Performance evaluation in healthcare buildings: a systematic literature review

Avaliação de desempenho em edificações assistenciais de saúde: uma revisão sistemática da literatura

Drielle Sanchez Leitner
Adriana de Paula Lacerda Santos

Abstract

Healthcare buildings are complex as their occupants may have different health conditions. In this context, building performance evaluations can help to achieve better performance perceived by occupants. Thus, this paper has developed a systematic literature review (SLR) on performance evaluation in healthcare buildings to understand their intrinsic characteristics, in addition to developing an overview of the subject. The objective was to identify the purpose of the evaluations, the criteria evaluated, the evaluation methods, the type of healthcare facilities evaluated, as well as the temporal and spatial distribution of papers. The research was conducted using three electronic databases, and eighty-three papers were examined according to the 5W1H tool. As a result, the buildings assessed covered health services at all stages of life, physical and mental issues. Six groups of criteria were identified, highlighting: spatial, lighting, acoustic comfort, energy issues, and the materials and finishes used. Moreover, relationships were established between the types of buildings, evaluated criteria, and tools used. Finally, the SLR collaborated with the understanding of performance in healthcare buildings, identified that these buildings are being evaluated, contributing to the health, well-being, and satisfaction of occupants as buildings that perform better tend to be better places of healing and work.

Keywords: Building performance evaluation. Healthcare. Literature review. 5W1H. Comfort.

Resumo

Edificações assistenciais de saúde são complexas pois abrangem ocupantes em diferentes condições de saúde. Nesse contexto, as avaliações de desempenho de edifícios podem ajudar a alcançar um melhor desempenho percebido pelos ocupantes. Assim, o presente trabalho desenvolveu uma revisão sistemática da literatura (RSL) sobre avaliações de desempenho em edificações assistenciais de saúde (EAS), visando compreender suas características intrínsecas e desenvolver visão geral do assunto. O objetivo foi identificar a finalidade das avaliações, critérios avaliados, métodos de avaliação, tipo de EAS avaliados, distribuição temporal e espacial das publicações. A pesquisa foi conduzida em três bancos de dados eletrônicos, e 83 artigos foram examinados com a ferramenta 5W1H. Como resultado, os edifícios avaliados englobaram serviços de saúde cobrindo todas as fases da vida, questões físicas e mentais. Foram identificados seis grupos de critérios, destacando-se: conforto espacial, luminoso e acústico, questões energéticas, materiais e acabamentos utilizados. Ademais, foram estabelecidas relações entre os tipos de edificações, critérios avaliados e ferramentas utilizadas. Finalmente, a RSL colaborou com o entendimento do desempenho em EAS, identificou que os EAS estão sendo avaliados, contribuindo com a saúde, bem-estar e satisfação dos ocupantes visto que edifícios com melhor desempenho tendem a ser melhores locais de cura e trabalho.

***Palavras-chave**: Avaliação de desempenho do edifício. Edificações assistenciais de saúde. Revisão de literature. 5W1H. Conforto.*

[1]**Drielle Sanchez Leitner**
[1]Universidade Federal do Paraná
Curitiba – PR – Brasil

[2]**Adriana de Paula Lacerda Santos**
[2]Universidade Federal do Paraná
Curitiba – PR – Brasil

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Introduction

Building performance evaluation (BPE) is a systematic and rigorous approach (MALLORY-HILL; PREISER; WATSON, 2012) that compares the real performance of buildings with explicitly documented criteria for expected performance (PREISER; VISCHER, 2005). As a goal, BPE aims to achieve a better building performance with better quality perceived by its occupants (PREISER; VISCHER, 2005) and contributes to more appropriate decision-making (MALLORY-HILL; PREISER; WATSON, 2012).

These objectives can be achieved by carrying out a cyclical assessment of a building, where information is transmitted continuously that contributes to better-informed design assumptions and better solutions (PREISER; VISCHER, 2005). Assessments can be used to identify and correct problems in individual buildings, and lessons from successes and failures of many studies can be used to inform the planning, programming, design, and management of future buildings. Thus, error propagation can be avoided (MALLORY-HILL; PREISER; WATSON, 2012).

BPE can cover a series of activities, which may include research, measurements, comparison, evaluation, and feedback, and happens at each stage of the life cycle of a building, comprising: planning, programming, conception (or project), construction, occupation, and recycling (MALLORY-HILL; PREISER; WATSON, 2012). BPE is a comprehensive approach applicable to all facility types encompassing relationships between the built environment, its occupants, or users, and their goals and needs (PREISER; VISCHER, 2005).

Regarding healthcare buildings, these relationships can become more complex due to their multidisciplinarity, which requires numerous technical and security requirements (PREISER; VISCHER, 2005), their size or specificity, professional performance processes at various levels of service, in addition to presenting industrial characteristics (laundry, nutrition service, transport, among others) (CARVALHO, 2014; DE GÓES, 2011). For Kendall (2019), more than any other type of building, hospitals are functionally diverse and technically complex. In addition, demographic changes, diseases, and their treatment, equipment, and regulations contribute to the need for a faster adjustment in the building's useful life (KENDALL, 2019).

In this context, developing performance evaluations in healthcare buildings becomes essential as many occupants may be in a situation of vulnerability in their health status, whether physical or psychological (patients and companions), and another large portion of the occupants uses the building for extended periods (employees), thus resulting in the need for a building that is suitable for all. Furthermore, the COVID-19 pandemic has had a worldwide impact and has influenced the construction sector and the built environment and has drawn attention to the healthcare facilities in contact with the virus.

Thus, due to the importance and complexity of health facilities, this research aims to build an overview of performance evaluation in healthcare buildings. It is intended to understand the historical context of this type of evaluation, identifying the temporal and spatial distribution of the BPE developed in this type of building, as well as other characteristics intrinsic to BPE's such as the tools used and the evaluated criteria, and possible relationships between these variables.

As a result, future designers and researchers will be able to better understand healthcare buildings and their performance needs. Thus, the material developed can help professionals make more assertive decisions and later in buildings with better performance and, therefore, in more suitable places to provide and receive healthcare.

In addition, the research fills a gap in terms of a complete understanding of healthcare building performance assessments covering not only the criteria but the overall functioning of the BPE. Thereby, this research can help improve the performance of healthcare buildings, both due to better-informed decision-making and the encouragement and understanding of conducting future BPE.

Research method

The method used for developing this paper was a systematic literature review (SLR), which allows researchers to keep well-informed of what has been studied in their areas of interest, providing a comprehensive view of the issue (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015). This method is being widely used in recent academic research (FENG *et al.*, 2020; KOMPIER; SMOLDERS; DE KORT, 2020; ROBERTS; ALLEN; COLEY, 2020; SUGIYAMA *et al.*, 2020) as it can minimize researchers' biases (KHALLAF; KANG; HASTAK, 2018).

To conduct the present SLR, the steps delimited by Dresch, Lacerda and Antunes Júnior (2015) were followed. According to the authors, the first step is to define the search terms, which should obtain results that fit the given objective. Following this logic, the search terms aimed to establish a connection between healthcare buildings with performance evaluations. The terms were divided into two categories, each one representing the subjects covered, as can be seen in Table 1.

The search was made seeking publications that mandatorily cited at least one of the terms of each category, related to each of the topics covered. For this purpose, the Boolean operator "OR" (conjunction indicating alternative) was used between the terms in the same category, and "AND" (conjunction indicating addition) between categories. Furthermore, the search was restricted to the location of the search terms in the title, abstract, and keywords of the documents and was not delimited by date.

Regarding the sources of the search, three different electronic databases, namely the platform Science Direct, Scopus, and Web of Science, were consulted. In addition, the SLR encompassed research or review articles, from journals and congresses, written in English or Portuguese. In the case of the Web of Science database, it was also necessary to select categories within the options provided by the platform. The selected categories were those related to engineering, architecture, construction, and multidisciplinary (civil engineering, construction building technology, environmental studies, management, engineering environmental, engineering sciences, green sustainable science technology, computer science hardware architecture, engineering multidisciplinary, architecture, acoustics, multidisciplinary sciences, ergonomics, ecology). Searches in the databases were carried out in February 2020. Table 2 shows the search settings by database.

Table 1 - **Definition of the search terms in two categories**

Category 1	Category 2
Building performance evaluation	Hospital
Post occupancy evaluation	Healthcare building
Post-occupancy evaluation	Emergency care unit
Pre occupancy evaluation	Outpatient department
Pre-occupancy evaluation	

Table 2 - **Search settings by database**

Electronic database	Search within	String – search terms	Article type	Language
Science Direct – advanced search	Title, abstract, keywords	(building performance evaluation OR post occupancy evaluation OR post-occupancy evaluation OR pre occupancy evaluation OR pre-occupancy evaluation) AND (hospital OR healthcare building OR emergency care unit OR outpatient department)	Review or research articles	-
Scopus - advanced search	Title, abstract, keywords	TITLE-ABS-KEY (("building performance evaluation" OR "post occupancy evaluation" OR "post-occupancy evaluation" OR "pre occupancy evaluation" OR "pre-occupancy evaluation") AND (hospital* OR "healthcare building*" OR "emergency care unit*" OR "outpatient department")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp")) AND (LIMIT-TO (LANGUAGE,"English"))	Article or conference papers	English (it was tested to add the Portuguese language, but no additional results were found)
Web of Science - advanced search	Title, abstract, keywords	((building performance evaluation OR post occupancy evaluation OR post-occupancy evaluation OR pre occupancy evaluation OR pre-occupancy evaluation) AND (hospital OR healthcare building OR emergency care unit* OR outpatient department))	Articles + proceeding papers + reviews + early access	Portuguese or English

After the first step was completed, which included defining search terms and other search definitions, other steps were also defined based on Dresch, Lacerda and Antunes Júnior (2015). Thus, continuing the SLR, all publications found were documented (step 2). Repeated publications and in languages other than those defined, were excluded (step 3). The title and abstracts of the publications were analyzed, considering those that could fit the proposed objective (step 4). Subsequently, the articles were thoroughly studied, evaluating whether they were pertinent to the central question of the research (step 5). This final step resulted in the selection of 83 papers, which had their information extracted contributing to the development of the research. The summary of results by step can be seen in Table 3. It is clarified that the papers included in this SLR were those that developed some type of BPE in healthcare buildings or even covered the subject theoretically.

It is noteworthy that it was chosen not to limit the SLR to papers with a certain stipulated quality level, but to encompass all publications that were consistent with the theme, regardless of their journal or means of publication, in order to include all available material. As for the means of publication, only three publications were from congresses (ADAMY; BAKAR, 2019; ÁMUNDADÓTTIR; LOCKLEY; ANDERSEN, 2013; VENTURA *et al*., 2018). In addition, the Health Environments Research & Design Journal (HERD) was the one that had the most publications identified, with 12 documents, followed by Building and Environment (6 publications) and Energy and Buildings (5 publications).

Concerning data extraction from the documents, an adaptation of the Who, What, When, Where, Why, and How (5W1H) method was used, which is the quality tool that can help identify intrinsic elements of a project, applied in recent publications and different contexts such as Lee *et al*. (2019) and Tang *et al*. (2019b). In the present study, however, the question Who, which could identify those responsible for conducting the assessment, for example, was not included. This choice was made as the publications themselves did not disclose information regarding the characterization of the researchers or those responsible for the research. In addition, there were two possible applications for the question What. To resolve this situation, it was chosen to add a Which question, resulting in a 5W1H tool adapted to the context in question. Table 4 shows the questions asked to extract data from the publications, as well as the information extracted to identify variables intrinsic to BPEs in healthcare buildings.

Results and discussion

In this step, the data extracted from the documents according to the 5W1H logic will be discussed. Table 5 shows the papers included in the SLR, as well as the type of healthcare establishment (when applicable), the location of the establishment, and the indication of the evaluation methods used in each survey.

Table 3 - **SLR steps and their results**

Step		Result		
2	Documentation of identified papers	270	Science Direct Scopus Web of Science	107 50 113
3	Exclusion of repeated papers and papers in other languages	222		
4	Title and summary analysis	112		
5	Full reading	83		

Table 4 - **5W1H analysis in BPE**

5W1H method categories	Questions regarding each category of the 5W1H method	Identified answer for each of the questions
When	When was the paper published?	Time distribution
Where	Where is the establishment located?	Spatial distribution
What	What types of healthcare buildings were evaluated?	Type of healthcare building
Which	Which items were evaluated?	Criteria
Why	Why are the criteria being evaluated?	Goal/objective
How	How are the criteria being evaluated?	Method / tools used

Table 5 – **Publications included in the SLR with the indication of the evaluated establishment and respective country, as well as the tools used (Continues...)**

What	Source	Healthcare facility evaluated	Site	Tools
Hospital	Adamy and Bakar (2019)	Hospital	Indonesia	Q
	Alzoubi, Al-Rqaibat and Bataineh (2010)	University Hospital	Jordan	A, E
	Bakowski (2017)	Hospital	Poland	E, M
	Calise *et al*. (2017)	Hospital	Italy	E
	Chiang *et al*. (2017)	Hospital	Taiwan	E, L
	Chen and Sanoff (1988)	General Hospital	USA	Q, O
	Ji and Qu (2019)	100 hospitals*	China	L
	Jing *et al*. (2017)	5 hospitals*	China	K, L
	Kavvadias, Tosios and Maroulis (2010)	Hospital	Greece	E, L
	Mahmood and Tayib (2019)	Two general hospitals*	Iraq	J, Q, M
	Mahmood and Tayib (2020)	2 hospitals*	Iraq	Q, M
	Meka, Navakazi and Pallaska (2017)	Regional Hospitals*	Kosovo	I, Q, M
	Reijula, Reijula and Reijula (2016)	Two university hospitals*	Finland	I
	Ruan *et al*. (2009)	Hospital	Japan	E, K, L
	Ryan-Fogarty, O'Regan and Moles (2016)	University Hospital	Ireland	L
	Santo (2014)	University hospital	Brazil	B'
	Silenzi, Priarone and Fossa (2018)	Hospital	Italy	E
	Tang, Ding and Lin (2020)	Hospital	China	A, Q
	Tang *et al*. (2019a)	General hospital	China	A, B, Q
	Tsoutsos *et al*. (2010)	General hospital	Greece	E, L
	Valentová and Bertoldi (2011)	13 hospitals*	Europe	L
	Vanhoudt *et al*. (2011)	Hospital	Belgium	B'
	Ventura *et al*. (2018)	Hospital pavilion	Italy	E, O, M
	Wang *et al*. (2011)	5 hospitals*	China	E
	Wu *et al*. (2014)	6 hospitals*	Japan	K, L
	Zheng *et al*. (2017)	Hospital	Shanghai	K, L
	Zheng, Wu and Zhai (2014)	Hospital	Shanghai	K, L
	Zuo, Yuan and Pullen (2011)	Hospital campus	China	I, L
	Sadatsafavi and Shepley (2016)	32 hospitals (children's hospitals, critical access hospitals, long-term care hospitals, psychiatric hospitals, rehabilitation hospitals, and others)*	USA	O
	Castro, Lima and Duarte (2015)	HIV Hospital	France	M, I
	Shepley, Bryant and Frohman (1995)	Women's Medical Center - Hospital	-	Q, I
	Yu *et al*. (2016)	Maternity hospital	China	Q

Note: *indication that more than one healthcare establishment was evaluated.
A - on-site measurements;
B - continuous monitoring;
B' - energy monitoring;
E – simulation;
G - literature review;
H – checklist;
I - interview;
J - application of available evaluation models;
K - mathematical model;
L - collected consumption, accounts, and other documents;
M - walkthroughs/on-site observations;
O - focal group;
Q - questionnaire; and
T - theoretical approach.

Table 5 – **Publications included in the SLR with the indication of the evaluated establishment and respective country, as well as the tools used (continued)**

What	Source	Healthcare facility evaluated	Site	Tools
Hospital + another facility	Alvaro *et al*. (2016)	2 hospitals and 1 Healthcare Center*	Canada	Q
	Barnes, Torrington and Lindquist (2016)	2 hospitals and a nursing home*	England	H, M
	Carbonari *et al*. (2015)	3 hospitals and two community clinics*	Italy	E, L, I
	Santamouris *et al*. (1994)	24 hospitals and 9 clinics*	Greece	Q, E, M
	Principi *et al*. (2016)	Three acute hospitals and two community clinics*	Italy	E
Healthcare facilities	Forcael *et al*. (2019)	5 healthcare centers*	Chile	I, E
	Liu *et al*. (2018)	Two healthcare facilities*	China	A, Q
	Naderi and Shin (2008)	Regional Healthcare Center	USA	Q, M, N
	Verderber and Refuerzo (1999)	Community health center	USA	Q, I, M
	Xuan (2016)	7 healthcare settings*	-	Q, I
	Xuan (2018)	6 healthcare facilities*	USA	Q, I
Pediatric	Abbas and Ghazali (2012)	Pediatric wards (3 hospitals)*	Malaysia	I, J, M
	Alzoubi and Al-Rqaibat (2015)	Pediatric ward (University Hospital)	Jordan	A, E
	Brown, Wright and Brown (1997)	Pediatric hospital	USA	I
	Ghazali and Abbas (2012a)	Pediatric wards (8 hospitals)*	Malaysia	Q, M, J
	Ghazali and Abbas (2012b)	8 pediatric wards (public hospitals)*	Malaysia	Q, M, J
	Sherman *et al*. (2005)	Pediatric cancer center	USA	A, Q, M
	Whitehouse *et al*. (2001)	Children's Hospital and Health Center*	USA	I, M
Patient and isolation room	Altizer *et al*. (2019)	Patients room	USA	Q
	Calama-González, León-Rodríguez and Suárez (2018)	2 hospital rooms	Spain	B, B’
	Cesari *et al*. (2018)	Hospital room	Italy	E
	Hill and Lavela (2015)	Patient rooms and nursing stations at 3 medical centers*	USA	A
	Tungjai and Kubaha (2017)	Single patient rooms - 11 hospitals*	Thailand	A
	Kim and Augenbroe (2013)	Hospital isolation rooms	-	E, K
	Wang and Kuo (2009)	Negative-pressure isolation rooms	Taiwan	O, M
Mental healthcare	Ámundadóttir, Lockley and Andersen (2013)	Healthcare facility - adult daycare center	-	E
	Kalantari and Snell (2017)	Mental healthcare facility	Canada	I, Q
	Ornstein *et al*. (2009)	Psychiatric facility	Brazil	I, Q, M, O
	Pink *et al*. (2020)	Mental Healthcare Facility	Australia	I, M
	Van Hoof *et al*. (2015)	Housing for people with dementia and hospital for psychiatric patients*	The Netherlands	E
	Van Hoof and Verkerk (2013)	Psychiatric hospital	The Netherlands	M

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T - theoretical approach.

Table 5 – **Publications included in the SLR with the indication of the evaluated establishment and respective country, as well as the tools used (continued)**

What	Source	Healthcare facility evaluated	Site	Tools
Hospital part	Guinther, Carll-White and Real (2014)	Hospital Emergency Department	USA	A, O, Q, M
	Hicks *et al*. (2015)	Hospital Endoscopy unit	England	M
	McCunn and Wright (2019)	Pharmacy unit in an urban hospital	Canada	Q
	Okcu *et al*. (2011)	Two intensive care units – Hospital *	USA	A, Q
	Samah *et al*. (2012)	Outpatient unit (government hospital)	Malaysia	Q, M
	Schaumann *et al*. (2019)	Outpatient ophthalmology clinic – 2 hospitals*	Israel	E
	Van Der Zwart e Van Der Voordt (2015)	Hospital nursing ward	The Netherlands	E
Others	Davis (2011)	Medical Center – physical rehabilitation	USA	I, Q, M
	Ferri *et al*. (2015)	Medical Centre intensive care unit	Canada	I
	Somboonwit and Sahachaisaeree (2012)	Emergency healthcare building	Thailand	E
	Schreuder *et al*. (2015)	Newly built nonpatient-related buildings (university medical center)	The Netherlands	Q
Theoretical	Brambilla and Capolongo (2019)	Literature review	-	G
	Brambilla, Rebecchi and Capolongo (2019)	Literature review	-	G
	Castro, Mateus and Bragança (2017)	Method	-	I, Q
	Connellan *et al*. (2013)	Literature review	-	G
	Nimlyat (2018)	Conceptual framework model	-	Q, K
	Nimlyat and Kandar (2015)	Literature review	-	G
	Paraskevopoulou and Kamperi (2018)	Literature review	-	G
	Wang, Mortazavi and Haghighat (2009)	Literature review	-	G
	Woon *et al*. (2014)	Theoretical	-	T

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H – checklist;
I - interview;
J - application of available evaluation models;
K - mathematical model;
L - collected consumption, accounts, and other documents;
M - walkthroughs/on-site observations;
O - focal group;
Q - questionnaire; and
T - theoretical approach.

When: time distribution

To construct a historical overview of papers, the publication dates in the SLR were not delimited. As a result, the time distribution ranged from 1988 to 2020, the year the SLR was developed. Regarding the publication dates, an increase can be observed in searches from 2009 with the highest peak in 2015 and again in 2019, with 10 publications each (Figure 1).

As for 2020, the search was conducted in the first quarter of this year, therefore the results show the partial quantity of publications. In addition, SLR steps were completed before the COVID-19 pandemic, which may have heightened concern about healthcare buildings, contributing to the development of more BPEs in this type of construction. The growing interest in the topic was also observed in Brambilla and Capolongo (2019).

Thus, it was observed that the topic has been discussed for at least 3 decades and was already on the rise before the pandemic. It can be expected that the peak of articles will grow even more, and the present SLR may enable the comparison between the study of healthcare buildings immediately before the COVID-19 pandemic and its influence on this type of study.

Where: spatial distribution and nature of publications

The study of the selected papers showed that the vast majority, about 90%, carried out applied research in some specific health building. Regarding the spatial distribution of these publications by continent, 26 papers developed studies in Asia, 24 in Europe, 17 in North America, 3 in South America, and finally 1 in Oceania (Figure 2). The country with the largest number of performance evaluations in healthcare establishments was the USA, with 13 papers, followed by China (8 papers) and Italy (6 papers).

This analysis identified gaps in BPEs in healthcare environments to be filled in regions such as South America, Oceania, and Africa. This indication may be related to the lack of knowledge on the topic, and this SLR contributes to this issue, as well as to failures in the local health system itself. Furthermore, the conduct of this SLR, identifying the study locations, allows benchmarks to be made between the indicated establishments. In this context, it is emphasized that the comparison of results through a benchmark is one of the objectives of a BPE, enhanced by SLR.

Furthermore, future research may relate the way in which the pandemic was faced with the concern about the performance of its healthcare buildings, showing that possibly an establishment that is concerned with the performance of its hospital building may have had more correct protocols about the pandemic.

Figure 1 - **Number of publications per year**

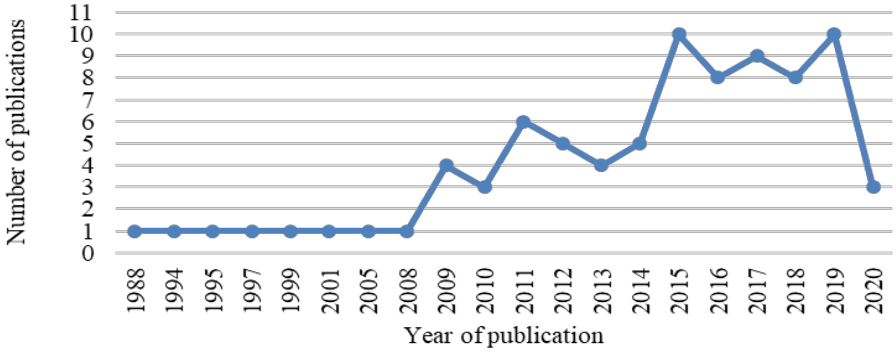
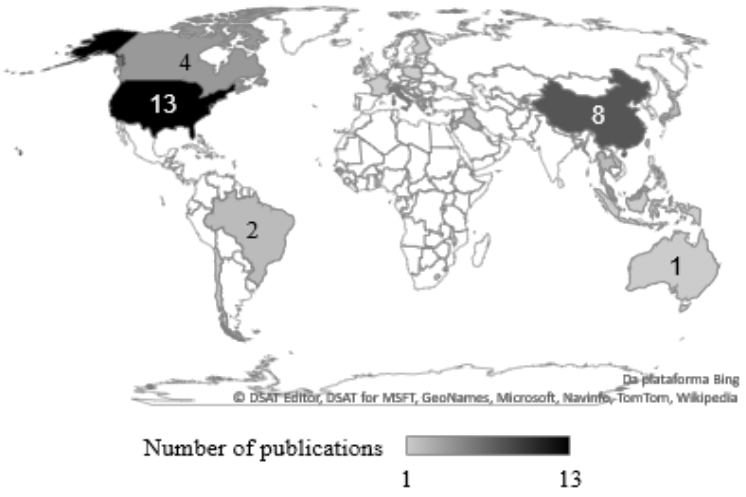


Figure 2 - **Spatial distribution of BPEs**



What: types of healthcare buildings

The number of buildings evaluated in each survey ranged from one building, or even a room or ward, to a hundred hospitals (JI; QU, 2019). In addition, 28 surveys chose to evaluate more than one healthcare facility, as indicated in Table 5. As for the types of healthcare buildings, from maternity hospitals to an adult daycare center were located, which shows concern with health and facilities, throughout all the phases of an individual's life cycle.

Hospital-type healthcare buildings were the most evaluated. About a third of the publications exclusively evaluated hospitals in general. In addition, other publications have also evaluated hospitals in conjunction with other types of healthcare buildings, several types of hospitals (SADATSAFAVI; SHEPLEY, 2016), or hospitals with a specific purpose, as dedicated to patients with HIV and maternities. In addition to hospitals, community health centers, and healthcare facilities, in general, were also found.

Other publications have evaluated some parts of the hospital as: patient rooms, pharmacy unit, nursing ward, intensive care units, outpatient unit, endoscopy unit, and outpatient ophthalmology clinic. Moreover, seven publications focused on pediatric buildings or wards, and six mental healthcare buildings evaluations were also identified in the review.

Besides that, some publications have evaluated establishments with a specific purpose of functioning such as emergencies and physical rehabilitation. One case also encompassed a nonpatient-related building of a university medical center (SCHREUDER *et al*., 2015), thus emphasizing the need to not only think about patients but also about service providers.

Finally, two publications stood out in the context of the COVID-19 pandemic as they developed evaluations in isolation rooms, which aims to control the airflow in the room so that the number of airborne infectious particles are reduced to a level that ensures cross-infection of other people within a health facility is highly unlikely (KIM; AUGENBROE, 2013; WANG; KUO, 2009). The types of buildings are also shown in Table 5.

How: evaluation methods

Regarding the assessment tools used, the most used one was the questionnaire, present in at least 30 surveys. In addition, the five-point Likert scale was the most widely used one considering the surveys that shared this information, followed by the seven-point Likert scale. It is noteworthy that the use of the same Likert scale between different research enables comparison of its results. Questionnaires were applied in different types of healthcare buildings. Among them, the patients' rooms were the ones that had the lowest use of the tool.

At least 23 surveys, about 28% of papers, carried out walkthroughs and on-site observations. The use of this tool has been identified in several types of health buildings. In the case of pediatric buildings, most of these buildings chose to use this tool. The use of walkthroughs in pediatric buildings, using visual scales, has already been validated when assessing pain in pediatric patients (SHERMAN *et al*., 2005), which may justify its use. The tool was also considerably used to assess psychological and physical comfort.

The third most used method was performance simulations, chosen by more than a quarter of the papers, including thermal, energetic, lighting, acoustic, and crowd simulations. Most of these were developed in hospitals. The choice of conducting simulations, mainly identified in hospitals, may be related to the complexity of these buildings, translating more adequately the various factors inherent to them.

Moreover, 19 papers opted for the development of interviews. Overall, the interviews were not widely used in hospitals and any inpatient room. They were conducted in pediatric buildings, mental healthcare facilities, and health centers, without any specific prominence. Moreover, 15% of papers used the collected consumption, accounts, and documents to evaluate the building. In this case, this evaluation method was used mostly in hospital buildings.

Thirteen publications opted to conduct on-site measurements or continuous measurements. The most evaluated criteria assessed by this method were quantitative criteria, such as: air temperature, relative humidity, lighting level, and sound level. Furthermore, specific criteria for healthcare buildings were also assessed through on-site measurements, encompassing the internal traffic and waiting time, as identified in Guinther, Carll-White and Real (2014). In the context of continuous measurements, research that monitored energy data was also identified (CALAMA-GONZÁLEZ; LEÓN-RODRÍGUEZ; SUÁREZ, 2018; SANTO, 2014; VANHOUDT *et al*., 2011).

Lastly, other methods of evaluation were also used, but to a lesser extent, such as focal groups, mathematical models, checklists, and theoretical approaches. Furthermore, four publications chose to use established BPE models, such as the AEDET (Achieving Excellence Design Evaluation Toolkit) and ASPECT (The Staff and Patient Environment Calibration Toolkit). Among these, three made use of the models in pediatric establishments.

Through the "How" section, the methods used to evaluate the performance of healthcare buildings were detected, identifying preferences between the tool and the purpose of the building. This information aimed to observe possible patterns, and thus helps to correctly choose the tools in future assessments, encouraging the conduction of BPE and benchmarking among its results. Table 6 shows the summary of the results for the "How" section.

Which and why: evaluated criteria and objective

During the development of this review, the criteria included in the performance evaluations were also identified. These criteria are related to the very purpose of the papers, as stated in Leitner, Sotsek and Santos (2020). Thus, this present topic aims to identify which items were evaluated and why they were evaluated. Thus, the criteria were grouped according to their affinity resulting in dividing them into six groups:

(a) comfort issues;

(b) spatial and visual issues;

(c) implantation and construction;

(d) health and staff issues;

(e) environmental and sustainability issues; and

(f) economic and social issues.

In total, more than 200 items were identified, many of them, however, with a low number of citations. Due to this situation, it was decided to highlight the main criteria for each group, citing, when adequate, other variables. The high number of items in assessing healthcare buildings confirmed the specificity and complexity of this type of buildings stated by Kendall (2019). Table 7 advances the results found in this stage, showing the groups of criteria, what types of healthcare buildings stood out in each group, in addition to the most evaluated criteria within the group, with their respective percentages and tools. The percentage shown in the table represents the relationship between the presence of the criterion with the total number of papers evaluated (83 papers).

Table 6 - **Evaluation methods identified, percentages and establishments of application**

Evaluation method – tool	Percentage	What type of establishment?
Questionnaire	36.14%	All types (low adherence in patient rooms)
Walkthroughs/on-site observations	27.71%	All types with high representativity in pediatric buildings
Simulation	26.51%	Hospital buildings
Interview	22.89%	Pediatric, mental healthcare facilities and healthcare centers (low adherence in hospitals and patient rooms)
On-site measurements / continuous measurements	15.66%	All types (not appearing in mental healthcare facilities)
Collected consumption, accounts, and documents	15.66%	Hospital buildings
Mathematical models	8.43%	Hospital buildings
Focal groups	7.23%	Several types
BPE models (AEDET and ASPECT)	4.82%	Pediatric facilities

Table 7 – **Groups of criteria and highlights of results**

Why	Comfort issues	Spatial and visual issues	Implantation and construction	Health and staff issues	Environmental and sustainability issues	Economic and social issues
What type of facility	All types (control of comfort linked to mental health concern)	All types (or even parts of the buildings)	Hospitals and general healthcare buildings	Pediatric and mental healthcare facilities	Hospitals and general healthcare buildings	Hospitals and general healthcare buildings
How - tools	Q, A, B, E, G, I	Q, M, I, G, E	G, E, Q	Q, I, G	E, L, K	G, T, K, Q

Which criteria - highlights

Why	Criteria	Percentage (%)	How - tool
Comfort issues	Noise satisfactory level	20.5	Q, I
	Natural lighting/ Daylight	19.3	Q, E
	Light satisfactory level	19.3	Q, I
	Comfort overall	14.5	Q
	Overall satisfaction	13.3	Q
	Thermal satisfactory level	12.0	Q
Spatial and visual issues	Layout/space planning	30.1	Q, M, I, G
	Safety and security	25.3	Q, G, I
	Wayfinding	24.1	Q, M, G
	Privacy	20.5	Q
	Accessibility	16.9	Q
	Ergonomics	16.9	Q, M, G
	Entrances/ Access	13.3	Q
Implantation and construction	Material and finishes	21.7	Q, E
Health and staff issues	Color	14.5	Q, M
	Awareness of the outside environment	13.3	Q, G
	Landscape	12.0	Q, M, G
Environmental and sustainability issues	Energy consumption	26.5	E
	Energy performance of the HVAC system	21.7	E
Economic and social issues	Investment Evaluation	12.0	Q, G

Comfort issues

The first set group comprises occupant comfort in general, encompassing environmental comfort, that is, thermal, acoustic, olfactory, and lighting issues in addition to their control, when suitable, and air quality. Correlating this group criteria with the types of health facilities, it was observed that they are intrinsic to all buildings. The result agrees with Leitner, Sotsek and Santos (2020) who indicated the presence of these issues in Post-Occupancy Evaluations (POE), regardless of the function of the building.

Table 8 shows the group divided into smaller plots, or subgroups, also presenting its criteria. The group was divided into subgroups due to the diversity of its criteria. The table also shows the global percentage of publications that included at least one item of that subgroup, as well as the global percentage of its most cited criterion and the tools that stood out in these assessments, both considering the total of 83 publications. In some cases, two or more criteria tied for the most evaluated criteria for that subgroup. Thus, the percentage of the criterion indicates the representativeness of each one of them.

As can be seen, the question of luminous comfort was the most present in the evaluations. As for the criteria individually, the most evaluated were satisfaction with lighting, natural lighting, and satisfaction with acoustics, each present in about 20% of the surveys.

The question of lighting was the most evaluated globally in Leitner, Sotsek and Santos (2020), reaching values above 70% of the surveys. In addition, the most representative criteria in each subgroup were also the most cited in this other SLR. Thus, there is a consensus on the most important comfort items to be evaluated. However, although the evaluation of these items is important regardless of the building use, these issues were not so present in health buildings.

Thus, the SLR found that the main issues related to comfort remain the same regardless of the function of the building. Despite this, in performance evaluations in healthcare buildings, due to their complexity, specificity, and the high number of criteria included, comfort items do not reach such great importance as in other buildings.

As a differential, items not found in other literature reviews (BRAMBILLA; CAPOLONGO, 2019; CASTRO; MATEUS; BRAGANÇA, 2017; LEITNER; SOTSEK; SANTOS, 2020), identified were: odor and odor sources (CONNELLAN *et al*., 2013; LIU *et al*., 2018; MAHMOOD; TAYIB, 2020; VAN HOOF *et al*., 2015; TANG *et al*., 2019a); noise from colleagues and other than colleagues (XUAN, 2016, 2018).

The concern with the control of at least one comfort variable was present in almost 20% of the publication. Criteria included were control over lightning, noise, heating, cooling, and ventilation and the importance of occupant control over these criteria (XUAN 2016, 2018). In this context, it was observed that there was a relationship between comfort control and the search for a psychologically healthier environment, even in healthcare buildings without this specific purpose (CONNELLAN *et al*., 2013; MAHMOOD; TAYIB, 2019, 2020).

Table 8 – **Comfort issues subgroups, criteria, and respective percentages and tools used**

Subgroup	Which criteria is being evaluated? (in bold the most evaluated criterion - with possible ties)	Percentage of subgroup and the most evaluated criterion (%)	How: most used tools (in bold, the tool that was most used when applicable)
Luminous comfort	Illumination level, Natural illuminance, Solar radiation level, Lighting electrical consumption (artificial), Light electrical intensity, **Light satisfactory**, **Natural lighting / Daylight**, Natural lighting glare, Artificial lighting, Artificial lighting glare, light pollution	Subgroup: 37.35 Criterion: 19.28	**Q**, **A**, B, E, G, I
General comfort	**Comfort overall**, Well-being, Overall satisfaction, Optimism and cheerful environment, Recommendation to others	Subgroup: 28.92 Criterion: 14.46	**Q**, I, G
Thermal comfort	Air temperature, Outdoor temperature, Ventilation, Temperature ranges, Thermal sensation, Temperature overall in summer/ winter, Temperature stability in winter/ winter, **Thermal satisfactory level**	Subgroup: 28.92 Criterion: 12.05	Q, A, B, G, E, I
Acoustic comfort	Sound level, Noise sensation, **Noise satisfactory level**, Noise from inside, Noise from outside, Noise from colleagues, Noise from people other than colleagues, Noise sources, Reducing noise pollution	Subgroup: 26.51 Criterion: 20.48	**Q**, I, A, G
Air quality	**Relative humidity**, Outdoor air change rate (CO2 concentration), TVOC concentration, PM 2.5 concentration, Air freshness, Air cleanliness, Air quality, Air humidity	Subgroup: 24.10 Criterion: 10.84	Q, A, B, E, G, I
Control of comfort	**Control of comfort**, **Control over heating**/ **lightning**/cooling/ventilation/ noise, Importance of control over heating/lightning/cooling/ ventilation/noise, window opening sensor	Subgroup: 19.28 Criterion: 8.43	**Q**, I, G
Olfactory comfort	**Odor**, Odor sources	Subgroup: 6.02 Criterion: 6.02	**Q**, G

Spatial and visual issues

The second identified group consisted of criteria that aimed to study spatial and visual issues. This subject had greater representativeness in the present SLR regarding healthcare buildings than in an SLR that also considered other types of buildings (LEITNER; SOTSEK; SANTOS, 2020). Within this scope, the most evaluated items were layout and space planning, present in more than 30% of the surveys, and wayfinding, present in almost a quarter of the surveys, as highlighted in Table 7.

Moreover, the evaluation of ergonomics and accessibility, issues related to space, was carried out in 14 surveys each. In this regard, physical, sensorial, and cognitive support was also identified (ALTIZER *et al.*, 2019; BARNES; TORRINGTON; LINDQUIST, 2016; BRAMBILLA; REBECCHI; CAPOLONGO, 2019; CONNELLAN *et al.*, 2013; MAHMOOD; TAYIB, 2020).

The group also covered:

(a) architecture and design;

(b) building aesthetics;

(c) entrances and accesses;

(d) safety and security, present in more than 25% of the surveys; and

(e) privacy, which was part of more than 20% of the articles.

In addition, the group presented the largest number of criteria with an elevated frequency of evaluation.

Moreover, the concern with spatial comfort and visual issues was not exclusive to a type of healthcare building. Thus, it is understood that spatial comfort is a primary issue for the occupant, regardless of the health service provided and the size of the building. As for the tools used for these assessments, questionnaires, interviews, and walkthroughs were identified, in addition to the presence of the subject in literature reviews.

The present results showed that, in the application of a BPE in healthcare environments, spatial issues can be prioritized. This information is intended to help with decision making considering a performance evaluation that can become extensive and complex given the large number of items included. Thus, the aim is to encourage the conduct of BPEs by identifying the most crucial items.

Implantation and construction

The third group of criteria was related to the implementation and construction of buildings and includes various items such as land use and occupation, materials and transport, comprising more technical items.

Within this group, the most cited item was materials and finishes, present in more than 21% of the surveys, standing out globally in the evaluations. The following was also included in this group:

(a) the building's implantation location;

(b) the proper use of the land and topography;

(c) distances traveled by users to access the building; and

(d) accessibility to public transport.

Thus, it can be seen that the group encompasses both issues of constructive choices and the location of the establishment. These items were part of the evaluation, mostly, of general-purpose health buildings, such as hospitals and healthcare centers.

Moreover, particularly important issues in healthcare buildings are related to space flexibility and space adaptability, especially in buildings for multidisciplinary use such as hospitals and healthcare centers (BRAMBILLA; CAPOLONGO, 2019; CASTRO; MATEUS; BRAGANÇA, 2017; REIJULA; REIJULA; REIJULA, 2016; VERDERBER; REFUERZO, 1999; XUAN, 2018). In this context, the use of prefabricated and modular building systems can be an ally (BRAMBILLA; CAPOLONGO, 2019) in addition to the reservation of space for reconstruction due to the increase or decrease of functions (ALTIZER *et al*., 2019; CALISE *et al*., 2017).

Finally, in addition to the highlighted criterion already mentioned, the group did not obtain other criteria with high evaluation incidence. This situation may indicate a gap in performance appraisals in covering all phases of the building's lifecycle.

Concerning the tools, the highlights were the simulations, used to evaluate the choice of materials, in addition to questionnaires and the identification of the subject in the literature reviews.

Health and staff issues

Some items stood out for being linked to the function provided in the building, constituting a group formed by criteria that sought a healing environment, health, and staff issues. These included issues related to service providers and to health services themselves, such as: the building's ability to reduce medical errors (CONNELLAN *et al*., 2013; KALANTARI; SNELL, 2017; SCHAUMANN *et al*., 2019) and positively influence the Length of Stay (LOS) (CONNELLAN *et al*., 2013; GHAZALI; ABBAS, 2012b; KALANTARI; SNELL, 2017; PINK *et al*., 2020; SCHAUMANN *et al*., 2019; SHEPLEY; BRYANT; FROHMAN, 1995); the suitability of the building for health services; and, opening hours (SOMBOONWIT; SAHACHAISAEREE, 2012; VAN HOOF *et al*., 2015).

Moreover, regarding the work functions of the team, the surveys assessed the building's ability to influence productivity and job satisfaction. It is emphasized that, among the items related to the operation of healthcare buildings, once again, those related to the occupant's spatial comfort can be mentioned, such as: staff space, including changing room, break room, workspace, overnight space, and family support area.

Furthermore, items that could contribute to a healing environment were identified, such as the presence of music, color and texture, arts, pet therapy, and aromatherapy. Among these, the most evaluated item was

color and texture, evaluated in almost 15% of the surveys. The items can be justified since, according to Brambilla, Rebecchi and Capolongo (2019), music can reduce patients' anxiety, and the correct choice of colors and textures can also positively influence the patient's recovery, assisting in the composition of a healing environment. Overall, almost 20% of surveys covered at least one item that could contribute to this issue. The search for a healing environment stood out in buildings that sought better mental quality for its occupants and were also part of the emergency, pediatric, and maternity facilities evaluations.

This group also incorporated the connection of the occupant with nature, the importance of being outside, the outdoor view, and the landscape, as healing gardens can also contribute to a healing environment. The subject had a significant presence among theoretical publications, such as literature reviews, and in those that valued the comfort of patients and staff satisfaction (ALVARO *et al*., 2016; NADERI; SHIN, 2008; PINK *et al*., 2020).

The group also included items that could assist, even partially, in the spread of contagious diseases such as the COVID-19 pandemic, especially hygiene and cleanliness. These, however, were found together in about 12% of the surveys, a number similar to that found by Brambilla and Capolongo (2019). The issue of hand hygiene (ALTIZER *et al*., 2019), infection control (CASTRO; MATEUS; BRAGANÇA, 2017), and air decontamination (ALTIZER *et al*., 2019; KIM; AUGENBROE, 2013; WANG; MORTAZAVI; HAGHIGHAT, 2009) were also found exactly. These items were also part of the evaluation, mostly, of general-purpose health buildings, such as hospitals and healthcare centers. Regarding this situation, due to the COVID-19 pandemic, it is expected that future reviews will register a greater number of evaluations regarding the cleanliness and hygiene of the establishments. Future BPEs may even encompass post-pandemic protocols regarding these items.

Environmental and sustainability issues

Items related to the sustainability of the building were also found, constituting the fifth group of criteria, which included:

(a) heat island effect;

(b) green rating tools;

(c) construction waste;

(d) waste management, separation, and storage;

(e) assessment of the building's life cycle impact;

(f) the use of passive systems;

(g) reuse products and recycled materials;

(h) environmental management plan; and

(i) the most included these items, CO_2 emissions, present in less than 10% of papers.

Two current articles stood out in this context: Brambilla and Capolongo (2019) and Castro, Mateus and Bragança (2017). Both publications also included the management of water use in their scopes.

Furthermore, the energy issue was widely addressed in the evaluation of healthcare buildings. A value greater than 37% of the papers included an item within this theme, which could be: energy consumption, energy efficiency, energy performance of the HVAC system, alternative energy sources, and local energy production. These items were part of the evaluation of general-purpose health buildings, such as hospitals and health centers, showing that the greater the complexity and size of the building, the greater the concern with this issue. In addition, within the energy context, mainly, the use of simulation tools, mathematical models, and collected consumption, accounts, and other documents, can be mentioned.

The results showed that the issue of sustainability is mainly linked to the energy issue and large health buildings. These results may indicate a greater concern with issues of building cost, or its economic sustainability, than with issues of environmental sustainability. Furthermore, it was shown that smaller buildings still need to be made aware of sustainability.

Although environmental sustainability may not be considered as important in health buildings, it can contribute to other items such as the occupant's connection to nature, thus becoming a factor in the search for a healing environment.

Economic and social issues

The last group of identified criteria aimed to complete the spheres of economic and social sustainability. In this context, the criteria identified were: investment evaluation (which aims to assess whether the project makes economic sense), costs, innovation and research, local priority, and cultural issues, such as the development of the local community, cultural value, and heritage framework. This group was the least present in the evaluations, showing a possible gap in the search for the social and economic performance of the building. The most cited criterion was the one referring to investment evaluation, having been evaluated in 10 papers. The presence of these items was found mostly in literature reviews and theoretical approaches. In addition, the investment return calculation was also conducted.

Despite not being as representative, the group's items are important and are part of current research such as Awada et al. (2020), which reports the impact of socioeconomic status on occupant health in addition to the economic impacts of unhealthy buildings. Another issue addressed on a small scale was innovations in healthcare buildings (BRAMBILLA; CAPOLONGO, 2019; FERRI *et al*., 2015), an issue also present in Awada *et al*. (2020), which highlighted the potential of emerging technologies to assist in healthy construction, which may even help in the context of the COVID-19 pandemic.

Conclusions

This article aimed to provide an overview of performance evaluations in healthcare buildings to understand their characteristics, encourage and assist in decision-making for future evaluations. This was accomplished by conducting an SLR, in which 83 papers concerning the subject were found. Thus, the number of BPEs developed in this type of building was considerable, in other words, this type of building is being assessed.

In addition, the date of the publications showed that this type of study has been developed since 1988 and may be on the rise. Furthermore, considering the COVID-19 pandemic, attention to this type of building, and the indoor environment in general (AWADA *et al*., 2020), tend to be even greater. The spatial distribution of papers drew attention to the large concentration of publications in Asia, Europe, and North America, showing a possible gap in research and conducting BPE in other continents, setting up an opportunity for future research.

Regarding the type of healthcare buildings evaluated, hospital-type healthcare buildings were the most frequently assessed. In addition, the buildings assessed covered health services at all stages of human life as well as both physical and mental health problems. However, some types of health buildings were found in a few surveys, which may represent a gap. Outpatient areas, for example, are understudied (EIJKELENBOOM; KIM; BLUYSSEN, 2020). Thus, this study drew attention to the importance of smaller healthcare buildings that may assist the daily healthcare system of a population, identifying a gap for future research and BPE.

As for the tools used in the evaluations, although it was better distributed than in Leitner, Sotsek and Santos (2020), the questionnaire remained the most chosen option. Beyond that, the use of this tool permeated all types of healthcare buildings and their different types of criteria. In contrast to the decrease in the frequency of use of the questionnaires, there was an increase in walkthrough conduction, which was the second most used tool, in addition to the considerable number of performance simulations, which occupied the third place of the most used tools.

Regarding tools, the use of performance simulations, physical measurements, and collected consumption, accounts, and other documents, was chosen preferentially to evaluate hospital-type healthcare buildings. On the other hand, the use of walkthroughs was emphasized in the evaluation of pediatric buildings. Moreover, more than half of the studies used multiple methods in the development of BPEs. On this issue, the adoption of multiple methods, qualitative and quantitative, can contribute to a result that is closer to reality (BORDASS; LEAMAN; ELEY, 2006; XUAN, 2016). Furthermore, almost 34% of publications chose to evaluate more than one building, which may also be contributing to better results.

The number of criteria identified in the evaluations was over 200. This may be related to the heterogeneity of the occupants and their respective needs, thus, with the high complexity involved in these buildings, as stated by Kendall (2019). For a better understanding of the criteria, and the evaluations themselves, they were divided, according to the affinity of subjects, into six groups:

(a) comfort issues;

(b) spatial and visual issues;

(c) implantation and construction;

(d) health and staff issues;

(e) environmental and sustainability issues; and

(f) economic and social issues.

The issue of spatial comfort was the most present in the evaluations, regardless of the health service provided, thus, the great importance of space in healthcare buildings was understood. The issues related to occupant comfort, especially its luminous, acoustic, and thermal comfort, were also present in many papers. In the case of the groups "Implantation and construction" and "Environmental and sustainability issues", each one stood out for specific items with great adherence in research. In the first, the item "Material and finishes" was the highlight. In the second, energy issues were evaluated in more than 37% of the surveys, which was one of the main points evaluated globally.

The other two groups, "Health and staff issues" and "Economic and social issues", had their criteria evaluated in a smaller number of publications, mostly in hospital-type and general healthcare buildings. Despite this, the presence of the latter group characterized the search for not only environmental concerns but also economic, and social concerns, thus encompassing the three pillars of sustainability, and therefore the concept of sustainability itself. This was a differential found in this research when compared to the SLR developed by Leitner, Sotsek and Santos (2020) on POE, which did not mention economic or social items. This can be justified as BPEs can cover all phases of the building's life cycle and are able to better encompass the spheres of sustainability and, therefore, predict possible failures and improvements. Furthermore, the matter showed the originality of the present research given its wide scope. The criteria that make up the social and economic pillars may represent a gap in BPE that can be filled by future research and evaluations.

In addition, other criteria are also connected with building phases other than post-occupation. This is the case of the criteria of the "Implantation and construction" group that focus on decisions made during the planning, programming, and conception stages. Regarding the stages of the building life cycle, Roberts, Allen and Coley (2020) cover the influence of the building phase on its performance, showing that the first stages may be those that could most influence performance. Therefore, it is necessary not only to evaluate the building in a phase but to think about its performance since its conception. Thus, it can also be seen that the high number of criteria identified is related to the large scope of BPEs.

Regarding the relationship between the type of healthcare building and the evaluated criteria, it was observed that the concern with the occupants' mental health may be related to the presence of criteria related to the healing environment and the control of comfort by the occupant. The criteria that characterized the search for the healing environment were also part of the pediatric buildings. It is noteworthy that the relationship between occupant-controlled parameters and mental health was also reported in Hoisington *et al*. (2019). Moreover, comfort issues, space, and visual issues were present in all types of healthcare buildings identified.

In addition, the SLR highlighted the importance of personalizing the BPE according to the specific function of the building, identifying the specificities of healthcare buildings. In this context, it can be understood that the notion of occupant comfort may vary according to its purpose in this building and may differ if the occupant is at leisure in a building, seeking a service, or providing a service.

Finally, this research was able to develop an overview of performance assessments in healthcare buildings, showing their distribution in time and space, their typical characteristics, and the relationships between variables. This is expected to help understand the issue and the development of future BPEs, thus contributing to better functioning buildings. In the context of the COVID-19 pandemic, we also aimed to draw attention to the potential of healthcare buildings to help, even partially, in the issue. Based on this knowledge, future research will be able to compare concerns about the performance of healthcare buildings before and after the COVID-19 period.

All things considered, conducting performance evaluations in healthcare buildings is of great importance and should be encouraged, as done by this review, since buildings that perform better tend to be better places of healing for their patients and work for their staff as well-designed facilities can "[…] help patients feel better and staff work efficiently and effectively in delivering health services […]" (PREISER; VISCHER, 2005, p. 51).

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Drielle Sanchez Leitner
Programa de Pós-Graduação em Engenharia Civil, Centro Politécnico | Universidade Federal do Paraná | Rua Evaristo F. Ferreira da Costa, 369-377, Jardim das Américas | Curitiba – PR – Brasil | CEP 81531-980 | Tel.: (41) 3361-3445 | E-mail: drielle.dsl@gmail.com

Adriana de Paula Lacerda Santos
Programa de Pós-Graduação em Engenharia Civil, Centro Politécnico | Universidade Federal do Paraná | E-mail: adrianapls@ufpr.br

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Revista da Associação Nacional de Tecnologia do Ambiente Construído
Av. Osvaldo Aranha, 99 - 3º andar, Centro
Porto Alegre – RS - Brasil
CEP 90035-190
Telefone: +55 (51) 3308-4084
www.seer.ufrgs.br/ambienteconstruido
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