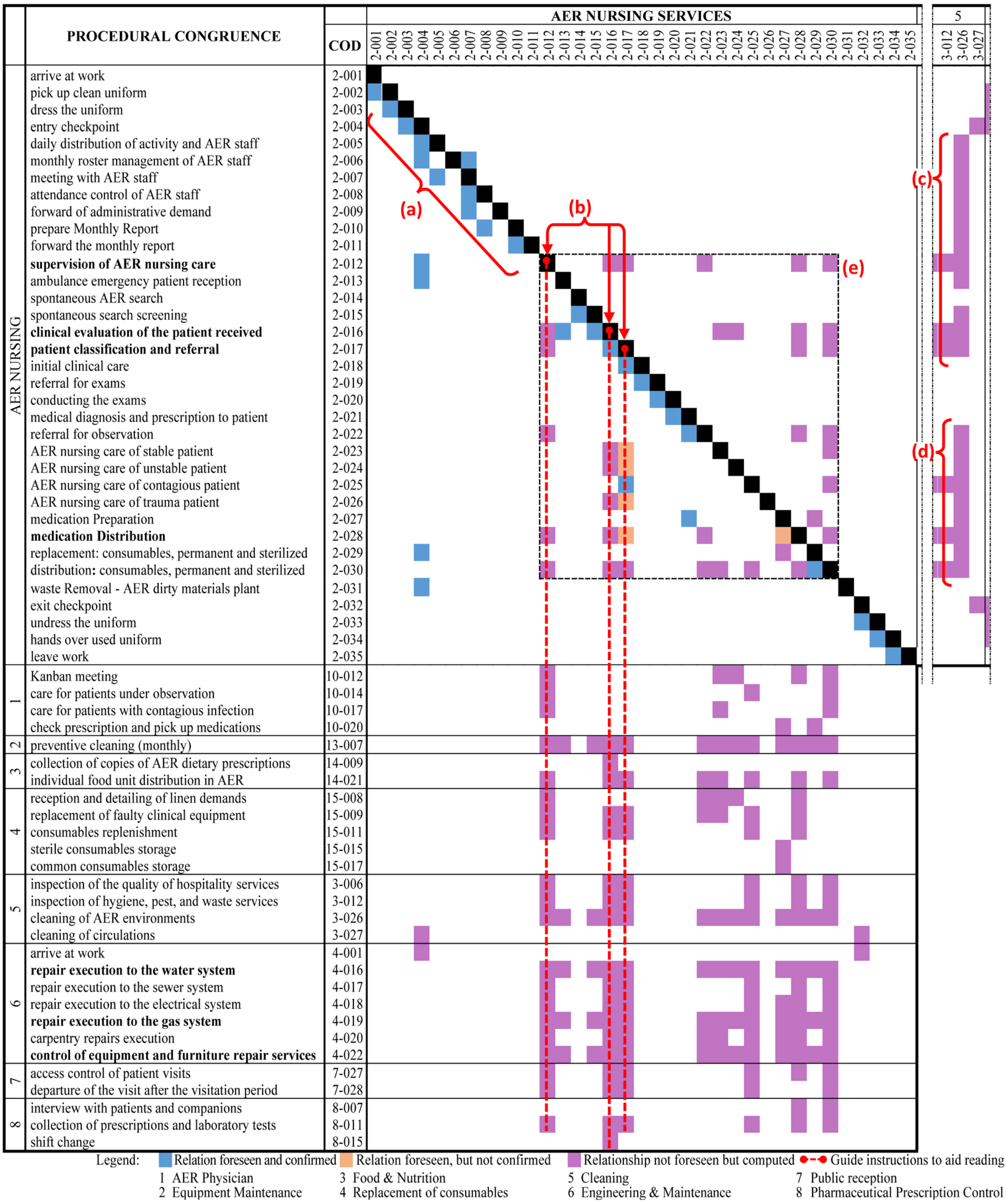


Illustration 7 . Excerpt of the congruence map between the process and the environment. Source: Authors.

The existence of these situations, linked to activities with a great impact of displacement and cyclical arrangements, is a driver for studies of new organizational arrangements, whether focusing on environmental or procedural change.

Considerations regarding the gathering of information through APO

Some considerations about the procedures adopted are noteworthy.

During the visits, some physical and occupational changes were identified in relation to the document analysis, carried out mainly to adapt the facilities to the pandemic. Therefore, when mapping existing cases, it is important to check if the documentation is consistent with the current situation of the analyzed healthcare facility. From an organizational perspective, this emphasizes the importance of keeping an updated as built.

As for the gathering of information about the process, the research focused on key agents to identify the main activities of each sector and service that affected the AER. This approach was suitable for testing the instrument. If more detailed records are needed, it is possible to interview the entire population involved in the organization.

Conclusions

The results presented and discussed in this document address the verification of the data processed by the MAEA by comparing them with the findings of an AER POE at the HU-USP. The details of the fundamentals of the instrument are described by PEREIRA et al. (2023). The confirmation of the relationships mapped by the method empirically corroborates the theoretical validation initially obtained. Thus, it is possible to point out that the MAEA provides a map of relationships between processes and environments of an organization, so that designers and building managers have a subsidy to decide on the maintenance of a situation or promote a change.

In existing allocations, maps are an initial piece of evidence, the occurrences of which should be investigated, as they can indicate both a failure in the mapping process and allocation problems, which provides an opportunity to design improvements to the existing arrangement. The occurrence of more cases like this offers more opportunities to compare mapping and the existing situation, which contributes to refining the interpretation of the results, if they are reported. MAEA can also be used as a PDE method, simulating the congruence of designed allocations. Therefore, it can support designers and managers' decisions in situations where activities will still be allocated in a space without predetermined use, or even in situations where the environment will be designed.

Limitations. MAEA is an analytical tool based on PDE, i.e., it is not suitable for the analysis of discrete and dynamic events. For these cases, an approach based on behavior simulation would be better, which requires greater expertise from users of the software and equipment with a high computing capacity. The results presented were obtained from a single case. Thus, the reporting of the application of the method in other cases is important for its consolidation, improvement, and statistical validation.

Further developments. The main development of this research is the development of the software that allows the application of MAEA by professionals and researchers in architecture, engineering, construction, and operational activities. Although it is particularly interesting for healthcare facilities, its uses extend to different types of work organization and other forms of social organization. In addition, you can incorporate more organizational domains to add breadth and depth to the mapping.

An ongoing development is the implementation of the automatic tracing of the paths taken by users for the allocated activities. In this modality, the program calculates the best route for the activities to take place and incorporates this information into the database. This will allow the study of better paths in locations not yet implemented (PDE). Another work in progress is the reading of floor plans in .PNG images, which automates the indication of spatial properties such as dimensions and relationships between environments. Both features will be made available in the final version of the software.

Acknowledgments and Funding. The authors would like to thank the researcher Vitória Sanches Lemes Soares for her collaboration in the field, the institutional cooperation of the UH-USP, as well as all the professionals involved, who collaborated with the development of the study. We would like to thank the following institutions for funding the research: Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), for granting the postdoctoral fellowship to the first author, process no. 2020/15909-8; Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq, for the productivity grant for the second author, process no 304131/2020-2.

Bibliography

BRAMBILLA, Andrea; MANGILI, Silvia; DAS, Mohana; LAL, Sanchit; CAPOLONGO, Stefano. Analysis of Functional Layout in Emergency Departments (ED). Shedding Light on the Free Standing Emergency Department (FSED) Model. **Applied Sciences**, [S. l.], v. 12, n. 10, p. 1–20, 2022. DOI: 10.3390/app12105099.

BRASIL. MINISTÉRIO DA SAÚDE. Portaria No 399, de 22 de fevereiro de 2006: divulga o Pacto pela Saúde 2006 – Consolidação do SUS e aprova as diretrizes operacionais do referido pacto.Brasil, 2006. Disponível em: https://bvsms.saude.gov.br/bvs/saudelegis/gm/2006/prt0399_22_02_2006.html.

BUENO, Cristiane; PEREIRA, Lucas Melchiori; FABRICIO, Márcio Minto. Life cycle assessment and environmental-based choices at the early design stages: an application using building information modelling. **Architectural Engineering and Design Management**, [S. l.], v. 14, n. 5, p. 332–346, 2018. DOI: 10.1080/17452007.2018.1458593. Disponível em: https://www.tandfonline.com/doi/full/10.1080/17452007.2018.1458593.

CAO, Xinying; LI, Xiaodong; YAN, Yangzhi; YUAN, Xiang. Skeleton and infill housing construction delivery process optimization based on the design structure matrix. **Sustainability (Switzerland)**, [S. l.], v. 10, n. 12, 2018. DOI: 10.3390/su10124570.

CRANZ, Galen; MORHAYIM, Lusi; LINDSAY, Georgia; SAGAN, Johann Hans. Post Occupancy Evaluation in Architectural Education and Practice. **Technology | Architecture + Design**, [S. l.], v. 5, n. 1, p. 25–30, 2021. DOI: 10.1080/24751448.2021.1863663. Disponível em: https://www.tandfonline.com/doi/full/10.1080/24751448.2021.1863663.

DAVOODI, Anahita; JOHANSSON, Peter; HENRICSON, Maria; ARIES, Myriam. A conceptual framework for integration of evidence-based design with lighting simulation tools. **Buildings**, [S. l.], v. 7, n. 4, p. 1–16, 2017. DOI: 10.3390/buildings7040082.

DEMIRDÖĞEN, Gökhan; IŞIK, Zeynep; ARAYICI, Yusuf. Determination of Business Intelligence and Analytics-Based Healthcare Facility Management Key Performance Indicators. **Applied Sciences**, [S. l.], v. 12, n. 2, p. 651, 2022. DOI: 10.3390/app12020651. Disponível em: https://www.mdpi.com/2076-3417/12/2/651.

ELF, Marie; ANÅKER, Anna; MARCHESCHI, Elizabeth; SIGURJÓNSSON, Ásgeir; ULRICH, Roger S. The built environment and its impact on health outcomes and experiences of patients, significant others and staff—A protocol for a systematic review. **Nursing Open**, [S. l.], v. 7, n. 3, p. 895–899, 2020. DOI: 10.1002/nop2.452. Disponível em: https://onlinelibrary.wiley.com/doi/10.1002/nop2.452.

EPPINGER, Steven D.; BROWNING, Tyson R. **Design Structure Matrix Methods and Applications**. 1. ed. Cambridge: The MIT Press, 2012. DOI: 10.7551/mitpress/8896.001.0001. Disponível em: https://direct.mit.edu/books/book/3361/design-structure-matrix-methods-and-applications.

GAYER, Bruna Dones; MARCON, Érico; BUENO, Wagner Pietrobelli; WACHS, Priscila; SAURIN, Tarcisio Abreu; GHINATO, Paulo. Analysis of hospital flow management: the 3 R's approach. **Production**, [S. l.], v. 30, n. 2011, 2020. DOI: 10.1590/0103-6513.20200033. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-65132020000100206&tlng=en.

HADJRI, Karim; CROZIER, Carl. Post-occupancy evaluation: Purpose, benefits and barriers. **Facilities**, [S. l.], v. 27, n. 1–2, p. 21–33, 2009. DOI: 10.1108/02632770910923063.

JOSEPH, Anjali; QUAN, Xiaobo; KELLER, Amy Beth; TAYLOR, Ellen; NANDA, Upali; HUA, Ying. Building a knowledge base for evidence-based healthcare facility design through a post-occupancy evaluation toolkit. **Intelligent Buildings International**, [S. l.], v. 6, n. 3, p. 155–169, 2014. DOI: 10.1080/17508975.2014.903163. Disponível em: http://www.tandfonline.com/doi/abs/10.1080/17508975.2014.903163.

LESAN, Maryam; KHOZAEI, Fatemeh; KIM, Mi Jeong; SHAHIDI NEJAD, Marziyeh. Identifying health care environment contradictions in terms of infection control during a pandemic with a focus on health workers' experience. **Sustainability (Switzerland)**, [S. l.], v. 13, n. 17, 2021. DOI: 10.3390/su13179964.

MARGARIDO, Paulo Francisco Ramos. Hospital Universitário da USP: 40 anos salvando vidas com ensino e pesquisa – Jornal da USP. **Jornal da USP**, São Paulo, 2021. Disponível em: https://jornal.usp.br/universidade/hospital-universitario-da-usp-40-anos-salvando-vidas-com-ensino-e-pesquisa/. Acesso em: 2 jun 2023.

MOHIUDDIN, Syed; BUSBY, John; SAVOVIĆ, Jelena; RICHARDS, Alison; NORTHSTONE, Kate; HOLLINGWORTH, William; DONOVAN, Jenny L.; VASILAKIS, Christos. Patient flow within UK emergency departments: a systematic review of the use of computer simulation modelling methods. **BMJ Open**, [S. l.], v. 7, n. 5, p. 1- 14 (e015007), 2017. DOI: 10.1136/bmjopen-2016-015007. Disponível em: https://bmjopen.bmj.com/lookup/doi/10.1136/bmjopen-2016-015007.

MORGAREIDGE, David; CAI, Hui; JIA, Jun. Performance-driven design with the support of digital tools: Applying discrete event simulation and space syntax on the design of the emergency department. **Frontiers of Architectural Research**, [S. l.], v. 3, n. 3, p. 250–264, 2014. DOI: 10.1016/j.foar.2014.04.006. Disponível em: http://dx.doi.org/10.1016/j.foar.2014.04.006.

ONO, Rosaria; ORNSTEIN, Sheila Walbe; VILLA, Simone Barbosa; FRANÇA, Ana Judite Galbiatti Limongi. **Avaliação pós-ocupação: na arquitetura, no urbanismo e no design: da teoria à prática**. 1. ed. São Carlos, SP: Oficina de Textos, 2018.

ORNSTEIN, Sheila Walbe; ONO, Rosaria. Post-occupancy evaluation and design quality in Brazil: Concepts, approaches and an example of application. **Architectural Engineering and Design Management**, [S. l.], v. 6, n. 1, p. 48–67, 2010. DOI: 10.3763/aedm.2009.0102.

PEKTAŞ, Şule Taşh; PULTAR, Mustafa. Modelling detailed information flows in building design with the parameter-based design structure matrix. **Design Studies**, [S. l.], v. 27, n. 1, p. 99–122, 2006. DOI: 10.1016/j.destud.2005.07.004.

PEREIRA, Lucas Melchiori; ORNSTEIN, Sheila Walbe. A Systematic Literature Review on Healthcare Facility Evaluation Methods. **HERD: Health Environments Research & Design Journal**, [S. l.], v. 16, n. 3, p. 338–361, 2023. DOI: 10.1177/19375867231166094. Disponível em: http://journals.sagepub.com/doi/10.1177/19375867231166094.

PEREIRA, Lucas Melchiori; ORNSTEIN, Sheila Walbe; SOARES, Vitória Sanches Lemes; AMARO, Jean; FRANÇA, Ana Judite Galbiatti Limongi. Congruence Mapping of the Activity Flows Allocated in Built Environments: A Pilot Application of Under-Development Software in an Emergency-Care Service. **Applied Sciences,** [S. l.], v. 13, n. 3, p. 1599, 2023. DOI: 10.3390/app13031599.

PHIRI, Michael; CHEN, Bing. **Sustainability and Evidence-Based Design in the Healthcare Estate**. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014. DOI: 10.1007/978-3-642-39203-0. Disponível em: http://ebookcentral.proquest.com/lib/salford/detail.action?docID=5347868.

PREISER, Wolfgang F. E.; HARDY, Andrea E.; SCHRAMM, Ulrich. **Building Performance Evaluation**. 2. ed. Cham: Springer International Publishing, 2018. DOI: 10.1007/978-3-319-56862-1.

ROMAN, Clara. Hospital Universitário consolida-se como local de ensino e pesquisa. **Espaço aberto, 170: A USP e a cidade de São Paulo**, São Paulo, v. 170, 2010. Disponível em: https://www.usp.br/espacoaberto/?p=11122.

SAHA, Nirvik; HAYMAKER, John; SHELDEN, Dennis. Space allocation techniques (SAT). Computable design problems and integrated framework of solvers. In: PROCEEDINGS OF THE 40TH ANNUAL CONFERENCE OF THE ASSOCIATION FOR COMPUTER AIDED DESIGN IN ARCHITECTURE: DISTRIBUTED PROXIMITIES, ACADIA 2020 2020, **Anais** [...]. [s.l: s.n.] p. 248–257.

SASANFAR, Soori; BAGHERPOUR, Morteza; MOATARI-KAZEROUNI, Afrooz. Improving emergency departments: Simulation-based optimization of patients waiting time and staff allocation in an Iranian hospital. **International Journal of Healthcare Management**, [S. l.], v. 14, n. 4, p. 1449–1456, 2021. DOI: 10.1080/20479700.2020.1765121. Disponível em: https://www.tandfonline.com/doi/full/10.1080/20479700.2020.1765121.

SCHMIDT, Robert; VIBAEK, Kasper Sanchez; AUSTIN, Simon. Evaluating the adaptability of an industrialized building using dependency structure matrices. **Construction Management and Economics**, [S. l.], v. 32, n. 1–2, p. 160–182, 2014. DOI: 10.1080/01446193.2013.847274. Disponível em: http://www.tandfonline.com/doi/abs/10.1080/01446193.2013.847274.

SHIN, Sangyun; JEONG, Sangah; LEE, Jaewook; HONG, Seung Wan; JUNG, Sungwon. Pre-Occupancy Evaluation based on user behavior prediction in 3D virtual simulation. **Automation in Construction**, [S. l.], v. 74, p. 55–65, 2017. DOI: 10.1016/j.autcon.2016.11.005. Disponível em: http://dx.doi.org/10.1016/j.autcon.2016.11.005.

SINHA, Kaushik; JAMES, Denman; WECK, Olivier De; WECK, Olivier De. Interplay between product architecture and organizational structure. In: GAIN COMPETITIVE ADVANTAGE BY MANAGING COMPLEXITY - PROCEEDINGS OF THE 14TH INTERNATIONAL DSM CONFERENCE, DSM 2012 2012, **Anais** [...]. [s.l: s.n.] p. 275–288.

SOSA, Manuel E. Aligning process, product, and organizational architectures in software development. In: PROCEEDINGS OF ICED 2007, THE 16TH INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN 2007, **Anais** [...]. [s.l: s.n.] p. 1–12. Disponível em: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84862592271&partnerID=40&md5=392d0b786dd507406ddc97432d84e79c.

UNGER, Darian; EPPINGER, Steven. Improving product development process design: A method for managing information flows, risks, and iterations. **Journal of Engineering Design**, [S. l.], v. 22, n. 10, p. 689–699, 2011. DOI: 10.1080/09544828.2010.524886.

VANBRABANT, Lien; BRAEKERS, Kris; RAMAEKERS, Katrien; VAN NIEUWENHUYSE, Inneke. Simulation of emergency department operations: A comprehensive review of KPIs and operational improvements. **Computers and Industrial Engineering**, [S. l.], v. 131, n. March, p. 356–381, 2019. DOI: 10.1016/j.cie.2019.03.025. Disponível em: https://doi.org/10.1016/j.cie.2019.03.025.

VISCHER, Jacqueline C. Applying knowledge on building performance: From evidence to intelligence. **Intelligent Buildings International**, [S. l.], v. 1, n. 4, p. 239–248, 2009. DOI: 10.3763/inbi.2009.SI02. Disponível em: http://www.tandfonline.com/doi/abs/10.3763/inbi.2009.SI02.

WATKINS, Nicholas; KELLER, Amy. Lost in Translation: Bridging Gaps between Design and Evidence-Based Design. **HERD: Health Environments Research & Design Journal**, [S. l.], v. 1, n. 2, p. 39–46, 2008. DOI: 10.1177/193758670800100205. Disponível em: http://journals.sagepub.com/doi/10.1177/193758670800100205.

WELCH, Shari J. Using Data to Drive Emergency Department Design: A Metasynthesis. **HERD: Health Environments Research & Design Journal**, [S. l.], v. 5, n. 3, p. 26–45, 2012. DOI: 10.1177/193758671200500305. Disponível em: http://journals.sagepub.com/doi/10.1177/193758671200500305.

Article

Hospital architecture sensitive to dementia

Author

Ciro Férrer Herbster Albuquerque Architect and urbanist specialized in Neuroscience Applied to Architecture and Gerontology, as well as in Neuroscience Applied to Learning. Master's student in Architecture, Urbanism and Design at the Federal University of Ceará (UFC). His enthusiasm towards knowledge and the aging capacity of human beings has led his research, and work to focus on architecture, urbanism, and design sensitive to dementia in the intention to delay dementia diagnosis by fostering cognitive stimuli through the built environment.

Abstract

Considering that dementia affects more than 1.2 million elderly people in Brazil, this article discusses the contributions of architectural design sensitive to dementia in health and in the qualification of the experience of the elderly in hospital environments. Based on a literature review, a selection of studies was carried out that highlight the most relevant concepts and that have contributed to the deepening of the understanding of design sensitive to dementia, presenting some examples of projects that incorporate these concepts and the theories that support them. This document is part of a broader research aimed at identifying the implications, benefits, and therapeutic possibilities of using neuroscience applied to architecture in health centers, to establish design concepts to be applied in a case study of homes for the elderly. The results showed that environmental variables such as light, geometry, layout, and access to nature tend to qualitatively affect the experience of these patients, in addition to reducing the workload of caregivers.

Keywords

hospital environments, hospital architecture, health, applied neuroscience, dementia.

Introduction

The increase in global life expectancy has boosted the number of elderly people with dementia, a condition that affects one person every seven seconds. Between 2000 and 2019, the cause of death from dementia increased by 181%, being more evident in underdeveloped countries and characterized as Alzheimer's disease (AD) in 60% of cases. In Brazil, it is estimated that, in 2050, dementia cases will increase by up to 240%, generating several social, family, and public health problems, since dementia symptoms gradually compromise the individual's cognitive autonomy (*Alzheimer's Association*, 2020; GBD *Dementia Forecasting Collaborators*, 2022; IBGE, 2019).

In addition, being referred to hospital units has proven to be a challenging period for patients with brain impairment, making it difficult for them to get adapted to an unfamiliar environment and unfamiliar people, such as the health staff (Sociedade Beneficente Israelita Brasileira Albert Einstein, 2019). It is estimated that the cost of hospitalization for people with dementia is almost three times higher compared to patients without dementia (Gutierrez et al., 2014). Older adults with dementia have almost twice as many annual hospital admissions as older adults without dementia (Sociedade Beneficente Israelita Brasileira Albert Einstein, 2019). Deterioration of spatial orientation is a symptom that manifests itself in the early stages and progresses depending on the environments experienced by the patients (Gazova et al., 2012).

In the city of São Paulo, for example, a significant portion of the population is elder, reaching about 1.9 million individuals, which is equivalent to 15% of the total. This population has specific needs related to mobility, accessibility, leisure, and health (Santos, 2022).

For elderly people in fragile health situations and with unique needs, considering dementia symptoms, São Paulo has the Reference Units for the Health of the Elderly (Ursis). The decision to refer a patient to the Ursis occurs after the staff at Basic Health Units (UBSs) carries out the Multidimensional Assessment of the Elderly (AMPI-AB). The AMPI-AB provides an accurate assessment of the aging process of the elderly, their level of frailty and their specific demands. In total, approximately 6,000 elderly people receive monthly care in Ursis. The main purpose is to ensure that the elderly can age autonomously and enjoy a good quality of life at this stage of life (Andrade et al., 2020). However, the exponential increase in the number of elderly people and the setting of these health spaces compromise the quality of the service, resulting in longer treatment time and medical expenses (GBD 2019 Dementia Forecasting Collaborators, 2022).

In this context, research in hospital architecture plays a fundamental role in the systematization of knowledge that can be applied nationally. In view of the scarcity of national bibliography on hospital architecture applied to the elderly with dementia (Wiener; Pazzaglia, 2021), the search for architectural design solutions appropriate to the growing demand of this public is essential to provide a therapeutic, safe, and welcoming environment for these patients.

Purpose and methodology

This study aimed to explore and discuss the implications of this issue, highlighting the importance of interdisciplinary research among architects, health professionals, and gerontology specialists for the development of architecture design guidelines for hospital units intended for the care of older adults with dementia and other frailties. Understanding the specific needs of these patients and understanding how the physical environment can influence their health and well-being is critical to developing spaces that promote recovery, comfort, and dignity.

For this study, we carried out a literature review on the existing content on the themes of aging, architecture, health spaces and dementia. As a result, the works of Barrett, Sharma and Zeisel (2018), Lawton M. Powell (1997), Mariana G. Figueiró (2008) and Gesine Marquardt (2014) were further analyzed, among other relevant authors in the context of spatial influence on dementia. The study highlights the importance of interdisciplinarity that permeates the knowledge of neuroscience and aging applied to hospital architecture, aiming to foster a set of recommendations applicable to health environments suitable for the public with dementia.

Typical aging and dementia

Both typical aging and dementia result in significant declines in spatial orientation and navigation skills[1] (Lester et al., 2017). Spatial orientation and navigational skills begin to deteriorate relatively early in the aging process, even when there are no apparent impairments in other cognitive abilities (Harris; Wolbers, 2012). This gradual loss of navigational skills is even more evident in individuals with mild cognitive impairment (MCI) or AD (Fasano et al., 2018), in which disorientation is typically one of the first symptoms (Serino et al., 2015), especially in unfamiliar environments. Research on typical aging has shown that older adults exhibit walkability performance similar to that of young adults on spatial tasks in familiar settings (Lopez et al., 2018). However, declining orientation and navigation skills make it difficult for seniors to walk and learn in unfamiliar new environments. This is problematic, since a considerable proportion of

1 According to Lester et al. (2017), spatial navigation is characterized as the individual's ability to locate and move from the built environment. The user is guided by the different landmarks in the space in which he or she is located. During aging, this ability can be affected mildly, moderately, or severely. When spatial navigation is altered, it can represent a strong marker of cognitive declines in the elderly.

older adults with and without dementia eventually move from their familiar environments to unfamiliar locations such as hospitals, clinics, and assisted care homes (Mufato et al., 2020). In 2018, ELSI-Brasil pointed out that 75.3% of elderly Brazilians depend exclusively on the services provided by the National Health Systema (SUS), and 83.1% had at least one medical appointment in the last 12 months. During this period, it was also identified that 10.2% of the elderly were hospitalized one or more times (Fiocruz et al., 2018).

Generally, the design of health care complexes does not take into account changes in the walking abilities of the elderly. If they had this biological factor during the design of the project, the transition of older adults with AD to facilities of this size could become simpler (O'Malley et al., 2016). To make it possible for the layouts of larger environments, such as care homes, retirement homes, or even hospitals, to be understood relatively easily, these environments need to be designed in a way that facilitates spatial orientation and compensates for diminished navigation skills. This allows residents to adapt more easily to the new accommodation and would improve their quality of life and well-being. In addition to allowing the maintenance of a greater degree of independence and a reduction in the workload of caregivers (Marquardt; Schmieg, 2009).

According to O'Malley et al. (2017), there are several architectural design guidelines and management tools that address the "dementia sensitivity" of an environment: the Dementia Audit Tool (DAT), developed at the Centre for the Development of Dementia Services; the EVOLVE design toolkit; the "Enhancing the Healing Environment" (EHE) assessment tool, by The King's Fund; the Environmental Audit Tool (EAT); and NHS Scotland's guidance document on guidance, the only one dedicated exclusively to guidance in healthcare facilities but not specifically focused on dementia-sensitive hospital settings (Estate, 2005).

While these guidelines provide advice on how to improve the design of care settings to support people with AD and other types of dementia, few design suggestions focus specifically on alleviating disorientation and aiding navigation; those that do are often not well-grounded by neuroscientific theories of walkability (O'Malley et al., 2016). In this article, based on the literature review pertinent to the subject, it is argued that neuroscientific theories of orientation and navigation, supported by experimental evidence and design applications, can and should play an important role in improving the design of health care environments for the elderly.

The concepts of aging and spatial navigation, neuroscience applied to architecture and the influence of environmental variables on users stand out among the most used in the area of architectural design of spaces intended for the provision of health services for the elderly.

Aging and wayfinding

Wayfinding involves coordinated, goal-oriented movement in the environment (Montello et al., 2005), being defined as the process of determining and navigating a route, from an origin to a destination (Golledge et al., 1987). Wayfinding is also considered a complex and multisensory skill susceptible to wide individual differences (Van Buuren; Mohammadi, 2021) which is affected by personal or collective emotions and motivations. For example, spatial anxiety has a detrimental effect on wayfinding performance, especially in complex navigation tasks (Marquardt, 2011). On the other hand, the sense of spatial self-efficacy and the pleasure of exploring unfamiliar environments are positively correlated with wayfinding performance (Pazzaglia; Meneghetti, 2017).

Good wayfinding skills (derived from the interaction between individual and environmental factors) are an important source of quality of life and autonomy. Emotions become even more relevant in atypical aging when people with dementia interact with unfamiliar environments. Several studies have shown that the role of the environment is extremely important in reducing stress and promoting quality of life. In a review on the impact of built environment design on people with dementia, Marquardt et al. (2014) found that small-scale environments, an environmental aspect strictly related to space navigation (Marquardt; Schmieg, 2009), are associated with reduced dysfunctional behavior and improved well-being, including reduced depressive symptoms and improved mood and quality of life.

When it comes to cognition, spatial navigation depends on various sensory and cognitive processes, as well as on long-lasting and transitory spatial representations (Wolbers; Hegarty, 2010). Visual and auditory stimuli capture information from the built environment, allowing spatial understanding by the user. Visual stimuli added to vestibular receptors and proprioceptors provide information about how people move through space. All these inputs are processed and integrated to allow the individual to locate themselves in their position, orient themselves and plan routes to their intended destination.

The ability to plan a route, move towards a destination, and reach it derives from the interaction between individual, sensory, and environmental factors (Pazzaglia; Meneghetti, 2017). In this context, certain interactive models of navigation and wayfinding have been proposed. Next, interactive navigation models and navigation studies were reviewed. Although the purpose of this article is to provide architectural design suggestions for the interiors of healthcare settings and care settings, it is observed that people employ the same walkability mechanisms both indoors and outdoors. Therefore, we cite research that used both types of environments.

Carpman and Grant (2002) analyzed wayfinding behavior in indoor environments in terms of systems in which combinations of behavioral factors (cognitive variables and individual differences), building design, and operational elements (e.g., indoor signage, location maps) interact to create an environment in which it can be easy to walk.

Carlson et al. (2010) suggested considering the complexity of indoor wayfinding in terms of environmental variables (characteristics of a building), spatial representations of people or cognitive maps (a kind of mental image of the environment) and personal factors (individual spatial skills and strategies). According to Tolman (1948), the way these elements interact can be analyzed in terms of: correspondence (between a building and a cognitive map); compatibility (between a building and individual strategies); and completeness (between a cognitive map and individual spatial skills and strategies). The joint analysis of these components can generate promising developments about navigation problems presented by a given building.

A similar interactive approach is adopted by ecological models of gerontology that explain the relationship between individual characteristics and environments in terms of user-environment adjustment (Kahana, 1982), in which people's ability to express their full potential depends on their compatibility with their environment.

The ability to cope with the environment may decrease as people become more vulnerable due to ageing (Schröder-Butterfill; Mariani, 2006). These vulnerabilities result in people becoming increasingly dependent on their environment, as predicted by the Environmental Docility Hypothesis (Fornara et al., 2019; Lawton, 1977; Lawton and Simon, 1968). This also explains why individual differences in each user's spatial mobility behavior must be analyzed, considering the environmental variables that facilitate or inhibit navigation (Devlin, 2014).

Such perspective can be observed in the architectural design proposed by the housing project focused on the health of the elderly with dementia, Hogeweyk Dementia Village, in the Netherlands, whose rooms for patients with dementia are customized according to culture, life history and leisure activities (Illustration 1). According to the Environmental Docility Hypothesis, recognizable environments contribute to emotional resilience and quality of life (Lawton, 1977).

Illustration 1 . In corridors and waiting rooms, familiar and cozy furnishings are applied, fostering an atmosphere that is diverse from the classic appearance of the healthcare environments present in Hogeweyk. The side view of the outdoor gardens helps in this ambience. Source: homesmiths.co.uk (2020).

For such reasons, the cognitive aspects contemplated by neuroscience applied to architecture were studied, with a view to analyzing the environmental variables that qualitatively affect the navigation of healthy elderly people with dementia in the built environment. Evidence from these individual and environmental factors will be used to inform the design guidelines listed in the last section of the article.

Neuroscience applied to architecture.

When applied to architectural design, neuroscience aims to improve built spaces to generate positive effects on the physical and mental health of human beings (Fajardo, 2018). This method of uniting research and design is crucial, since elderly people spend more than 87% of their time in a closed hospital environment, and possibly these spaces are not suitable for them (Bruchert; Baumgart; Bolte, 2021).

Neuroscience presents itself as the scientific field dedicated to the study of the functioning and understanding of the nervous system, composed of the brain, spinal cord, and peripheral nerves. In this sense, neuroscience applied to the built environment starts to bring design strategies to stimulate welcoming (Solís; Herrera, 2017), well-being (Paiva; Jedon, 2019), faster recoveries, and therapeutic effects (Shaaban et al., 2023). Some examples of these strategies include the use of natural materials, natural lighting, colors, architectural shapes, textures, natural materials, and the arrangement of furniture and objects.

According to Browning, Ryan, and Clancy (2014), buildings that have multisensory connections to the outside world can provide therapeutic benefits, as occupants consistently express a preference for visual and non-visual engagement with nature and landscape. Furthermore, Kellert (2008) argues that the presence of water is aesthetically appealing and has the ability to stimulate a wide range of senses, including hearing, movement, touch, taste, and smell. The multisensory and timeless engagement makes it an ideal choice for incorporation into outdoor spaces whose purpose is to mitigate anxiety and stress on the part of patients undergoing treatment or even to serve as a visual landmark for space orientation. These are just a few examples of design strategies that neuroscience applied to architecture uses to achieve its goals.

In this aspect, the built environment is initially perceived through emotions, an instinctive and efficient system, sensitive to both negative and positive emotional repercussions[2]. Paiva and Jedon (2019) state that individuals in a hot environment, for example, may sweat, feel uncomfortable, and be unable to concentrate. Another example is the feelings of fear, anxiety, and alertness that can be generated in dark and unfamiliar environments.

Such interaction between the environment and the individual can go unnoticed to users, considering that some sensations are unconsciously captured by the brain, according to the studies of Eberhard (2009). Paiva (2018) and Khaleghimoghaddam et al. (2022) argue that such interactions can result in changes in physiological state, such as changes in hormone levels, heart rate, skin conductance, blood pressure, body temperature, and muscle tension. They can also modify emotional state, behavior, decision-making, and mental health. Villarouco et al. (2021) corroborates by highlighting that:

> [...] the environment constantly provides stimuli — of greater or lesser intensity — that are captured by the body as sensations for the mind to process, generating perceptions and awareness, which can trigger a behavioral response (Villarouco et al., 2021, p. 20).

2 According to Paiva and Jedon (2019), they are characterized by physical manifestations, and may present psychological symptoms, which may include anxiety, irritability, impatience, fatigue, tiredness, sadness, loss of pleasure, and lack of interest in daily activities.

In other words, the characteristics of the environment cause physiological reactions that can increase or reduce the mental capacity to perform a specific task. Therefore, it is necessary to create spaces that can encourage human beings to improve their performance, in order to maintain the well-being and health of users.

With neuroscience applied to architectural design, it is possible to design environments for older adults with dementia that are able to compensate for certain cognitive weaknesses, such as the loss of balance during a walk, enabling autonomy and improvement in the experience of these patients in hospital environments. Mental health, safety when walking through corridors, well-being, and lower stress levels in hospital settings can all be achieved depending on the architectural design strategies applied to the variables of the hospital environment. Next, we will present the environmental variables evidenced by neuroscience that can qualify the experience of elderly patients with dementia in health care settings.

Influence of environmental variables on users in the built environment

As mentioned, as human beings age, especially with the advent of neurodegenerative conditions, the ability to roam freely through space tends to decrease, making it challenging to explore unfamiliar environments without the support of a caregiver (Wolbers; Hegarty, 2010). In addition, when the elderly need to go to the health environment, whether in hospitals, assisted living homes, or rehabilitation clinics, it is essential to promote spatial improvements in the architectural design that compensate for the patient's declining orientation skills (Wiener; Pazzaglia, 2021).

It should be noted that care environments differ greatly in size, architecture, available resources, and freedom to implement changes. Therefore, it aims to provide generic architectural design principles based on scientific evidence rather than specific solutions. These design principles can then be translated into customized solutions for specific environments, depending on how they will be used by the designers of the hospital environments.

Considering the spatial navigation, layout, light, geometry, and access to nature will be presented as the main environmental influences that can qualify the experience of the elderly, caregivers, and employees in health environments.

Layout

When developing environments for people with declining navigation skills, design should consider simple corridor layouts, excellent visual access, some asymmetry, a clear signage system, and the presence of visual landmarks. The most effective layouts for the reception of seniors are accommodations in small spaces, where everything a resident needs is always in sight, in a comfortable way, allowing them to walk between their own rooms and the common areas with ease. Smaller-area accommodations with good visual access reduce spatial disorientation because this layout facilitates spatial memory processing and recall, as well as redundant path decisions, with a well-defined and easy-to-understand start and end. In this sense, the arrangement of space plays a central role.

Simplified and straightforward layouts, as pointed out by Marquardt (2011), have the potential to provide a more intuitive understanding of the environment, which is crucial for patients with cognitive declines. These layouts prevent confusion and anxiety, allowing patients to move more easily (Lithfous; Dufour; Després, 2013). In addition, visibility and identification of areas are crucial for successful walkability. Studies by Garling, Book, and Lindberg (1986) underscore the importance of clear and wide visual access, allowing residents to quickly identify different parts of the environment. The presence of distinct visual elements and landmarks helps to build a mental network of spatial orientation, as proposed by Ishikawa and Nakamura (2012).

The study by Van Buuren and Mohammadi (2021) analyzed 14 floor plans of care spaces for older adults with dementia. Such plants were evaluated by 14 design criteria dedicated to supporting orientation skills for the target group. From qualitative and quantitative analyses of the study, it was found that 3 of the 14 plants had better spatial walkability performances. Similar corridor layouts were found in Marquardt's 2011 study (Illustration 2). In addition, in both studies, special attention is suggested to the configuration of the floor plans, the shape and the natural light of the corridor (Van Buuren; Mohammadi, 2021; Marquardt, 2011).

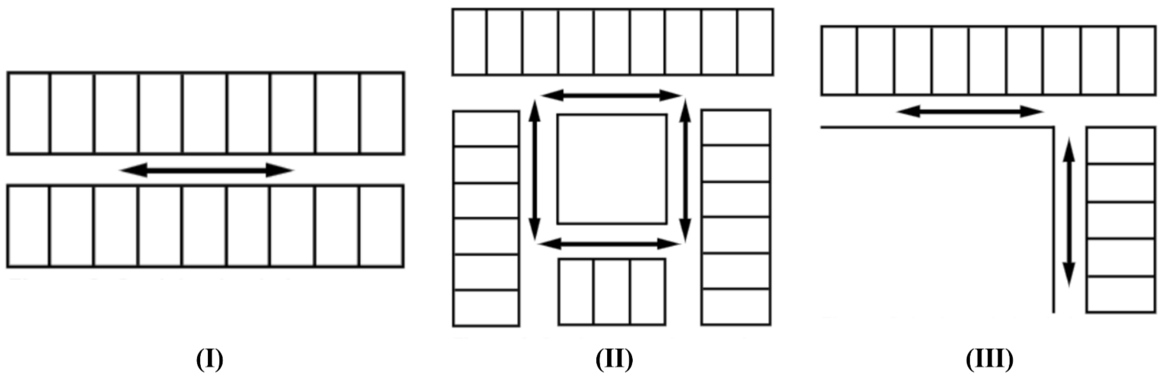


Illustration 2 . Corridor layouts found in the studies by Marquardt (2011) and Van Buuren and Mohammadi (2021). (I) Narrow, straight, and uniform corridor; (II) Continuous path around an inner courtyard; (III) L-shaped circulation system with change of direction. Source: Adapted from Marquardt (2011).

Although interventions, such as signage, furniture, lighting, and colors, can qualify the performance in the orientation of older adults with dementia, they cannot compensate for the inadequate architectural design present in the layout (Marquardt; Schmieg, 2009). Thus, based on the results of the studies discussed, it can be hypothesized that the designs whose layouts are designed with those presented play a significant role in supporting the spatial orientation and navigation of people with dementia.

Lighting in Healthcare Environments

Having contact with natural lighting is of obvious importance for human health. Studies indicate that this feature affects the circadian cycle, performance, energy, sleep quality, vitamin D and serotonin levels in the body, as well as eye health (Kellert; Calabrese, 2015).

The studies of Eberhard (2009) observed that natural lighting, when applied to the built environment, was able to affect the memory retention of users present in the environment. The results of the memorization tests done between the group with natural lighting and only the group with artificial lighting demonstrated this theory. Research shows that in classrooms with large openings for natural light, higher levels of attention and better learning have been found (Kaplan, 1995). In addition, studies such as the one by Boubekri et al. (2014, p.14) demonstrate that "[...] people who work in sunny environments sleep better and laugh more than those who spend the day in dimly lit offices," besides contributing to improvements in sleep quality and the reduction of physical and mental problems.

Regarding elderly patients, after the age of 60, several structural changes in the eyeball become more expressive than in adulthood. The aging eye becomes more sensitive, has lower visual acuity, less pupil opening, and light capture from the external environment (Chang; Guarente, 2013). The yellowing of the lens promotes less capture of the blue-length light present in the sun and indoors during the day (Sahar; Farajnia et al., 2012).

This change, when added to the lack of light capture during the day by the elderly, causes metabolic disorders, among them: worse sleep efficiency; increased night awakening and sleep latency; and higher levels of daytime sleepiness because they do not effectively capture daily light stimuli (Feinslier et al., 2017).

When they are taken to nursing homes, healthy elderly people with dementia are, in most cases, exposed to less environmental stimuli, less physical activity and less exposure to light stimuli, contributing to an increase in neurodegenerative symptoms (Feinslier et al., 2017). In this sense of exposure to light, the color temperature emitted by electric lighting can be modified according to the circadian rhythm of inpatients, ranging from 6,500 Kelvin at dawn, 4,000 Kelvin in the afternoon, and less than 2,800 Kelvin in the twilight. When performed, this lighting system can provide improvements to mood, sleep, and a decrease in behavioral disorders present in patients with dementia (Barret et al., 2018). To facilitate these color temperature modifications, it is used tunable white[3]

3 This technology makes it possible for the color temperature of the light to change automatically from warm (less than 2,800 Kelvin) to cool (more than 2,800 Kenvin), and vice versa, according to what was previously programmed. This allows you to manipulate the lighting according to the needs of each time and environment. With tunable white it is possible to simulate the daily cycle of the sun, helping to regulate the circadian cycle, better known as the biological clock. This alternative is excellent for patients hospitalized in hospital rooms and ICUs who do not have access to natural lighting and, therefore, have their physiological functions unregulated, since sunlight has a direct influence on the correct functioning of the circadian rhythm (Tuaycharoen, 2020).

lighting systems, as they can mimic the intensity of natural lighting, as shown in Illustration 3 (Tuaycharoen, 2020).

In this regard, the research conducted in Asia evaluated the behavior of 308 elderly Thais aged between 61 and 79 years old, coming from six different controlled health environments. It was found that Thai elderly people begin to acquire greater autonomy and independence in a favorable environment that compensates for their biological and functional needs after the application of the tunable white lighting system, as shown in Illustration 3 (Tuaycharoen, 2020). In this study, significant factors included the type of opening, the type of lamp, the type of lamp bulb, and the type of view, as well as other factors related to the color, signage, and furnishings of the nursing home environments. In another study, it was observed that appropriate lighting and architectural features in terms of color, signage and furniture promoted the discovery of internal pathways, improvements in mood and sleep quality in elderly people living in nursing homes or inpatients in health settings (Figueiró, 2008).

Illustration 3 . Examples of image samples in the first part. The effect of CCT (a) cold (6,500 Kelvin), (b) white (4,000 Kelvin), (C) hot (2,800 Kelvin). The effect of the color of the room: (d) surface of the room in cool color tone, (e) surface of the room in white color tone and (f) surface of the room in warm color tone. Source: Tuaycharoen (2020).

The use of lighting with warm color temperature, about 2,800 Kelvin, at night in the rooms of residents in nursing homes showed: a decrease in sleep disorders; improvement in the mood and behavior of residents; improvements in the quality of treatment of dementia and cognitive conditions; and less burden on nurses (Figueiró et al., 2011). A similar study (2011) found that the use of extra light near the floor and contrasting colors between floor and wall can help patients in healthcare settings find their way to their respective room more easily (Wolkove et al., 2007).

In another experiment carried out in a home for the elderly for dementia care, the modification of the lighting to a carefully specified and implemented one provided improvements in sleep and mood during the day by AD patients (Figueiró et al., 2019). Thus, lighting integrated with the circadian rhythm, when carefully specified and implemented, provides improvements in mood, sleep and a decrease in behavioral disorders present in patients with dementia.

Finally, the recent study by Figueiró et al. (2020) aimed to analyze the sleep quality of 47 older adults with dementia in nine different controlled healthcare settings. The clinical trial was done at 25 weeks from modifications administered to all-day lighting. Using measures from actigraphy monitoring[4] and standardized measures of sleep quality, mood, and behavior were used (Figueiró et al., 2020), the study found that a regular daytime lighting intervention with circadian efficacy can improve nighttime sleep and reduce depression and agitation in dementia patients living in controlled healthcare settings.

Therefore, in view of the studies demonstrated, it can be affirmed that lighting has a strong influence on mood, sleep, and the ability to recover and well-being of users of internal spaces, especially elderly patients. Therefore, it is essential to consider it in a hospital project that is receptive to patients with dementia.

Color

Choosing appropriate colors is crucial in architectural design for people with dementia. The use of colors present in nature and high contrast between wall, floor and ceiling can improve walkability and object recall. Color preferences seem to remain stable, so customizing room colors can be beneficial (Ishikawa; Nakamura, 2012). Additionally, light colors can create a sense of spatial amplitude, while appropriate colors and contrasts can be used to differentiate areas and hallways. However, it is important to consider the ability of people with dementia to discriminate colors and contrasts, which may be reduced due to the yellowing process of the lens (Ishikawa; Nakamura, 2012).

4 Simple and painless examination carried out with a device similar to a watch applied around the wrist. It has no age restriction and is indicated for patients with circadian rhythm disorders — that is, when bedtime and wake-up time are not in sync with the cycle of day and night. The test investigates excessive sleepiness or insomnia problems (Figueiró et al., 2020).

O’Connor (2020) corroborates this by verifying in his study improvements in reading, inclusion, environmental comfort, and independence in walking. The main objective was to promote reading strategies for the public with dementia based on the workability of contrast with colors in texts and signage panels. The result was effective in the quality of adding possibilities of independence to the public with dementia from the easy reading of graphic signs (O’Connor, 2020).

The use of artificial colors should be applied with caution, especially the shiny ones. Tones and imagery arrangements of natural tones mimicking flowers, sunsets, rainbows, plants, and animals can be applied in places whose function is to promote tranquility (Duzenli et al., 2018). Kellert and Calabrese (2015) corroborate the suggestion of using natural colors for welcoming and soothing atmospheres, considering that such shades create connections between the built environment and nature. Green, blue, and yellow, for example, are shades related to nature, allowing influences on stress reduction by stimulating the sense of environmental comfort and proximity to the external environment (Fernández, 2019). On the other hand, individuals exposed to red, or other colors with a high degree of saturation, may have their physiological state altered, such as increased muscle tension, adrenaline release, increased metabolism, heart rate, and physiological activities of the digestive system (Roth; Clar, 2018).

In this regard, the use of colors can promote positive or negative emotional valences in the elderly with dementia in health care environments, depending on how and in which place a certain shade is used. Therefore, it becomes an environmental variable to be considered in projects of environments sensitive to dementia.

Shapes

Architectural shapes also have an impact on the human brain. Square spaces can convey a sense of confinement, as the brain understands that it as an enclosed space. The studies of Lei Xia (2020) show that sharp angles in furniture, for example, can evoke a sense of danger, since human beings are instinctively threatened by sharp objects, considered a potential risk to injury. Such risk tends to cause stress and anxiety, even if unconsciously (Lei Xia, 2020).

In contrast, the use of mild curves or contours conveys a sense of security and comfort, as they resemble natural shapes (Kellert; Calabrese, 2015). Therefore, the mix of curved geometries creates a sense of dynamism, making the space less static and creating ever-changing, nature-like environments (Shaaban; Kamel; Khodeir, 2023).

In general, people prefer objects with curved contours over objects with sharp contours, such as the ends of a rectangular dining table. “This trend [...] seems to be related to the human mind’s implicit perception that pointed shapes are threatening and therefore can hurt” (Pati et al., 2016, p.175).

Another important element to evoke emotions in architecture is texture, due to its visual effect and, mainly, the possibility of tactile sensation, according to Roth and Clar (2018). The sense of touch plays a relevant role in perceptions, as it promotes the action of generating and modifying sensations. Textures and emotions are associated and can be measured based on temperature, softness, roughness, and the pleasure they provide to the individual (Iosifyan; Korolkova, 2019). Texture can be provided by natural materials, such as wood, natural stone, bamboo, straw, and clay, which bring textures and colors reminiscent of nature (Kellert; Heerwagen; Mador, 2011).

In addition, the height of the ceiling influences the journey of the experience in the built environment and consequently affects the user’s concentration levels. Such influence was shown in the research of Fernández (2019) and Shaaban, Kamel, and Khodeir (2023). High ceilings, for example, are suitable for environments intended for creative activities. In this case, it was recorded that the ceiling height above 2.5 meters promotes the activation of areas of the central nervous system related to freedom and exploration by the user. This activation makes it possible to promote both creativity and spontaneous behaviors. On the other hand, ceilings closer to the floor, less than 2.5 meter high, favor tasks that require more concentration and repetition. Both studies recorded that areas of the central nervous system related to goal setting, purposes, and attentional focus are activated in these spaces (Fernández, 2019; Shaaban, Kamel, and Khodeir, 2023). In this way, both the distances between the floor and the ceiling influence the unconscious behavior of the brains of users of built environments.

In the healthcare environment sensitive to dementia, the strategic use of colors, curvilinear paths, patterns, and materials that refer to nature is noticeable. These features provide easy orientation in the South Hill tower of the Rockwood Retirement Communities nursing home, located in Spokane, Washington, enabling residents to navigate the building independently, contributing to feelings of self-assurance and self-confidence (Illustration 4).

Illustration 4 . South Hill Tower of Rockwood Retirement Communities nursing home, located in Spokane, Washington (2019)/Photo; Ben Benschneider (2019).

Access to nature

When considering access to nature, the Stress Reduction Theory, developed in the 1990s by Roger Ulrich, suggests that natural environments can reduce physiological stress and aversive emotions. Another relevant theory was the one developed by Kaplan (1995): the Attention Restoration Theory, which argues that nature helps to renew attention after the exhaustion of cognitive resources used during daily activities. The theory suggests that the mental resources of human beings are limited, and therefore activities involving cognition, self-control, creativity, and concentration consume much of the human body's energy resources. Thus, both theories propose that the approximation of environmental resources contributes to the promotion of pleasant environments for the occupants of built spaces (Kaplan, 1995; Ulrich, 1993). Therefore, the introduction of direct or indirect contact with natural aspects in healthcare environments becomes a promising architectural design strategy to mitigate stressors for older adults with dementia.

Regarding the use of surfaces resembling natural features, the work conducted by Ikei et al. (2017) revealed that "[...] touching the wood with the palm of the hand calms the activity of the prefrontal cortex and induces parasympathetic nerve activity more than other materials [...]", thus inducing physiological relaxation in users. This was also evidenced in the study by Bhatta et al. (2017) by showing that natural and smooth wood surfaces were perceived more positively in the emotional touch than those covered with materials that did not exist in the natural environment.

Studies related to soundscape have shown that the sonority of the environment influences the emotional valence of elderly people with dementia in clinical support homes. The study conducted by Devos et al. (2019) showed that adequate noise monitoring and the application of sounds considered "soothing", such as those of birds and those from nature, provide positive emotional valences, such as a sense of well-being, comfort, and security (Devos et al., 2019).

Kosters et al. (2019) corroborates that by identifying the clinically relevant reduction in neuropsychiatric symptoms of 110 older adults with dementia in five support homes by mitigating urban noise and introducing natural sounds, as well as those pointed out by Devos et al. (2019). Another study, by De Pessemier et al. (2022), suggests that the incorporation of soundscapes recognizable as natural and appreciated by the public with dementia in clinical support homes contributes positively to the emotional valence of occupants. In the investigation, it was shown that approximately 70% of users improved their well-being and environmental comfort (De Pessemier et al., 2022).

Regarding natural fragrances, the study conducted by Silva et al. (2023) verified the efficacy of Lavandula angustifolia Mill. as an essential oil for pain relief and anxiety reduction. In this research, 83 studies from different countries were evaluated, involving different methods, applications, and effects. From the studies evaluated, 83% involved oil inhalation; 14%, oil application to the skin; and 3%, the ingestion of pills containing this substance (Silva et al., 2023). Thus, the application of this natural essence to architectural design presents itself as a promising sensory stimulus regarding the anxiolytic behavior and well-being of elderly patients with dementia in health care environments.

Conclusions and recommendations

Architecture design sensitive to the elderly with dementia must carefully consider shapes, textures, ceiling height, access to nature, surfaces resembling nature, and natural scents to create environments that promote the well-being and quality of life of such population. These elements can play a significant role in improving the built environment to meet the specific needs of people with dementia.

a Wayfinding: wayfinding is a critical aspect in the design of environments for older adults with dementia, as they often face spatial orientation challenges. The layout of the environment, including simple corridors, clear visual access, asymmetry, effective signage, and visual landmarks, plays a key role in improving their walkability.

b Natural lighting: exposure to natural lighting is essential for the physical and mental health of older adults, including those with dementia. Natural light affects circadian rhythm, improves mood, promotes well-being, and can help reduce sleep disturbances. Integrating tunable white lighting systems, which mimic the intensity of natural light, can be beneficial.

c Artificial lighting: carefully designed and implemented artificial lighting, including circadian lighting, can improve nighttime sleep, reduce depression and agitation in dementia patients. Lighting should be adapted to the needs of patients, considering the aging of the eyes and individual needs.

d Use of colors: choosing appropriate colors is crucial to create welcoming and peaceful environments for dementia patients. Natural colors and soft tones are associated with nature and can promote feelings of comfort and connection with the environment. Excessive use of bright and saturated colors should be avoided since it can cause agitation.

e Architectural shapes: avoiding sharp angles and sharp shapes, opting for soft curves and contours, convey feelings of security and comfort.

f Architectural textures: using natural materials that provide textures and colors resembling nature to create a sense of familiarity and connection with the environment.

g Ceiling height: the height of the ceiling should be established according to the purpose of the space. Higher ceilings can be ideal for creative environments, while lowered ceilings can improve concentration.

h Access to nature: integrating natural elements, such as green areas, natural light, and views of nature, reduce stress and improve the well-being of residents.

i Surfaces that evoke nature: using materials that resemble nature, such as natural wood, create welcoming and comforting environments.

j Soundscape and natural fragrances: considering the soundscape, incorporating calming natural sounds, such as those of birds, and natural scents, such as Lavandula angustifolia Mill essential oil., create environments that promote feelings of well-being, comfort, and self-assurance.

To sum up, architectural design sensitive to the elderly with dementia must be thought of in a systemic way, taking into account not only the physical aspects of the environment, but also the sensory elements that can positively influence the emotional and cognitive state of residents. This approach can contribute to the creation of therapeutic environments that improve life quality and experience of people with dementia, promoting independence, well-being, and less work overload for caregivers and family members involved.

Bibliography

ALZHEIMER'S ASSOCIATION. **2020 Alzheimer's Disease Facts and Figures**. Alzheimers Dement 2020, v. 16, n. 3, p. 391. Disponível em: <https://www.alz.org/media/Documents/alzheimers-facts-and-figures.pdf>. Acesso em: 2 jun 2020.

ANDRADE, S. C. V. DE et al. Perfil de saúde dos idosos assistidos pelo Programa Acompanhante de Idosos na Rede de Atenção à Saúde do Município de São Paulo. **Einstein Journal**, v. 18, p. –, 2020.

BARRETT, P.; SHARMA, M.; ZEISEL, J. Optimal spaces for those living with dementia: principles and evidence. **Building Research & Information**, v. 47, n. 6, p. 734–746, 2018.

BARRETT, S. et al. Integrated motivational interviewing and cognitive behavior therapy for lifestyle mediators of overweight and obesity in community-dwelling adults: a systematic review and meta-analyses. **BMC Public Health**, v. 18, n. 1, 2018.

BHATTA, S. R. et al. Sensory and Emotional Perception of Wooden Surfaces through Fingertip Touch. **Frontiers in Psychology**, v. 8, p.8-367, 2017.

BOUBEKRI, M. et al. Impact of Windows and Daylight Exposure on Overall Health and Sleep Quality of Office Workers: A Case-Control Pilot Study. **Journal of Clinical Sleep Medicine**, v. 10, n. 6, 2014.

BROWNING, W. D., RYAN, C. O., AND CLANCY, J. O. **14 Patterns of biophilic design**. Terrapin Bright Green, 2014.

BRÜCHERT, T.; BAUMGART, S.; BOLTE, G. Social determinants of older adults' urban design preference: a cross-sectional study. **Cities & Health**, p. 1–15, 2021.

CARLSON, LA; HÖLSCHER, C; SHIPLEY, TF; DALTON, RC. Getting lost in buildings. **Curr Dir Psychol Sci**, n. 1, p. 284–289, 2010.

CARPMAN, JR; GRANT, MA. Wayfinding: a broad view. In: BECHTEL, RB; CHURCHMAN, A. (eds) **Handbook of environmental psychology**. Wiley, New York, p. 427–442, 2002.

CHANG, H.-C.; GUARENTE, L. SIRT1 Mediates Central Circadian Control in the SCN by a Mechanism that Decays with Aging. **Cell**, v. 153, n. 7, p. 1448–1460, 2013.

CHO, M. E.; KIM, M. J. Measurement of User Emotion and Experience in Interaction with Space. **Journal of Asian Architecture and Building Engineering**, 2017.

DE PESSEMIER, T. et al. Personalising augmented soundscapes for supporting persons with dementia. **Multimedia Tools and Applications**, v. 82, n. 9, p. 14171–14192, 2022.

DEVLIN, A. Wayfinding in healthcare facilities: contributions from environmental psychology. **Behavoral Scienses**, p. 423–436, 2014.

DEVOS, P. et al. Designing Supportive Soundscapes for Nursing Home Residents with Dementia. **International Journal of Environmental Research and Public Health**, v. 16, n. 24, 2019.

DÜZENLİ, T.; EREN, E. T.; AKYOL, D. Concept of sustainability and biophilic design in landscape architecture. **ASOS JOURNAL**, The Journal of Academic Social Science, p 43-49, 2017.

EBERHARD, J. P. **Brain Landscape**: The Coexistence of Neuroscience and Architecture. University Press, Oxford, 2009.

ESTATES, N. H. S. ***Wayfinding***: Effective Wayfinding and Signing Systems; Guidance for Healthcare Facilities. [s.l.] The Stationery Office, 2005.

FAJARDO, J. L. C. Arquitectura e inteligencia emocional en el pensamiento de Juhani Pallasmaa. **Revista científica: El pájaro de Benín**, Espanha, v. 4, 2018.

FASANO, F. et al. Combining Structural Magnetic Resonance Imaging and Visuospatial Tests to Classify Mild Cognitive Impairment. **Current Alzheimer Research**, v. 15, n. 3, 2018.

FEINSILVER, S. H.; HERNANDEZ, A. B. Sleep in the Elderly. **Clinics in Geriatric Medicine**, v. 33, n. 4, p. 579–596, 2017.

FERNÁNDEZ, I. Cinco elementos clave de la neuroarquitectura: arquitectura sostenible. **Revista digital Arquitetura**, 2019. Disponível em: <https://arquitecturasostenible.es/5-elementos-claves-de-la-neuroarquitectura>. Acesso em 1º set 2021.

FIGUEIRO, M. A proposed 24 h lighting scheme for older adults. **Lighting Research & Technology**, v. 40, n. 2, p. 153–160, 2008.

FIGUEIRO, M. G. et al. Effects of a Tailored Lighting Intervention on Sleep Quality, Rest–Activity, Mood, and Behavior in Older Adults With Alzheimer Disease and Related Dementias: A Randomized Clinical Trial. **Journal of Clinical Sleep Medicine**, v. 15, n. 12, p. 1757–1767, 2019.

FIGUEIRO, M. G. et al. Long-Term, All-Day Exposure to Circadian-Effective Light Improves Sleep, Mood, and Behavior in Persons with Dementia. **Journal of Alzheimer's Disease Reports**, v. 4, n. 1, p. 297–312, 2020.

FIGUEIRO, M. G.; LESNIAK, N. Z.; REA, M. S. Implications of controlled short-wavelength light exposure for sleep in older adults. **BMC Research Notes**, v. 4, n. 1, 2011.

FIOCRUZ. **ELSI-Brasil – Estudo longitudinal da saúde dos idosos brasileiros**. Disponível em: <https://elsi.cpqrr.fiocruz.br/>. Acesso em: 4 out 2023.

FORNARA, F; LAI, AE; BONAIUTO, M; PAZZAGLIA, F. Residential place attachment as an adaptive strategy for coping with the reduction of spatial abilities in old age. **Front, Psychol**, p. 10-856, 2019.

GÄRLING, T; BÖÖK, A; LINDBERG, E. Spatial orientation, and wayfinding in the designed environment: a conceptual analysis and some suggestions for post occupancy evaluation. **J Archit Plann Res**, p. 55–64, 1986.

GAZOVA, I. et al. Spatial navigation—a unique window into physiological and pathological aging. **Frontiers in Aging Neuroscience**, v. 4, 2012.

GBD 2019 DEMENTIA FORECASTING COLLABORATORS. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. **The Lancet Public Health**, v. 7, n. 2, 2022.

GOLLEDGE, RG. Environmental cognition. In: STOKOLS D, ALTMAN I (eds) **Handbook of environmental psychology**. Wiley, New York, 1987, p. 131–174.

GUTIERREZ, B. A. O. et al. Impacto econômico da doença de Alzheimer no Brasil: é possível melhorar a assistência e reduzir custos? **Ciência & Saúde Coletiva**, v. 19, n. 11, p. 4479–4486, 2014.

HARRIS, M. A.; WOLBERS, T. Ageing effects on path integration and landmark navigation. **Hippocampus**, v. 22, n. 8, p. 1770–1780, 2012.

HUIBERTS, S. **Light, space and mood**: How natural light in architecture affects mood and health. Amsterdam: University of Amsterdam, 2015.

IKEI, H.; SONG, C.; MIYAZAKI, Y. Physiological Effects of Touching Wood. **International Journal of Environmental Research and Public Health**, v. 14, n. 7, p. 801, 2017.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Pesquisa Nacional por Amostra de Domicílio Contínua** – PNAD Contínua, 2019.

IOSIFYAN, M.; KOROLKOVA, O. A. Emotions associated with different textures during touch. **Consciousness and Cognition**, v.71, n.1, p. 79-85, 2019. Disponível em: <https://www.researchgate.net/publication/332564189_Emotions_associated_with_different_textures_during_touch>. Acesso em: 8 mai 2022.

ISHIKAWA, T.; NAKAMURA, U. Landmark Selection in the Environment: Relationships with Object Characteristics and Sense of Direction. **Spatial Cognition & Computation**, v. 12, n. 1, p. 1–22, 2012.

JOSON, Jullia. "**Como Singapura está criando um ambiente urbano mais verde**". ArchDaily, 2022. Disponível em: <https://www.archdaily.com.br/br/977113/como-singapura-esta-criando-um-ambiente-urbano-mais-verde>. Acesso em: 25 ago 2022.

KAHANA, E. A congruence model of person-environment interaction. **Aging Environ Theor Appr**, p. 97–121, 1982.

KAPLAN, S. The restorative benefits of nature: Toward an integrative framework. **Journal of Environmental Psychology**, v. 15, n. 3, p. 169–182, 1995.

KELLERT, S. R. The biological basis for human values of nature. In: VALDÉS-PÉREZ, G. (ed.). **Ethical Land Use**: Principles of Policy and Planning. Baltimore: Johns Hopkins University Press, 2012.

KELLERT, S. R., HEERWAGEN, J. H., MADOR, M. L. Biophilic Design: The theory, Science, and practice of bringing buildings to life. **Revista John Wiley & Sons**, Inc., 2008. Disponível em: < https://www.researchgate.net/publication/284608721>. Acesso: 18 abr 2023.

KELLERT, S. R.; CALABRESE, E. F. **The practice of biophilic design**. 2015. Disponível em: <https://www.researchgate.net/publication/321959928_The_Practice_of_Biophilic_Design>. Acesso em: 15 abr 2023.

KELLERT, S. R.; HEERWAGEN, J.; MADOR, M. **Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life**. [s.l.] John Wiley & Sons, 2011.

KHALEGHIMOGHADDAM, N. et al. Neuroscience and architecture: What does the brain tell to an emotion experience of architecture via a functional MR study? **Revista Higher Education Press**, 2022.

KOSTERS, J. et al. Soundscape Awareness Intervention Reduced Neuropsychiatric Symptoms in Nursing Home Residents with Dementia: A Cluster-Randomized Trial With MoSART+. **Journal of the American Medical Directors Association**, v. 24, n. 2, p. 192-198, 2023.

KURT, S., OSUEKE, K. K. The Effects of Color on the Moods of College Students. **Jornal SAGE Open**, 2014.

LAWTON, M. The impact of environment on ageing and behaviour. In: SCHAIE, KW; BIRREN, JE. **Handbook of physiology of ageing**. Van Nostrand Reinhold, New York, USA, p 276–301, 1997.

LAWTON, MP; SIMON, B. The ecology of social relationships in housing for the elderly. **Gerontologist**, 8:108–115, 1968. Disponível em:<https://doi.org/ 10.1093/geront/8.2.108>. Acesso em: 15 set 2023.

LEI XIA, Y. P. **Neuroarquitetura**: Neurociência aplicada a espaços educativos. Trabalho final de Grado – Universidad Politécnica de Madrid, 2020.

LESTER, A. W. et al. The Aging Navigational System. **Neuron**, v. 95, n. 5, p. 1019–1035, 2017.

LITHFOUS, S; DUFOUR, A; DESPRÉS, O. Spatial navigation in normal aging and the prodromal stage of Alzheimer's disease: insights from imaging and behavioral studies. **Ageing Research Reviews**, p.201– 213, 2013.

LOPEZ, A. et al. The Effect of Aging on Memory for Recent and Remote Egocentric and Allocentric Information. Experimental Aging Research, v. 45, n. 1, p. 57–73, 2018.

MARQUARDT, G. Wayfinding for People with Dementia: A Review of the Role of Architectural Design. **HERD**: Health Environments Research & Design Journal, v. 4, n. 2, p. 75–90, 2011.

MARQUARDT, G; SCHMIEG, P. Dementia-friendly architecture: environments that facilitate wayfinding in nursing homes. **American Journal of Alzheimer's Disease & Other Dementias**, p. 333–340, 2009.

MINISTERIO DE DISEÑO. **Neuroarquitetura**: o poder de encontro sobre o cérebro. Editorial digital de tendências de arquitetura e design, 2020. Disponível em: <https://www.xn--ministeriodediseo-uxb.com/actualidad/neuroarquitectura-el-poder-del-entorno-sobre-el-cerebro>. Acesso em: 1º ago 2021.

MONTELLO, DR. Navigation. In: SHAH, P; MIYAKE, A (eds). **The Cambridge handbook of visuospatial thinking**. Cambridge University Press, Cambridge, p. 257–294, 2005.

MUFATO, V; MENEGHETTI, C; DORIA, S; DE BENI, R. The orientation of young and older adults' mental representations of their hometown with familiar and new landmarks. **Br J Psychol** 111, p. 762–781, 2020,.

O'CONNOR, Z. Color Design and Dementia: Harnessing HCI to Improve Environmental Visual Literacy. **Human–Computer Interaction Series**, p. 223–235, 2020.

O'MALLEY, M.; INNES, A.; WIENER, J. M. Decreasing spatial disorientation in care-home settings: How psychology can guide the development of dementia friendly design guidelines. **Dementia**, v. 16, n. 3, p. 315–328, 2016.

O'MALLEY, M; INNES, A; MUIR, S; WIENER, JM. All the corridors are the same': a qualitative study of the orientation experiences and design preferences of UK older adults living in a communal retirement development. **Ageing Soc** 38(9):1791–1816, 2017.

PAIVA, A. Neuroarchitecture and the role of emotions. **International Research Network Perception + Space**, 2018. Disponível em: < https://hub.salford.ac.uk/perception-space/2021/06/11/neuroarchitecture-and-the-role-of-emotions/ >. Acesso em: 22 abr 2023.

PAIVA, A. The role of the physical environment on memorization of experiences: perspectives and possibilities. Conferência: **ANFA SYMPOSIUM**, 2021.

PAIVA, A.; JEDON, R. Short- and long-term effects of architecture on the brain: Toward theoretical formalization. Frontiers of Architectural Research, p. 564-571, 2019. Disponível em: <https://doi.org/10.1016/j.foar.2019.07.004>. Acesso em: 4 mar 2023.

PATI, D. et al. The Impact of Simulated Nature on Patient Outcomes. **HERD**: Health Environments Research & Design Journal, v. 9, n. 2, p. 36–51, 2015.

PAZZAGLIA, F; MENEGHETTI, C. Acquiring spatial knowledge from different sources and perspectives: abilities, strategies, and representations. In: Zacks JM, Taylor HA (eds) **Representations in mind and world.** Taylor & Francis, New York, p. 120–134, 2017.

RODRIGUES, F. A. A. Neuroanatomia das cores. Ciencia Latina Revista Multidisciplinar, 2022. Disponível em: <https://www.ciencialatina.org/index.php/cienciala/article/view/1731/2448>. Acesso em: 10 mai 2022.

ROEHR, D.; BAILEY, S. G. **Gardens are... Buildings**: A Garden's Role in Unprecedented Times. Universidade de British Columbia – Vancouver, 2020.

ROTH, L. M.; CLAR A. C. **Understanding Architecture**. Its Elements, History, and Meaning. Terceira edição. Editora: Routledge, Londres, 2018.

SAFAR FARAJNIA et al. Evidence for Neuronal Desynchrony in the Aged Suprachiasmatic Nucleus Clock. **Journal of Neuroscience**, v. 32, n. 17, p. 5891–5899, 25 abr. 2012.

SALVADOR, I. R. Las 6 hormonas del estrés y sus efectos en el organismo. Artigo neurociência. **Psicología y mente**, 2021. Disponível em: <https://psicologiaymente.com/neurociencias/hormonas-de-estres>. Acesso em: 1º ago 2021.

SANTOS, E. de S. A.; CHUBACI, R. Y. S.; GUTIERREZ, B. A. O.; BORJA-OLIVEIRA, C. R. Prescrições inapropriadas para idosos entre usuários da atenção primária da zona leste do município de São Paulo. **Revista Kairós-Gerontologia**, [S. l.], v. 24, n. 2, p. 231–247, 2022. Disponível em: <https://revistas.pucsp.br/index.php/kairos/article/view/47326>. Acesso em: 20 out 2023.

SCHRÖDER-BUTTERFLL, E; MARIANTI, R. A framework for understanding old-age vulnerabilities. **Ageing Soc**, p. 9–35, 2006.

SERINO, S. et al. The role of egocentric and allocentric abilities in Alzheimer's disease: A systematic review. **Ageing Research Reviews**, v. 16, p. 32–44, jul. 2014.

SHAABAN, D. E. A.; KAMEL, S.; KHODEIR, L. **Exploring the architectural design powers with the aid of neuroscience**: little architect's adventure. Department of Architecture, Ain Shams University, Cairo, Egypt, 2023.

SILVA, L. C. DE M. A. et al. Use of Lavandula angustifolia essential oil as a complementary therapy in adult health care: A scoping review. **Heliyon**, v. 9, n. 5, p. 2023.

SOCIEDADE BENEFICENTE ISRAELITA BRASILEIRA ALBERT EINSTEIN. **Nota técnica para organização da rede de atenção à saúde com foco na atenção primária à saúde e na atenção ambulatorial especializada**: saúde da mulher na gestação, parto e puerpério, p. 56–56, 2019.

SOLÍS, J. HERRERA, V., El espacio físico y la mente: Reflexión sobre la neuroarquitectura. **Revista Caderno de Arquitetura**, 2017.

TOLMAN, EC. Cognitive maps in rats and men. **Psychol Rev**, 1948.

TUAYCHAROEN, N. Lighting to Enhance Wayfinding for Thai Elderly Adults in Nursing Homes. **Journal of Daylighting**, v. 7, n. 1, p. 25–36, 2020.

ULRICH, R. S. Biophilia, **Biophobia, and Natural Landscapes**. Universidade Técnica de Chalmers, Suécia, 1993. Disponível em: <https://www.researchgate.net/publication/284655696 >. Acesso em: 20 abr 2023.

VAN BUUREN, L. P. G.; MOHAMMADI, M. Dementia-Friendly Design: A Set of Design Criteria and Design Typologies Supporting Wayfinding. **HERD**: Health Environments Research & Design Journal, 2021.

VILLAROUCO, V. et al. **Neuroarquitetura**: a neurociência no ambiente construído. Rio de Janeiro: Rio Books, 2021.

VIOLA, D. Revisiting Canada's Most Hated Building. **Revista Azure**, 2017. Disponível em: <https://www.azuremagazine.com/article/rom-crystal-10-years-later/> Acesso em: 14 abr 2022.

WANG, S. et al. The Embodiment of Architectural Experience: A Methodological Perspective on Neuro-Architecture. **Frontiers in Human Neuroscience**, v. 16, 2022.

WIENER, J. M.; PAZZAGLIA, F. Aging- and dementia-friendly design: theory and evidence from cognitive psychology, neuropsychology and environmental psychology can contribute to design guidelines that minimize spatial disorientation. **Cognitive Processing**, v. 22, 2021.

WILSON, E. O. **Biophilia**. Cambridge: Harvard University Press, 1984.

WOLBERS, T.; HEGARTY, M. What determines our navigational abilities? **Trends in Cognitive Sciences,** v. 14, n. 3, p. 138–146, 2010.

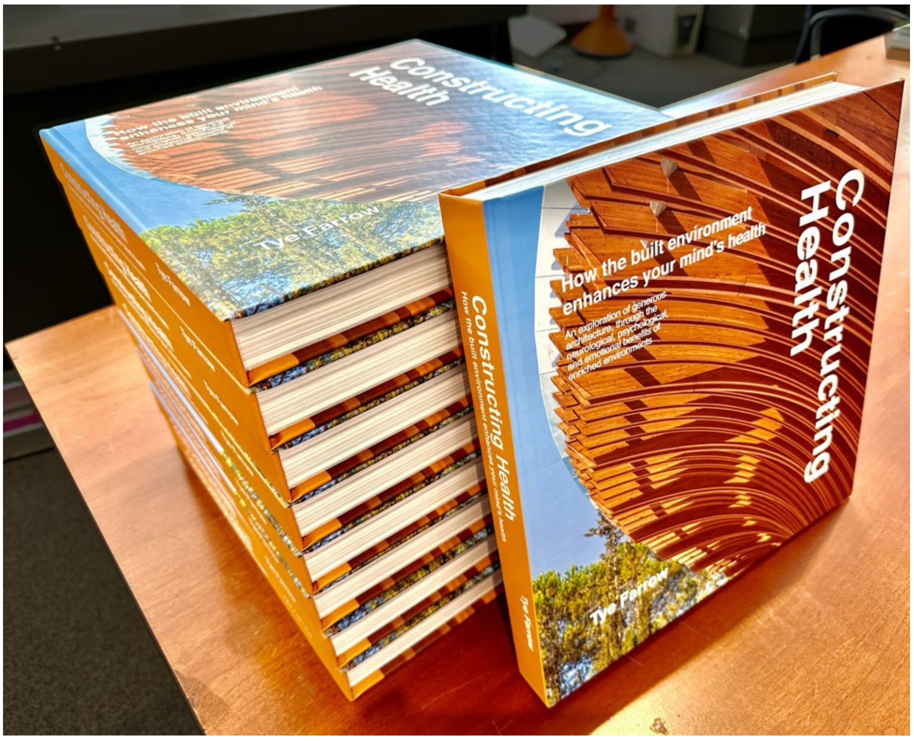
WOLKOVE, N. et al. Sleep and aging: 1. Sleep disorders commonly found in older people. **Canadian Medical Association Journal**, v. 176, n. 9, p. 1299–1304, 2007.

Revise

Constructing health – reflections and contributions to an enriched environment

Author

Marcio N. de Oliveira



Tye Farrow is a Canadian architect, graduated in 1987 from the University of Toronto, where he worked and later established his firm Farrow Partners. Since 2004, his office has been dedicated to the development of projects in health, education and housing, guided by a design sensitive to the local context and characterized by the use of natural materials and less environmental impact, notably exemplified by the undulating structures of engineered wood (mass timber) that mark some of his most recent projects.

With the release of his book Constructing Health, Tye Farrow shows us how concepts from studies on neuroscience and salutogenesis, among others, can offer a way to "build health through specific and measurable design qualities and characteristics" and thus improve human performance in settings like housing, schools, healing spaces, urban and social spaces.

Farrow begins his book as he usually does in his famous lectures, showing a series of thought-provoking phrases and questions, accompanied by equally impactful images, which include photographs of iconic locations and records of projects carried out by his office. In this section, the author not only seeks to draw the readers' attention, but also to invite them to reflect on the main themes that will be explored later. The text itself is structured in an unpretentious way, in the first person, emphasizing the experience of the architect himself, thinker of spaces, from the realization that the environments he designs influence in different ways the health of those who use them.

Based on studies conducted during a specialization in neuroarchitecture at the University of Venice (Italy), Farrow identifies the key elements to be observed to create what he calls "enriched environments." By arguing that the architecture of built spaces can either "promote" or harm health", especially mental health or, as he prefers it, the "mind health", the author offers a brief exposition on the main concepts, theories and definitions related to the interaction between the built environment and health. It is thus identified which of these concepts are gradually being adopted by contemporary designers with a brief explanation of each.

In the opening chapters, the author explores the workings of the human brain and mind, addressing their characteristics such as sensations, emotions, feelings, and perceptions. Often using the metaphor of food, Farrow argues that in addition to promoting health, an enriched architecture has the power to nourish the senses. The following are brief comments on the main concepts related to human health and well-being, highlighting their characteristics and variations in different geographical and cultural contexts over the last centuries.

Farrow points out that, throughout history, the concept of health has acquired different meanings, as in ancient Egypt, China, and among North American Indigenous Peoples. The author argues that we are now entering a "third era" of public health, characterized by a most comprehensive and holistic definition of health, according to the World Health Organization (WHO), which defines it as a complete state of physical, mental, and social well-being, not just the absence of disease.

The author then goes on to comment on the most current theories and concepts related to the person-environment relationship, with an emphasis on the concepts the sociologist Aaron Antonovsky presents in his well-known book Health, Stress and Coping, in which he develops the concept of salutogenesis, which proposed a paradigm shift to our approach: focusing on the causes of health instead of the disease (aka pathogenesis).

By stating that “architecture is never neutral”, Farrow develops the concept of an “enriched environment” characterized by having neuro-therapeutic qualities, which, in addition to satisfying functional and comfort aspects, stimulate creativity, facilitate social connections, and ultimately promote health in its most holistic sense. Moreover, he lists the various qualities of enriched environments, including generosity, variety and vitality, authenticity, hope, nature, silence, calm, solidity, and intimacy.

The author then lists the environmental qualities that have the effect of awakening the senses, such as sight, smell, sound, touch, and taste, relating these to the feeling of well-being in people. Farrow argues that we should prioritize the design of places that may enrich people’s lives through experiences and multiply their opportunities to stand out, connect, and improve their health and well-being.

Tye Farrow ultimately proposes a saluto-systemic approach to both the process and the formal ideas in the architectural design process. This type of perspective promotes, according to the author, transformative narratives, leading to healthy habits and behaviors for those who may have to spend time in hospitals and other health spaces, whether as patients, employees, or visitors.

In short, Constructing Health offers a captivating and transformative insight into the role of architecture in promoting human health and well-being, besides inviting us to think about the desirable variety of qualities so the environments we design, and build can nourish the senses, stimulate creativity, and strengthen social connections in a holistic view of health.

With over 300 images that illustrate Tye Farrow’s unique approach, this is a must-read for anyone interested in the power of design to improve people’s lives. The book is available in print in English on the website of the University of Toronto Press (https://utorontopress.com/) and on major online bookstores.

Interview with Tye Farrow

october 2023

Author

Marcio Oliveira

Marcio Oliveira Neuro-architecture is a fascinating and emerging field that explores the impact of the built environment on human well-being and cognitive function. Can you share some insights on how this field of study has influenced your design of healthcare settings to promote healing and well-being?

Tye Farrow In the early days of my career, designing hospitals, intuitively I began to understand how certain hospital environments made us feel, and how other made us feel – better – for both those that healed and worked there. And this began to influence how we could create high performance medical facilities, but also importantly human performance "healthy" environments. And health is the key word as it relates to humans, not "healthcare."

Today the word "health" has become synonymous with "healthcare." Debates over efficiencies, wait times, and delivery systems have obscured the much larger question of how to reduce overall usage of and dependence on medical services.

A Google search for "cause health" yields countless variations of "cause health problems," "cause health abnormalities," "cause health risks," and "cause ill health." Any positive search results on how we might actually create – or cause – health is absent from the online torrent of healthcare deficiencies and disease prevention tips. It appears we are living in a culture of negative health. No wonder the costs associated with keeping our society healthy have ballooned out of control.

If we wish to transform the culture of health and reduce its costs, we need to re-think hospital design. For this to happen, we need a saluto-systemic approach to both the process of designing and the formal ideas in architectural design – linked to mind health, and this perspective is at the intersection of neuroscience and architecture. This kind of perspective promotes transformative narratives, leading to healthy habits and behaviours for those who spend time in our hospitals as patients, staff, and visitors.

MO Mass-timber construction has been gaining popularity in recent years for its sustainability and aesthetic qualities. How have you integrated mass-timber materials into your projects, and what benefits do they offer in terms of patient experience and sustainability?

TF Certainly, the use of wood in terms of sustainability is great, as we try to de-carbon our hospitals, which are some of the worst building types in that regards.

But wood is remarkable, as it relates to human performance and outcomes, where there has been a lot of little-known research. Wood in healthcare/long term care facilities has a lot of physiological and psychological benefits:

-The material & immaterial benefits include significant impact on health outcomes.

-It is hypoallergenic, has antimicrobial properties, as well as sound absorption & low off-gassing.

-Collectively decrease negative physiological effects on occupants.

-On a neurobiological level, it supports the concept of Environmental Enrichment through all our senses: olfactory, tactile, visual & auditory influence on cognitive & physical health.

- Sensory intakes of wood derived olfactory, auditory, tactile, & visual stimulation resulted in a host of physiological benefits (Ikei, Song and Miyazaki.)

- Wood olfactory stimulation reduces blood pressure & cortisol levels.

- Auditory tapping of wood calms theta and beta waves in the brain.

- Wood in neonatal units: improved sleeping habits of newborns by +20%.

- Wood in long term care environments supports convalescence, inspire hope, measuring resident's subjective experience (Puuinfo, 2014).

MO Healthcare facilities often require a delicate balance between functionality, aesthetics, and patient comfort. Could you discuss some innovative design approaches or strategies you've employed to create healthcare settings that are both efficient and welcoming for patients and staff?

TF Three examples come to mind:

a Thunder Bay Regional Hospital Cancer Radiation Treatment Rooms

The cancer radiation treatment rooms of Thunder Bay Regional Hospital were the first of their type in Canada. Typically, cancer radiation treatment rooms (also known, in war-like jargon, as cancer "bunkers") are quite gloomy places with no natural light, but our treatment room design bring in direct sunlight from a carefully modeled skylight. While designing the rooms to control the radiation was technically challenging and had to meet the strict requirements of Atomic Energy Canada, the impact on the psychological well-being of patients and healthcare workers is enormous.

Radiation dissipates its energy, and as a result its harmful properties, exponentially. Therefore, in cancer bunker design, we can limit its spread by manipulating the distance it travels and the shape of the route it must bounce through. Additionally, when a patient receives treatment, the radiation machine focuses laser lights on pre-painted marks on the body that allow for the required precision treatment of the cancer. This requires a very low light level to ensure the lasers are visible.

To meet these requirements, we began to study art gallery designs that allow the penetration of natural light, in focused ways, on paintings that should be viewed in natural light but are also highly susceptible to damage from it. The team arrived at an authentic solution that brings the north light straight down, in a focused way, along a modeled wall that grabs the light as it penetrates the room, to illuminate a naturally planted garden below. This way the light raises and lowers in intensity with changing weather and seasons, while keeping the daylight focused on the foot of the treatment bed, where patients undergoing radiation therapy can see it.

Usually, when you enter a radiation treatment room you move through an entry maze that dissipates the radiation. Typically, when you reach the end of it, you turn a corner and find yourself looking directly at the seemingly over-scaled treatment machine, which can be a deflating experience. In the radiation treatment rooms at Thunder Bay, however, we flipped the machine around, so that when you enter you look past the machine to the sun-lit garden beyond, a simple but notable design breakthrough in cancer bunker design for the way it provides a sense of stillness, intimacy, and hope for patients and staff.

b High Performance COVID-19 Intensive Care Inpatient Units

To increase the chances of a better outcome, medical staff enrich the oxygen levels for COVID-19 patients, which allows their lungs to function at a higher level than would be possible without oxygen enrichment. Likewise, our design strategy for rapid assembly COVID-19 ICU patient wards explored the ability to both “enrich” a typical intensive care unit to achieve better outcomes for patients, and to help medical staff do their best work at a time when they are labouring incessantly under some of the worst medical conditions imaginable.

We began exploring how the physical space of a COVID-19 ICU ward could achieve solace for those caring or healing under very difficult conditions. Building on our work at the Thunder Bay Regional Hospital’s cancer radiation treatment rooms, where we applied daylight in treatment areas, we designed something similar as an accelerant for health and wellness outcomes.

The COVID-19 ICU inpatient unit is a simple rectangular form with twelve single patient rooms on three sides of the floorplate and staff support areas on the fourth. The centre of rectangle contains the medical staff care zone. Above this central area, we raised the ceiling to create a four-sided clerestory window-lined lantern, allowing daylight to illuminate staff work areas – a rare condition in most intensive care units.

For patients that need to face into the care zone for observation, windows at the back or side of their rooms would not provide much daylight and no view. However, the raised lantern provides direct views for ventilated patient lying in their beds – they can see out the windows above the care station, allowing them to feel part of the changing day/night cycles, seasons, and weather conditions.

Even for patients who may be unconscious at first, this contributes to improved outcomes. The effects of improved health through participation in the regular circadian rhythms of daylight have been well documented with premature babies in neonatal intensive care units. The salutary effects of proximity to a window and natural day/night light are similar for COVID-19 patients as they move from unconsciousness to semi-consciousness and finally consciousness again. Being able to sense or see the changing light conditions of a passing cloud, a sudden rainstorm, the warm afternoon sun, gentle moonlight, or dawn gives a sense of life, time, coherence, and hope.

c Embreathment, Embodiment, Environmental Enrichment, and Improved Oncology Outcomes in Israel's Newest Cancer Centre

The final example is at our recently opened Jerusalem cancer centre. We know today's medical spaces need to be designed to surpass mere technical medical treatments, to enhance the entire human experience. In 2013, Shaare Zedek Medical Center (SZMC), in Jerusalem, began designing a new flagship Cancer Center for Israel, by combining several fields of knowledge in creating an "enhanced" or enriched healthcare environment, which leverages scientifically grounded, multi-sensory, neuro-wellness interventions, to increase the full clinical human experience.

One's physical environment impacts mental and physical wellbeing, referred to as Environmental Enrichment (EE). Diamond and Rosenzweig showed that immersive physical environments can alter the biochemical milieu and neuroanatomical structure of the brain (#Rosenzweig). Furthermore, "embreathment", a relatively new concept in embodied cognition, is the representation of one's physiological breath, in immersive experiences, used to enhance presence and body awareness; examples include body scan meditation and progressive muscle relaxation.

Embreathment can be used to reduce claustrophobia and associated negative cognitions including feelings of restriction and suffocation, by enhancing agency, sustained hopefulness, and interoception, where one's ability to act is restricted.

In cancer centres, claustrophobia in MRI suites presents a significant psychological challenge in delivering optimal medical treatments. However, using the representation of one's breath to increase the sense of control has been shown to decrease one's sense of claustrophobia.

A unique aspect of the recently opened SZMC cancer centre builds on these principles, with scientifically grounded, neuro-wellness interventions based on pioneering, world-leading research in multisensory integration carried out in Prof Amir Amedi's Institute for Brain Cognition and Technology at Reichman University. Recent neuroscientific breakthroughs have uncovered new insights into the senses and the bidirectional effect of the mind on the body (top-down) and vice versa (bottom-up), such as one's perception of pain. Historically, pain triggered physicians to prescribe analgesics, yet chronic and acute pain are known to be complex phenomena, with a subjective veneer. Different people can experience the same physical nociceptive stimulus yet report differing levels of pain. Moreover, it is known that the senses influence our pain perception.

Amedi's lab has shown the overlaps between body representations, and areas related to high-order mental and emotional functions, (#Zeharia et al. 2019) whereby sensory information, such as pain, can be conveyed by alternative sensory modalities through sensory substitution, meaning that immersive experiences can reprogram the brain to bring about desired top-down influences.

For example, the use of external visual and auditory multisensory feedback immersive systems, that react to one's breath in real time, through a process known as embreathment, has been shown to induce mind-body sensory substitution, which modifies one's internal awareness.

In the new SZMC cancer centre, the CT simulator room served to explore these multi-sensory neuro-wellness treatment experiences. The room was designed with maximal sensory programming capabilities, enabling multisensory integration with respect to concomitant presentation of auditory, visual, and tactile cues, including: a curved, LED display "surrounding" the CT, with ambient lights extending the display's effect to the whole room; unique ambisonic audio system consisting of nine speakers, which allows for applying algorithms to localize sounds in space; and haptic interfaces along the beds surface.

Finally, sensors were integrated to create interactive experiences, enabling a dynamic interaction to one's own physiological signals through a personalized user experience. Reducing anxiety via localized sounds, representation of the user's breath for enhancing sense of control and body awareness, which guides the user to a desired, calmer breathing pattern, resulting in, among other things, a sense of hopefulness.

Projecting into the future, similar implementations would be constructed using human responsive technology, reactive lighting, and interactive kinetic architectural elements, in treatment rooms, waiting areas, and staff lounges, and eventually, applied to the entire range of the patient experience, beginning with the car park, through the main lobby, and all circulation routes. By the time the patient reaches the radiation treatment room, the patient's sense of agency – through an environmental enrichment journey, would be well underway leading to an enhancement of the whole human experience including hopefulness. Hopefulness is regarded as a scientifically-sound construct that is both cognitive and pragmatic (#Corn), building on Snyder's model for hope (#Snyder) based on an orientation around goals that are plausible as well as meaningful, known as "Hope Theory".

MO Farrow Partners has built a reputation for its work in healthcare architecture but has also worked with other themes. Can you share some examples of these projects you've worked on that you find particularly impactful or meaningful, and what challenges did you face in their design and implementation?

TF Internationally, indeed we are known primarily by our "healthcare" work, but as the book show examples of, we are very active in the city/urban design and knowledge/education zone. We have designed a few hospitals that have garnered international recognition for their thinking in this area. However, and while it may seem counter-intuitive professionally, I believe there are two questions we should collectively be asking. First, what would we need to do to "eradicate" hospitals as they are presently conceived, beyond the episodic events in life in which they are necessary, such as breaking an arm or the treatment of major illnesses? Second, what would we need to change in how our societies are structured and operate to enable this to occur? I believe we must move away from the idea of hospitals as "Centres of Excellence" in pathogenic healthcare, to that of salutogenic "Centres of Influence" that cause optimal health and well-being. Our health promoting Lifestyle Centres in South Africa are a good example of this thinking and resulting building typology.

In the structures of our present governments, health, what causes it, and the healthcare system, are siloed. We have ministries or departments of municipal affairs, housing, education, economic development, social services, and "health," yet optimal health results from the combined influence of where we live, work, learn, heal, and play, our forms of transportation, what we eat, our social habits and interactions with others, and our natural and built environments. This siloing must change if we are to create a transformational revolution instead of small, incremental improvements. We must not just work on preventive health strategies, such as immunization, antibiotics, and proactive screening tactics that keep bad things from occurring, but fundamentally move our gaze further upstream and turn our focus to what actively causes optimal health.

Our The Venice Archipelago Project in Venice, Italy is an example of city-making with a saluto-systemic approach to urban design and explores new research hypotheses in human and health-centered urban design strategies for complex urban systems and build strong person-to-place relationships by prioritizing the reverberation between inner space (individual) and outer space (environment) through the Theory of Constructed Emotion. The project is a previously unimagined, and practical way for Venice to address the "twin floods" of rising sea levels and mass tourism which have inundated the city with devastating effects over the last fifty years. How we can cause health' through the act of city making.

Also, our "Living Bridge Project" continues our interest in multi-use infrastructure in the Venice Archipelago master plan. In this instance, it explores using existing bridges to accommodate other uses, including reasonably priced housing in dense urban cities where available, affordable land is a scarce commodity; think of the Rialto Bridge in Venice or the Ponte Vecchio Bridge in Florence, which long ago combined infrastructure with human-scale, walkable, mixed-uses, thereby creating beloved urban environments and landmarks.

Vibrant cities around the world are facing urgent demand to offset an alarming side-effect of their success – a high quality of life that rapidly becomes inaccessible for people who are essential to nurturing healthy and resilient communities but can't afford to live there anymore. This includes nurses, schoolteachers, and police, among others, who must face long commutes from suburbs and exurbs because of unaffordable living conditions in the city itself.

Paired with this, we are seeing rising levels of mental health issues, specifically among those who live alone, young people, and seniors, due to growing levels of isolation in mind-numbing high-rise condominiums and apartment buildings. Many of the affordable projects being built also consist of only one age or socio-economic group, versus being multi-generational and economically and socially diverse, which creates more vibrant, helpful, and healthy communities.

The Living Bridge is a cost effective, micro-housing solution using modular, rapid assembly, lightweight building systems that emerged out of the automobile sector, which we have been involved in adapting to the construction sector.

However, the common theme in all our buildings, healthcare, and other “health-causing” buildings is an exploration of the following:

How do buildings make us feel?

How can they make us feel better?

Using research in the emerging intersection of neuroscience and architecture, we explore how our mind, and its various sensory systems, interacts with our built environment to enhance or harm health and well-being.

Although the biological brain is physically housed in the skull, recent research reveals that the mind, the brain’s operating system, extends through and beyond the body to engage with our surroundings. This raises urgent questions about the role of architecture and placemaking in creating mind health.

We are working to bridge the gap in knowledge between the therapeutic medical world and the design community to reveal how the intentional shaping of our environment can support our physical and neurological health and well-being. It draws on research in fields of sensory integration theory, environmental psychology, occupational psychology, human factor psychology, experimental psychology, cognitive neuroscience, and attention restoration theory, as well as related non-clinical areas of health enhancement that include biophilia, neurodiversity, sensory impact, neuroaesthetics, neuroarts, neurophenomenology, neuro wellness, environmental neuroscience, and neurourbanism.

Our projects explore recent discoveries in cognitive psychology (the science of the mind) and neuroscience (the science of the brain) on how we form salutogenic, health-giving, person-to-place relationships that are similar to healthy and meaningful person-to-person relationships.

Through the study and application of environmental enrichment, we can discover how we can intentionally design our environments to make them more generous and offer affordances that help us in our daily life. This not only reduces environmental damage but also enhances physical, societal, and mind health.

My new book Constructing Health: How the built environment enhances your mind’s health, attempts to offer an engaging and accessible way forward in how we can construct health through specific, measurable design qualities and characteristics which enhance human performance in the cities we live, the homes we dwell, the places we learn, and the spaces we heal.

IPH

INSTITUTO DE PESQUISAS HOSPITALARES ARQUITETO JARBAS KARMAN