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Review

Healthy and Sustainable Hospital Evaluation—A Review of POE Tools for Hospital Assessment in an Evidence-Based Design Framework

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Abstract: Hospitals are complex, high-performance systems that demand continuous quality improvement. Several instruments evaluate the organizational or clinical qualities but very few focus on the built environment. The purpose of this paper is to compare and review the recent tools able to assess the hospital built environment and test how they measure health, sustainability, or both through Post Occupancy Evaluation (POE). A literature review has been conducted in the field of hospital quality assessment and 13 POE instruments have been included and analyzed through Ulrich's Evidence-Based Design (EBD) framework. The percentage and the content of health or sustainability-related criteria have been compared and further discussed. Health related criteria the most recent tools are used three times more than in the tools developed in the nineties. The most used EBD criteria are safety enhancement (n = 131; 14%) and visual environment (n = 119; 13%). Although sustainability remains a relevant issue, today, growing attention is dedicated to the impact of built environment on occupant's health. Further investigation is needed to understand the effectiveness of those instruments in practice.

Keywords: evidence based design; post occupancy evaluation; assessment tool; hospital; built environment; quality

1. Introduction

1.1. Physical Environment Assessment and POE

Several tools and methodologies have been developed to assess the qualities of the physical environment. This happened because of the growing awareness of the benefits that a good physical setting can give to occupants and stakeholders [1]. A very effective and well-structured approach is Post Occupancy Evaluation (POE), defined as the process of systematically comparing actual building performance after completion and occupation [2,3]. This approach of obtaining feedback about a building's performance looks at the architecture not only from the aesthetic point of view, but also with concerns from social and behavioral fields by comparing building performances with explicit human needs [4]. It can be used for several reasons, such as to verify if the results meet the intended organizational goals and user-occupant expectations. POE can be also seen as a strategy to make buildings more sustainable [5].

The social research applied to architecture with focus both on the space and on the users started to be used by American psychologists at the end of the 50s with the beginning of the environmental psychology field and was encouraged in the architecture as being in contrast with the rationalism of the modern movement and, in the 60s and 70s, started to be applied within the overall design process [6]. During the 80s, POE evolved into a more performance-oriented approach overlapping

with the concept Building Performance Evaluation (BPE) [1,7]. In more recent times, the concept is well established among academics but is still a challenging process in practice. Indeed, in empirical research, it is possible to use an ad-hoc POE protocol, but in the market world, certifications with standard items are more diffused and, today, several tools have a specific version able to assess the POE phase of a project [8].

1.2. Assessing Hospital Built Environment: Yesterday, Today, and Tomorrow

POE is very well diffused in residential and office buildings [1,9] but it is important to mention that its first applications were on healthcare facilities [10]. Moreover, a very famous POE program is the one instituted by the Federal Department of Health and Welfare in Canada in conjunction with the provincial health authorities to evaluate all the Canadian hospitals [11]. POE of medical buildings is quite difficult due to the intrinsic characteristics of an hospital—the variety of users, the strict regulations on sanitary issues, and the complexities of the "in-use" phase [12]. Recent studies highlight a lack of research in this direction [1,13]. Nevertheless, the hospital environment can be very interesting for three main reasons:

1. Looking at the Scopus database, there is a growing interest in the topic which could lead to a subfield of POE [5,14]. Indeed, in recent times, up to 22 papers were published each year, as shown in Figure 1.
2. It is important to note that within the hospital design and evaluation research field, a theoretical model is available to assess the impact of physical environment on user's health outcomes based on evidence. Those topics, some of which are connected to Indoor Environmental Quality (IEQ) dimensions [9,15], have been stated after collecting several papers and reviews. The EBD theory developed by Ulrich [16–18] and its further applications in several healthcare settings (i.e., [19,20]) is able to support IEQ analysis and POE evaluations with a structured framework different empirical studies (Figure 2).
3. Several versions of evaluation tools and certifications have been developed with POE methodologies specifically for hospital environments [21–24]. The most known are related to sustainability but many of them include IEQ considerations and building effects on occupants' health and wellness.

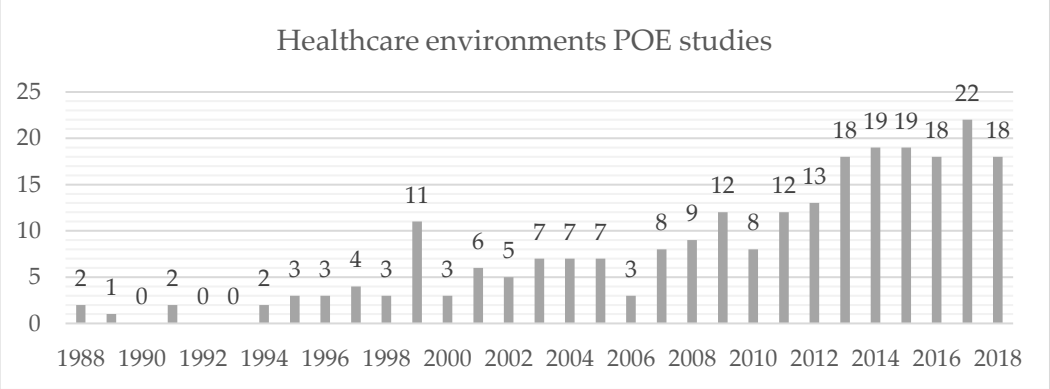


Figure 1. Number of Post Occupancy Evaluation (POE) studies or reviews published with focus on healthcare environments. The graph shows the there is a growing interest into the topic. The complete list and search process are available in Table S1.

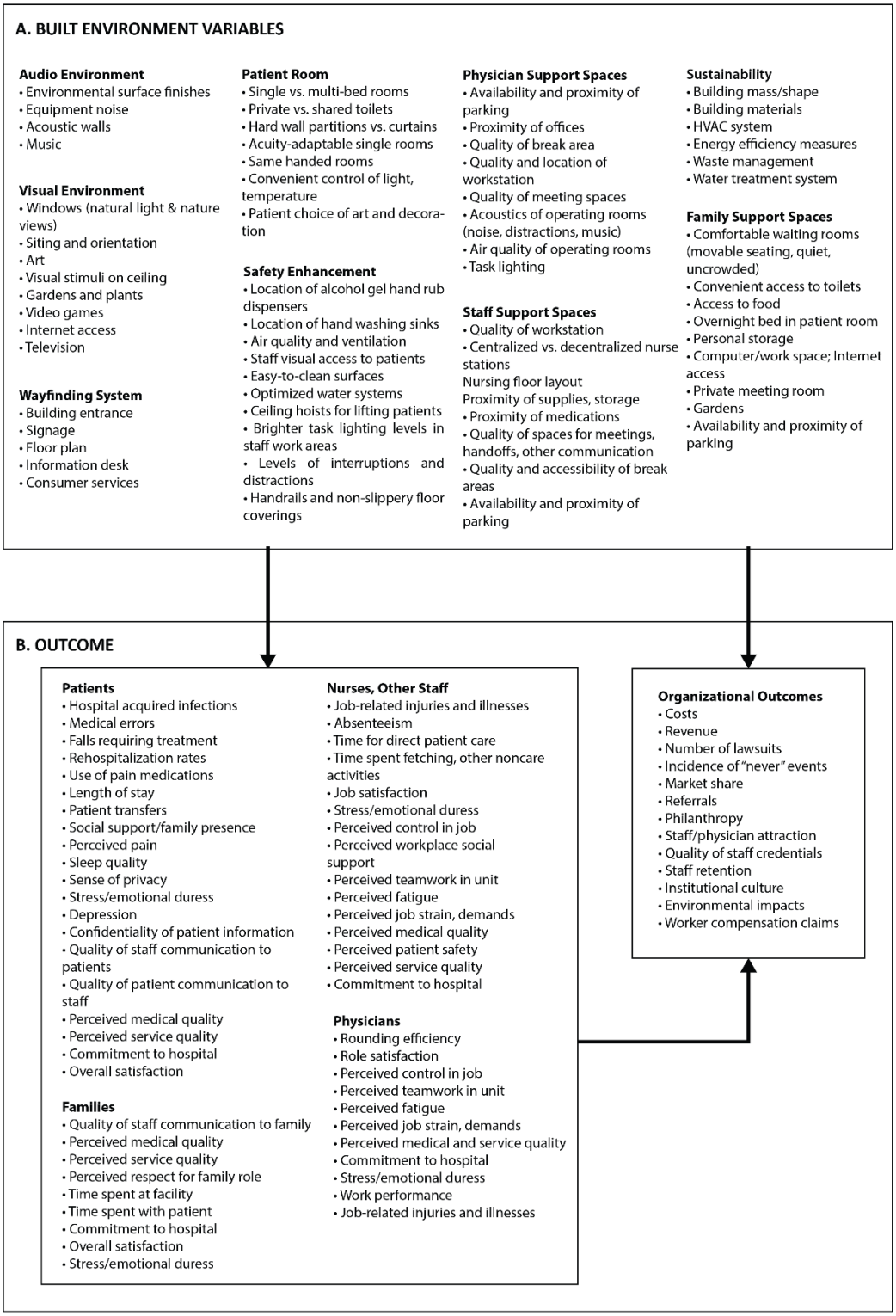


Figure 2. The Evidence-Based Design theoretical framework. Elaborated by the authors starting from Ulrich studies [18].

1.3. Hospitals as High-Performance Environments

Healthcare facilities are a very complex building type due to the different users, the continuous needs of transformation [25], the relevant integrated technologies and systems, and the building's role as Public Health promoter [26]. They are energy demanding systems [27], active 24 h per day,

seven days per week; therefore, they can be considered as high-performance buildings, such as physical environments capable of obtaining measurable outcomes from different areas of interest, i.e., sustainability and health. This kind of facility has the objective of decreasing building energy use, providing a comfortable and healthy environment, and increasing productivity for occupants [28].

In hospitals, there is demand for overall quality and several methodologies have been developed in order to evaluate, assess, and measure it. Great importance is related to organizational performances or clinical outcomes [29,30], but the physical setting also has relevance in providing a Patient-Center Design (PCD) that pays attention to the needs of the users and, at the same time, is able to enhance overall hospital organization [31–33].

1.4. Research Gap and the Paper's Objective

Knowledge about POE evaluation of hospitals is scattered but very promising. Through a review of the existing body of knowledge in EBD, POE, and the hospital design and assessment field, 13 POE tools have been selected and further investigated. Taking into account the aforementioned gap highlighted in the hospital built environment assessment field, three questions emerge:

- are there tools able to evaluate hospital physical environment through POE?
- which are the most used assessment criteria and with which terms do they measure health and/or sustainability?
- is it possible to frame trends or insights for future research on the topic?

The objective of the paper is to compare and review the recent POE tools that evaluate hospital built environment and critically identify in which terms they are able to measure health, sustainability, or both, retrospectively to Ulrich's EBD theoretical framework. Additionally, a focus on specific tools that embed both sustainability and health with different intensity is provided.

2. Methods

In order to gather the most recent information about the topic, a systematic and explicit design for identifying, evaluating, and interpreting the existing body of recorded documents has been considered [23,34,35]. With the objective of collecting all the tools able to assess the environmental qualities of healthcare buildings, a step by step methodological model has been followed for the Literature Search, as shown in Figure 3.

Appropriate search terms have been selected based on previous literature reviews and papers collected in the field of healthcare architecture, EBD, POE, and built environment assessment. A three-level set of keywords has been identified as well as some eligibility criteria, as show in Table 1.

Table 1. Keyword identification and eligibility criteria used.

Keywords search string:	"HOSPITAL" or "HEALTHCARE ENVIRONMENT" or "HEALTHCARE BUILDING" or "HEALTHCARE FACILITIES" and "QUALITY" and "DESIGN" or "ARCHITECTURE or "BUILT ENVIRONMENT" or "PHYSICAL SPACE"
Eligibility criteria:	Exclusion of fields where the search terms have a different meaning, i.e., Computer Science (software architecture) and Biology (bone architecture, cells design) fields for risk of biases

Including "Post Occupancy evaluation" or "POE" in the search phase excessively narrowed the search. Indeed, although not explicitly mentioning POE, several studies conducted assessment of built environmental qualities with the same approach and have been included. Using the "title, abstract, keywords" and "title, abstract" search in Scopus and PubMed databases, several articles have

been collected and stored. Due to the novelty and multidisciplinary nature of the topic, additional information has been gathered from secondary sources such as research centers repositories:

- Center of Health Design (CHD). Available online: https://www.healthdesign.org
- Health and Care Infrastructure Research and Innovation Centre (HaCiCR). Available online: http://www.haciric.org
- International Academy for Design & Health (IADH). Available online: https://www.designandhealth.org

resulting, after removal of duplicates, in 2228 papers. Titles, abstracts, and keywords of the selected papers have been critically read and processed according to some exclusion criteria, resulting in 256 papers. Eighty-four papers have been excluded because they were published before the last review on the topic by the founder of EBD [17], resulting in 172 documents. While extensive description of the different empirical studies and review papers on the topic is available in other contributions [23,36,37], this review will focus specifically on the assessment tools, rating tools, and certifications that emerged. Although some researchers question the relevance of certifications [38], they are instruments that are used both in practice and in academic fields and are therefore investigated. Probably the most known are the sustainability assessment tools (i.e., LEED, BREEAM) but many others exist, as Mills et al. [24] and Elf et al. [21] reported. Life Cycle Assessment (LCA) protocols and software are not included since they look at the topic with a process perspective, as other scholars have already underlined [22]. In this review, neither single POE research protocols nor methodologies extracted from empirical studies are considered due to the difficulties of finding single item information and their application in one or a limited number of cases. Tools that include feedback from both users and instrumental measurements have also been considered [39].

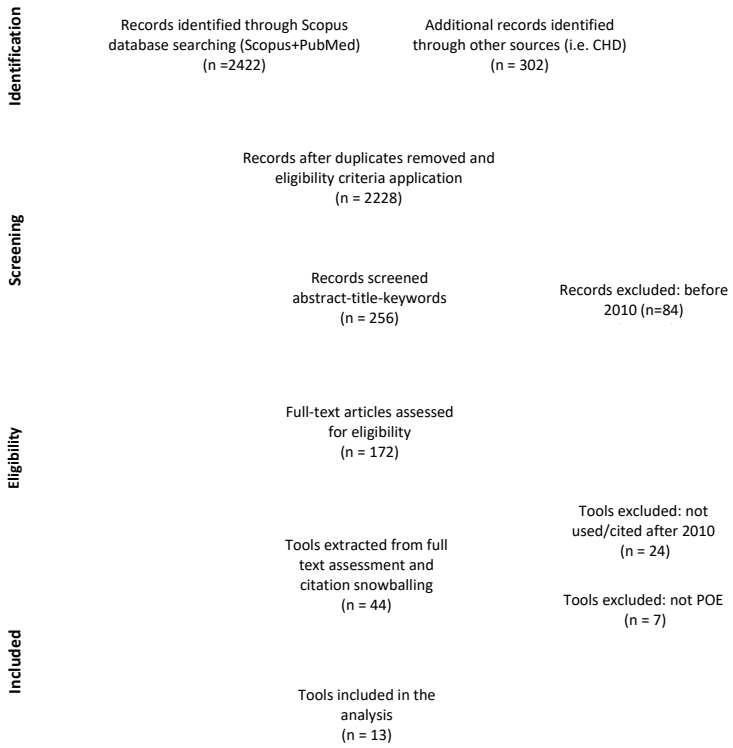


Figure 3. The Prisma Flow Diagram shows the process followed for the identification of the 13 POE tools included in the analysis.

Forty-four tools for building assessment or rating systems have been extracted from full-text assessment and citation "snowballing" from the collected documents. The full list is available in Table S2. Only instruments with a clear output and a clear focus on the building sustainability or

health have been considered. Finally, specific focus or at least possibilities of applying the tool to a hospital building has been considered as exclusion criteria. The instruments can provide standardized and comparable information of different environments, identify strengths and weaknesses, and offer insights into how environments can be better adapted to users' needs [21]. The eligible tools have been collected in an Excel spreadsheet and analyzed. In order to understand the most recent development on the topic, only the tools applied or mentioned as relevant in publications after 2010 have been considered in the analysis (n = 24). Furthermore, some tools evaluate only the design or planning phase of a project and therefore have been excluded (n = 7). Finally, 13 POE tools have been included in the analysis. Each tool has been further investigated via published papers, technical manuals and official websites. A sheet for each tool has been created with the full list of macro-area, criteria and indicators. Each indicator has been assigned to a specific EBD dimension based on Ulrich's theoretical framework [18] in order to understand the prevalence of a topic in retrospect to another. Within each of the nine dimensions, similar items have been grouped into smaller clusters. The groups are derived from Ulrich's framework and the association of each indicator to a specific group has been conducted through a deep analysis of the assessment methods, official websites, and, where not available, through direct investigation of the reports available.

The full list of the tools included is available in Table 2 and additional information is provided in Table S3.

Table 2. List of tools included in the review and their acronyms used in the following paragraphs.

n	Name	Acronym
1	Building Research Establishment Environmental Assessment Method	BREEAM
2	Leadership in Energy and Environmental Design	LEED
3	Comprehensive Assessment System for Building Environment Efficiency	CASBEE
4	Green Star	GS
5	A Staff and Patient Environment Calibration Toolkit (plug-in of AEDET)	ASPECT
6	Achieving Excellence Design Evaluation Toolkit	AEDET
7	Green Guide for Healthcare	GGHC
8	Sustainable High Quality Healthcare	SUSTHEALTH
9	Birthing Unit Design Spatial Evaluation Tool 2.0	BUDSET
10	Healthcare Building Sustainability Assessment tool	HBSA
11	Design Quality Indicator	DQI
12	Well Building Standard	WELL
13	Community Health Center Facility Evaluation Tool	CHD-CHC

3. Results

3.1. General Information

3.1.1. Tools' Structure

Generally, the tools are based on a hierarchical structure and the different parts can be related to a hierarchical pyramid. The basis of the pyramid is formed by fundamental and interconnected macroareas [40]. Each area is evaluated through a hierarchical framework of Criteria & Indicator (C&I type), which are the elements concurring to the final score of each specific aspect. Each criterion relates to one key macroarea and may be described by one or more indicators. The evaluation of each indicator gives direct information to the overall assessment both in qualitative and quantitative aspects. Eventually, an indicator might be composed by one or more very specific items to measure or verify with specific rationale and method. This hierarchical structure reflects the complexity of the decision-making processes and the possibility of defining an objective system of measurement and comparison between different alternatives [41,42]. The tools collected have 1, 3, 4, or 5 macroareas, between 6 and 24 criteria, and between 21 and 193 indicators. Each indicator might have one or more item with different techniques of measurement, either qualitative or quantitative. Five tools (38%) include mandatory prerequisites to be completed before having access to the whole assessment; four of those are commercial certifications.

3.1.2. Item Sources and Selection

The items, criteria, and indicator sources are very different among the tools but can be related mainly to bibliographic research or literature reviews (n = 8) (AEDET, BUDSET, HBSA, WELL, CHD-CHC, SUSTHEALTH, ASPECT, GGHC), review of existing tools (n=4) (CASBEE, GGHC, HBSA, DQI), regulations and guidelines (n = 5) (LEED, BREEAM, CASBEE, HBSA, WELL). In all cases (n = 13), more than one source is used and the items are selected through focus groups and/or expert opinion. This underlines that the selection of experts is very important in the tool development process.

In some cases, the selected items do not have the same importance in the overall process. Indeed, weighting systems have been adopted, often with the support of steering groups of experts and/or thorough Analytic Hierarchic Process (AHP) [43,44]. Although some critiques emerged regarding the multicriteria methodology with respect to the Social Impact Assessment methods [45], the former is still a valuable and diffuse way to deal with a methodologically systematic and replicable assessment of qualitative and quantitative factors.

3.1.3. Economic Purpose

About half of the tools (7 over 13) are developed in not-for-profit environments and are available without a fee, while the other 47% (6 over 13) are owned by certification agencies or companies and the participation in the assessment process requires a charge for the service. Generally, the nonprofit tools do not guarantee a formal certification, whereas the commercial ones do.

3.1.4. Territorial Development

Although the tools may appear very different, it is possible to clearly state that the evaluation approach is more developed in English-speaking countries. Four of the tools (30%) have been developed and applied in the USA, four instruments have roots in UK institutions or agencies (30%), and two are Australian protocols (15%). These represent the majority of the contributions, while the remaining 23% is covered by Italy, Portugal, and Japan which have only 1 tool each, out of the 13 collected (Table 3).

Table 3. Classification of the tools collected according to the geographic area of development.

USA (n = 4; 30%)	UK (n = 4; 30%)	Australia (n = 2; 15%)	Others (n = 3; 23%)
- LEED - GGHC - WELL - CHD-CHC	- BREEAM - ASPECT - AEDET - DQI	- GS - BUDSET	- CASBEE (Japan) - SUSTHEALTH (Italy) - HBSA (Portugal)

3.1.5. Recurrent Topics

An analysis of the most recurrent topics among the POE tools indicators has been conducted and the main results are presented below, divided into Health, Sustainability, and Other topics, respectively contributing 55%, 33%, and 16% of the total amount of indicators. Health-related items have been further analyzed through the EBD framework [18] and the results are hereafter presented. The most used EBD criteria are Safety enhancement (n = 131; 14%) and Visual environment (n = 119; 13%). The complete lists are available in Tables S4 and S5.

3.2. EBD Health-Related Topics

3.2.1. Safety Enhancement

Built environment can lower the incidence of nosocomial infections, medical errors, patient falls, and staff injuries [18]. Among the tools, the highest percentage of indicators focus on this important topic (131 indicators, 14% of the total and 28% of the health-related indicators). The most recurrent

ones are the pollution risks (both chemical, biological, or environmental, 15%), risk management (12%), Indoor Air Quality (IAQ) [46], issues related to cleaning products or procedures (11%), and the important topic of Accessibility (11%), with reference to the universal design [47]. Minor topics below 10%, but interesting for future research, are: occupants' education, emergency management, tobacco smoke reduction, and security, as shown in Table 4.

Table 4. Number and percentage of indicators grouped according to Safety enhancement topics.

Safety Enhancement Topics	n (/131)	%
Pollution risks	19	15%
Risk Management	16	12%
Accessibility	14	11%
Cleaning	14	11%
Indoor Air Quality (IAQ)	14	11%
Security	12	9%
Education	10	8%
Water risks	8	6%
Management of emergencies	6	5%
Materials	6	5%
Layout features	5	4%
Smoke	3	2%
Technologies	3	2%
Outdoor risks	1	1%

3.2.2. Visual Environment

Since the seminal EBD and Biophilia studies [16,48], we know visual environment has important benefits on patient's health outcomes, staff satisfaction [49], and organizational performance [50]. All the tools collected deal with this topic and a significant amount of indicators (119; 13% of the total; 25% of the health-related) assess the quality of visual environment, mainly in terms of interior design (30/119), views (21/119), light control (13%), outdoor design (13%), artificial light (10%), and outdoor access (7%), as highlighted in Table 5. Indeed, studies show that a simple window is able to significantly impact overall occupant health and wellbeing [6].

Table 5. Number and percentage of indicators grouped according to Visual Environment topics.

Visual Environment Topics	n (/119)	%
Interior design appearance	30	25%
Outdoor views	21	18%
Lighting control	15	13%
Outdoor design appearance	15	13%
Artificial light	12	10%
Natural light	10	8%
Outdoor access	8	7%
Light pollution	5	4%
Privacy	3	3%

3.2.3. Staff and Doctors' Space Features

According to the collected tools, an excellent environment for staff satisfaction needs to provide adequate and additional services (i.e., food, physical activities, mental health support, 34%), space flexibility (22%) [51], and completely dedicated spaces for working, resting, changing, and storage (22%). Transportation management policies and spaces and furniture are also important (11% each).

Finally, only three indicators from two tools explicitly mention Medical Doctor space features in terms of dedicated areas, as shown in Table 6.

Table 6. Number and percentage of indicators grouped according to Staff and doctors' space features topics.

Staff and Doctors' Space Features	n(/76)	%
Dedicated services	25	34%
Flexibility of space	16	22%
Dedicated space (work, rest, change)	15	21%
Furniture quality	8	11%
Transportation management	8	11%
Dedicated space for Medical Doctors	3	3%
Storage space	1	1%

3.2.4. Patient Room Features

Patient room-related features to be measured when dealing with a POE assessment are bathroom presence and characteristics (26%), privacy (20%), furniture layout and materials (17%), and food service and nutrition (15%). Moreover, the availability of large space over the minimum standard requirements is widely addressed (13%), as indicated in Table 7.

Table 7. Number and percentage of indicators grouped according to Patient room topics.

Patient Room Features	n (/46)	%
Toilets	12	26%
Privacy	9	20%
Furniture quality	8	17%
Nutrition	7	15%
Wide space	6	13%
Medical utilities	2	4%
Overall satisfaction	2	4%

3.2.5. Wayfinding Features

A simple building that is easy to navigate enhances occupants' satisfaction, optimizes logistics, and reduces the risk of falls in fragile people [52]. This is challenging in complex healthcare facilities; therefore, wayfinding strategies have to be adopted [26].

Eight of the collected tools are aware of this issue and suggest indicators related to indoor signage (26%), layout legibility (23%), entrance clarity (19%), architectural features (9%), distances between functions (6%), finishing (6%), and logistic flow management (4%), as shown in Table 8. These are qualitative issues mainly assessed through on-site surveys or interviews.

Table 8. Number and percentage of indicators grouped according to Wayfinding topics.

Wayfinding Features	n (/47)	%
Layout legibility	11	23%
Indoor signage	9	19%
Entrance clarity	9	19%
Architectural composition	4	9%
Interior finishing/art	3	6%
Outdoor signage	3	6%
Path distance	3	6%
Logistics	2	4%

3.2.6. Family/Visitors' Space Features

Spaces for family and visitors are important and contribute to the social support of occupants by providing social space (18%), space or services for community enhancement (16%), parking facilities (13%), public transportation accesses (11%), proximity to territorial services (8%), and opportunities

for physical activities (8%). Indicators related to these categories are the most recurrent among the tools and protocols collected, altought some others are present as described in Table 9.

Table 9. Number and percentage of indicators grouped according to Family/visitors space features topics.

Family/Visitors Space Features	n (/38)	%
Socialization space	7	18%
Community enhancement	6	16%
Parking space	5	13%
Public transportation accessibility	4	11%
Physical activities promotion	3	8%
Service proximity	3	8%
Furniture qualities	2	5%
Landscape qualities	2	5%
Night space area	2	5%
Nutrition services	2	5%
Bike accessibility	1	3%
Playground areas	1	3%

3.2.7. Audio Environment

Bad acoustics is a major environmental stressor that negatively influences hospital occupants [18]. The World Health Organization (WHO) also express concern in this direction by promoting guidelines and best practices [53]. Despite its relevance, only 2% of the total indicators (21/933) and 4% of the health-related indicators (21/475) cover acoustics-related issues. Totally, 10 of 13 tools deal with this topic. They request the analysis of noise level (10/21; 48%) and the presence of specific materials or layout features able to guarantee sound absorption, noise reduction, or sound masking (7/21; 33%). Other qualitative aspects that are covered in the tools are, as shown in Table 10 the possibility of having and controlling music (2/21; 10%), proved to be important for patient anxiety reduction [54], guaranteed privacy (1/21; 5%), and the reduction of outdoor noise pollution (1/21;5%).

Table 10. Number and percentage of indicators grouped according to Audio environment topics.

Audio Environment	n (/21)	%
Noise level (DbA)	10	48%
Materials and layout features	7	33%
Music features	2	10%
Noise pollution	1	5%
Privacy	1	5%

3.3. Sustainability Topics

Sustainability issues cover more than 1/3 of the total amount of indicators collected from the 13 tools. In this category, only indicators that have a direct impact on the overall sustainability have been included and it is interesting to notice that even the traditional sustainable assessment tools consider this issue as wider than just energy saving strategies. In the results shown hereafter, the concept of sustainability is defined as actions that can either reduce the overall environmental impact of a building or improve the energetic efficiency of the facility. The object of analysis is considered to be composed of different systems (i.e., lighting, water, HVAC) and components (i.e., materials, construction techniques, insulations) and important attention is devoted to the impact that the building can have on the surroundings (i.e., in terms of pollution, site management, and transportation strategies).

Naturally a big part is dedicated to energy consumption reduction (20%), but a significant number of indicators deal with water management (12%), sustainable materials (9%), thermal comfort (8%), indoor/outdoor pollutant reduction (8%), waste management (7%), sustainable and durable choices

during construction (i.e., prefabrication strategies, 7%), site management (6%), and renewable energy sources (6%) [55]. Interesting issues but with minor presence (<5%) are related to the possibility of conducting Life Cycle Assessment (LCA), educating occupants on sustainability practices, adoption of rating tools (i.e., LEED), or heat island effect reduction, as shown in Table 11. Those topics are considered important in fostering the concept of sustainability and a "green" approach that is fundamental for maintaining the relationship with the natural, social, and economic environment for a long-term period. For example, this approach is particularly interested in the Edge Lane hospital (Liverpool, UK) that achieved an "Excellent" BREEAM rating in the design stage assessment. In addition to performance-oriented and technological system efficiency operations, several strategies have been taken into account, such as the use of extensive green roofing, trees shadings, reflective materials, and heat island effect reduction, as shown in Figure 4. Implementation strategies for the upcoming years have been also considered by the designers and several iterations to achieve the best configuration have been conducted [56].

Table 11. Number and percentage of indicators grouped according to Sustainability topics.

Sustainability	n (/313)	%
Energy consumption	63	20%
Water use	39	12%
Material sustainability	28	9%
Environmental pollution	24	8%
Thermal comfort	24	8%
Waste management	23	7%
Construction choices	21	7%
Energy sources	20	6%
Site management	20	6%
HVAC efficiency	17	5%
Management of environmental policies	16	5%
Heat island effect reduction	4	1%
Passive environmental strategies	4	1%
Sustainability education	3	1%
Green rating tools	3	1%
Transportation sustainability	2	1%
Life Cycle Assessment (LCA)	1	<1%
Lighting efficiency	1	<1%

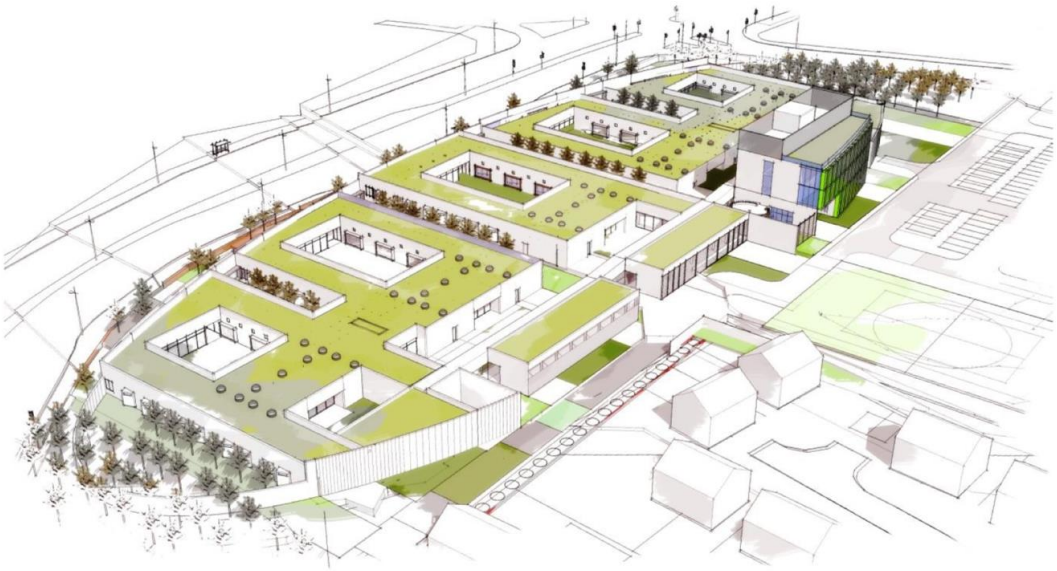


Figure 4. Early visualization of the Edge Lane Hospital, taken from Medical Architecture reports available online [56].

3.4. Other Topics

The remaining 154 indicators (16%) that are neither directly related to Sustainability nor included in the EBD framework for health-related outcomes are collected into a wide "Other topics" category.

This list might appear as "miscellaneous", but it contains a pattern to highlight, shown in Table 12. Indeed, 18% of the indicators are related to education and services for occupants (not related to sustainability), organizational qualities and performance improvement policies (16%), maintenance and facility management (9%), and urban and social integration (8%). Indicators present between 5% and 2% are architectural appearance, satisfaction surveys, design process and professional involvement, innovation, space ratio data, and costs, to mention the most interesting.

Table 12. Number and percentage of indicators grouped according to Other topics.

Other Topics	n (/154)	%
Occupants education & services	27	18%
Organizational quality	25	16%
Maintenance and Facility Management (FM)	14	9%
Urban and social integration	13	8%
Food services	9	6%
Building survey/commissioning	8	5%
Design process	8	5%
Building appearance	7	5%
Innovation/research	7	5%
Satisfaction surveys	6	4%
Construction process	5	3%
Cultural issues	5	3%
Materials data & certification	5	3%
Transportations	4	3%
Costs and budgeting	3	2%
Professionals involvement	3	2%
Space ratio	3	2%
Bonus points	1	1%
Regional priority	1	1%

4. Discussion

4.1. Evolution of POE Tools over Time

Although POE methodologies have been available since the 60s [4,10], the tools that are in use nowadays have been developed in the last 20–30 years. The first one is the English BREEAM released in the early 90s in UK by the Building Research Establishment (BRE) [57], followed by the USA Green Building Council in 1998 with the well-known LEED (Leadership in Energy and Environmental Design) [58–60].

Those two tools were developed to face the great challenge of environmental sustainability that emerged during the 90s. Second in time, but first in terms of sustainability coverage of the topics, the LEED tool developed a version specifically designed for hospitals in 2009 (LEED Healthcare) with updated indicators applicable to the specific high-performance building type [60,61]. Starting from building regulation and technical guidance, it collects a wide range of indicators; all of them are weighted according to experts' interviews, focus groups, National Institute of Standards and Technology (NIST), and some of them are also prerequirements. The tool has different versions and the LEED BUILDING OPERATION & MANAGEMENT (O+M) is a POE instrument for assessing buildings after they are occupied with a unique macroarea, eight criteria (Location and transportation, Sustainable sites, Water efficiency, Energy and atmosphere, Materials and resources, Indoor Environmental Quality, Innovation, and Regional priority) with 49 indicators. As expected, the majority of indicators (73%) is directly related to Environmental Sustainability, while, based on Ulrich's EBD framework, only 10% have possible impacts on occupant health. The remaining 16% are

related to other topics, such as building maintenance, building survey and commissioning, innovation, regional priority, and occupant satisfaction surveys. Starting from those two milestones, the other tools that progressively include those items are the Japanese CASBEE [62] and the US-based GGHC OPERATIONS [63] and GS-PERFORMANCE [64].

On the other side of the timeline, a completely different result is shown. The last tool found in the review is called the CHD-CHC evaluation tool (Community Health Center Facility Evaluation Tool) developed in 2017 by the Center for Health Design (CHD), a not-for-profit Research Institution based in the USA and active in the past 25 years in the field of hospital design and research [65]. The center develops research and several tools are available [19,24]; they also provide a professional certification for practitioners. A comparison of the three aforementioned tools is provided in Figure 5. The CHD-CHC tool is structured according to building areas (exterior, interior, waiting, patient clinician interactions, staff space) and counts 115 indicators [65].

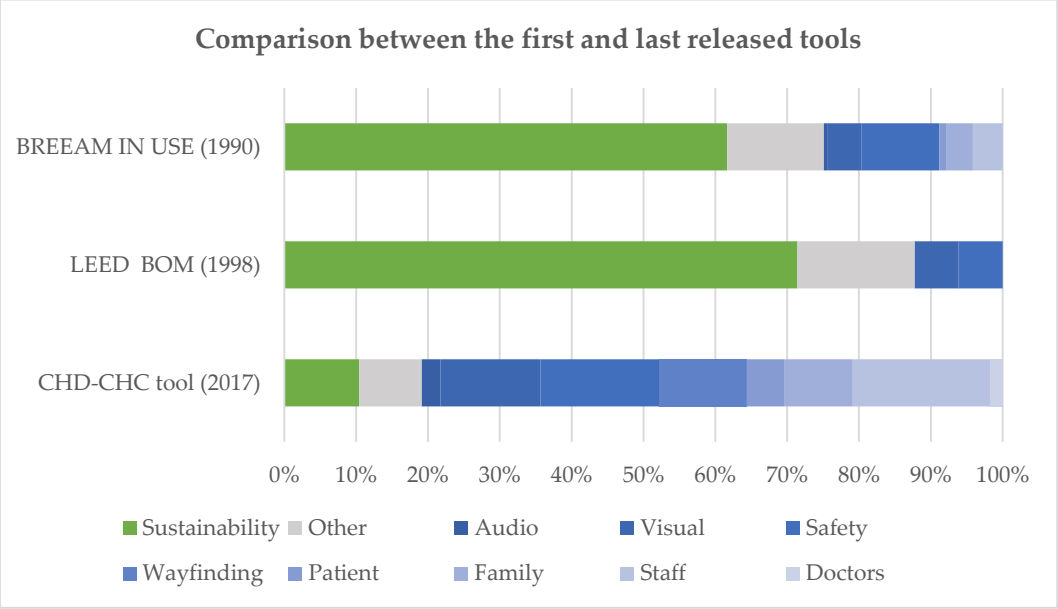
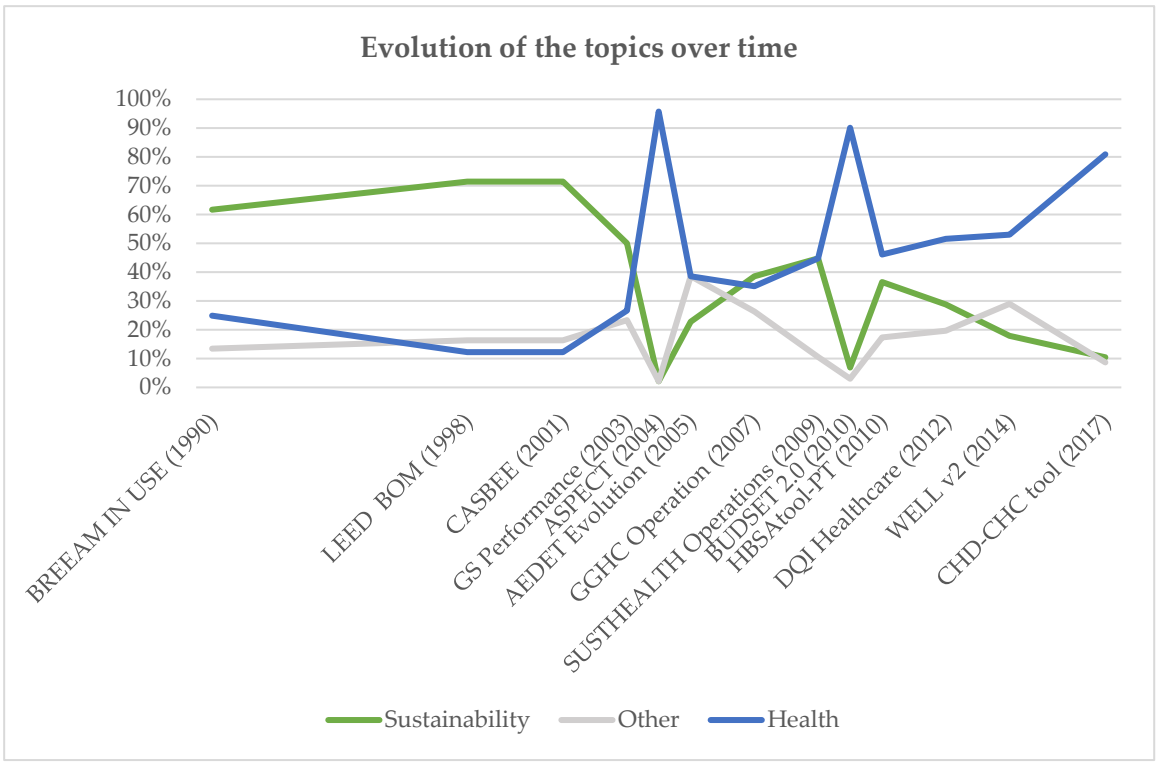
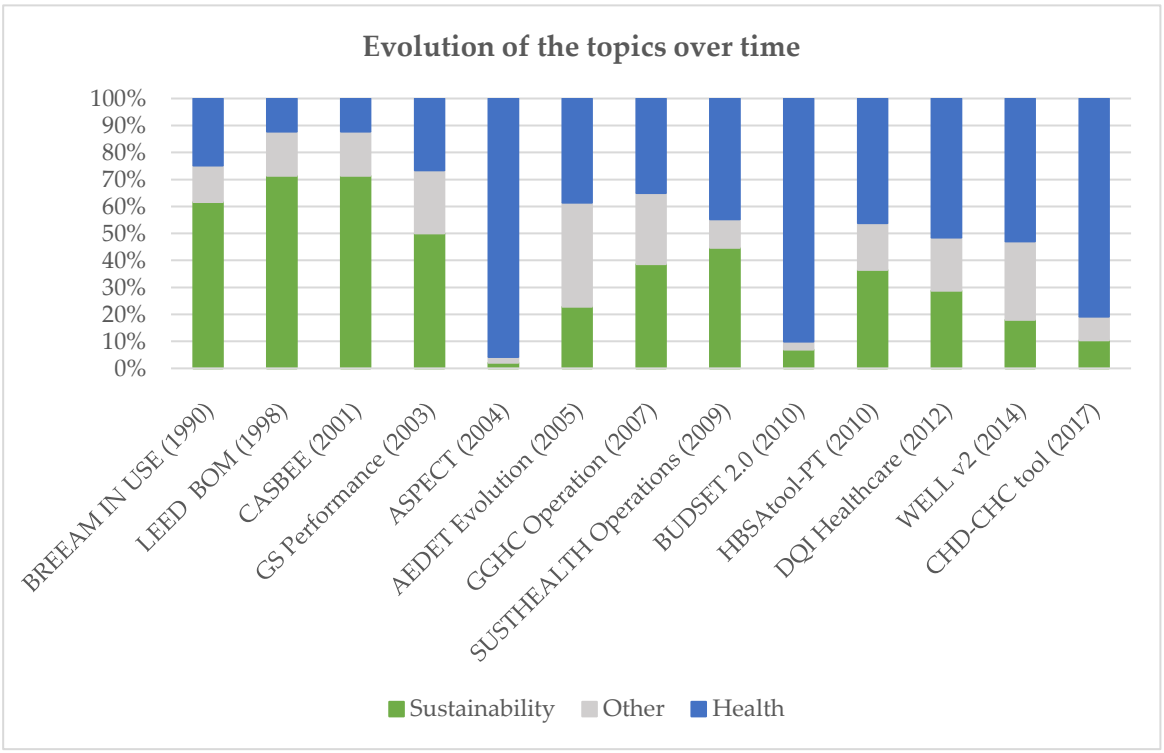


Figure 5. Comparison between the first developed tools (BREEAM and LEED), with focus on sustainability, and the last released one, which has a prevalence of health-related indicators (CHD-CHC).

Only 10% of those indicators are related to sustainability issues, with particular reference to Heat island effect reduction, HVAC efficiency, thermal comfort, and use of other sustainability rating tools (i.e., LEED). The indicators that are related neither to health nor to sustainability (9%) are evaluating procedures for occupants' educations and services, organizational quality, or integration with the neighboring environment. More than 80% of the indicators are instead specifically focused on health, as the EBD analysis highlighted. The staff environment is the most recurrent topic (21%), with important considerations about the need of a dedicated space for the several activities scheduled in a day, the quality of furniture and equipment (i.e., workstation), the need for flexible spaces, and the possibility of providing space and services for physical activities as health promotion and prevention strategies [66]. The visual environment and the safety-related issues are important as well (15%), with interesting items related to views, natural light and light control, outdoor design and accessibility/universal design, cleaning, and security (i.e., crime prevention through environmental design). Finally, wayfinding strategies are mentioned several times (12%) and evaluated according to indicators mainly related to indoor/outdoor signage and layout legibility. Looking at the different tools on a timeline, it is possible to understand the evolution of the "health" topic and the decrease of the "sustainability" topic, as shown in Figure 6a,b.



(a)



(b)

Figure 6. Evolution of the topics Sustainability, Health, and Others over time, from 1990 to 2017 (**a**) and distribution of the topics in the different instruments, listed in chronological order (**b**).

4.2. Health and Sustainability Balance

Between the two extremes, the tool that counts the highest percentage of health-related indicators (91%) is the English ASPECT (A Staff and Patient Environment Calibration Toolkit). The instrument is diffused mainly in the UK area because it is a specific plug-in of the National Health System (NHS) tool AEDET (Achieving Excellence Design Evaluation Toolkit) recently included into the more balanced DQI (Design Quality Indicators) evaluation system [24,67]. The NHS tools are valuable for their attention to the process since they are able to collect several stakeholders and improve the overall process in a collective way of receiving inputs and feedbacks on the design choices. Some items of the DQI tool enhance the possibility of achieving a BREEAM accreditation, as in the case of the UCLH Proton Beam Therapy, London [68], where, thanks to the DQI workshops, several stakeholders have been involved.

First released in 2004, ASPECT is a tool for evaluating the quality of design of staff and patient environments in healthcare buildings. It delivers a profile that indicates the strengths and weaknesses of a design or an existing building and can be used as standalone form or for evaluation workshops [69–71]. Each indicator can be weighted as high (2), normal (1), or zero (0) and is evaluated with a six-point Likert scale. The most recurrent indicators related to health are the visual environment ones (36%), with evaluation of views, outdoor access, light control, privacy, and interior design. Another tool high-ranked in terms of health-related outcomes is the Australian BUDSET 2.0 (Birth Unit Design Spatial Evaluation Tool). Specifically designed by the Sidney University of Technology, it embeds criteria and indicators able to evaluate the design effectiveness of birth unit spaces and provides a way to assess the optimality of birth units and determine which domain areas may need to be improved [72]. Eighty-five percent of the indicators have a relationship with EBD domains with significant insights from the Safety enhancement area (15%) and the patient room layout (22%). A comparison between the tools with a higher percentage of health-related indicators is provided in Figure 7.

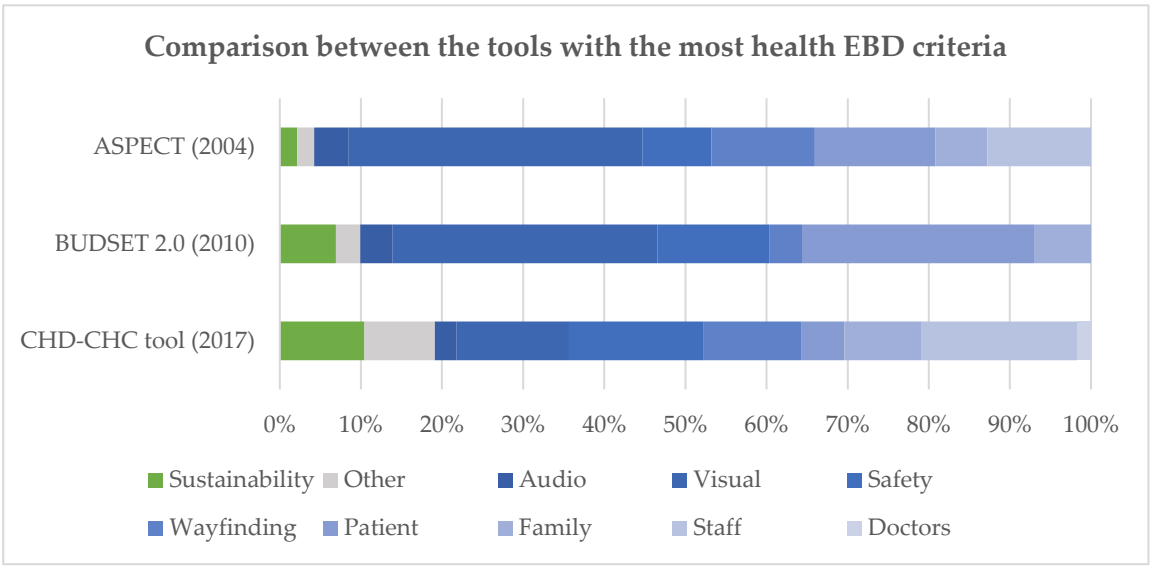


Figure 7. Comparison between the tools that, according to the EBD analysis, have most of the indicators related to health.

More balanced instruments developed in two completely different environments are the academic tools SUSTHEALTH and HBSA and the commercial certification WELL.

The former was developed in 2009 by a multidisciplinary academic group coordinated by one of the authors. SUSTHEALTH (Sustainable High Quality Healthcare) has the objective of evaluating hospital projects from the economic, environmental, and social sustainability point of view. It has been

developed with the support of several experts, literature reviews, and case study analysis and the indicators are weighted with Analytic Network Process [40,73]. The "SUSTHEALTH OPERATIONS" version is able to assess operating hospitals conducting POE.

About half of the indicators (47%) are specific for environmental sustainability evaluation (i.e., energy source, energy consumption, waste and water management) but 42% have impact on occupants' health. In particular, 16% of the indicators are able to assess safety and security-related topics in terms of accessibility, education, risk management, and technologies.

The Portuguese HBSA tool has a similar approach but explicitly implements the concept of EBD into a well-structured sustainability set of criteria derived from the aforementioned tools of Eco-Effective Design (EED), including BREEAM, LEED, GREEN STAR, and CASBEE [22].

The latter is a recent tool developed by the International WELL Building Institute (IWBI) in 2014 and is third-party certified through IWBI's collaboration with Green Business Certification Inc. (GBCI)—the certification body for the LEED Green Building Rating System. At its 2.0 version, the WELL tool incorporates 117 indicators divided into 11 criteria. The indicators have been selected by a three-step peer review done by experts in different fields (scientific, professionals, medical) and they are updated regularly [74,75]. The core focus is on office and corporate buildings but, as specified in the official website, high-performance healthcare facilities are also assessable. In this case, half of the indicators (48%) are related to health and several aspects are covered mainly in terms of occupant safety enhancements (16%), staff space and services (14%), and visual environment (11%).

One fifth of the total indicators (21%) are core sustainability topics, while one third (31%) covers several organizational or procedural aspects focused on education and services, food service and delivery, innovation, and organizational qualities. For example, in the "mind" area of the WELL tool, some criteria are directly related to Biophilia aspects with specific indicators that evaluate the application of this concept to the design. A comparison between the tools with a balanced profile is provided in Figure 8.

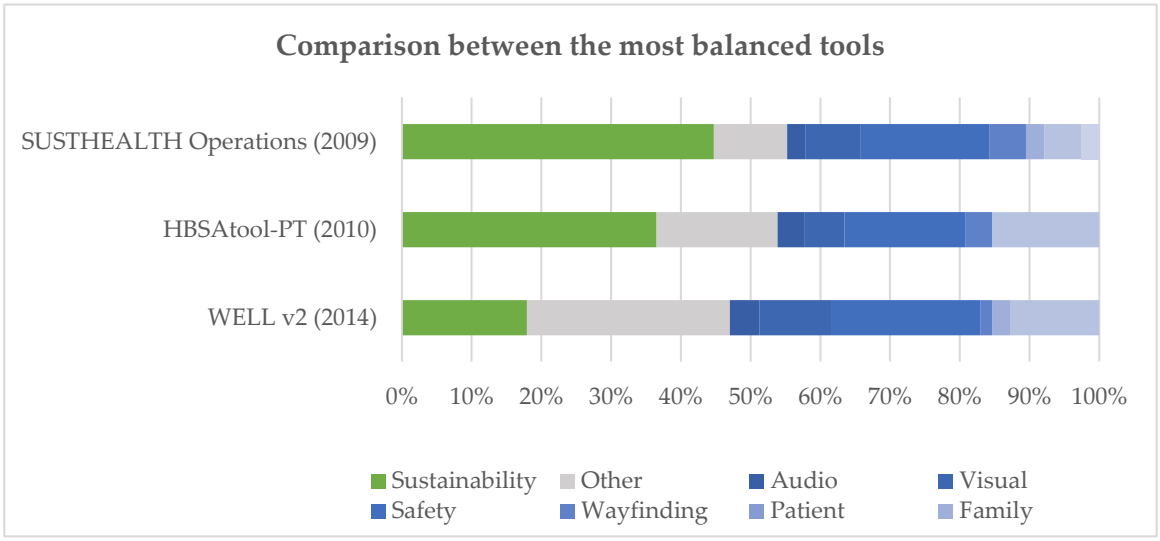


Figure 8. Comparison between the more balanced tools WELL, SUSTHEALTH, and HBSA.

The analysis of those instruments and the discussion of the most relevant ones lead to highlight a gradual, but not always linear growth of the prevalence of health-related indicators within POE rating tools for hospital built environment quality assessment.

While in the nineties and early 2000s, the most recurrent topics were mainly related to environmental sustainability, today, the evaluation of high-performance environments, such as hospitals, always include more health-related topics.

5. Conclusions

A review of the literature in the field of hospital built environmental quality assessment and EBD highlighted the presence of several POE tools able to measure the quality of high-performance environments in terms of sustainability and health.

Amongst the 13 instruments collected, the most recent ones show a trend of increasing the percentage of indicators related to health rather than related to sustainability.

In the first tools developed in the 90s, great attention was dedicated to sustainability (M1 = 67%). This can be an indicator of a shift in the paradigm of built environment evaluation from a pure sustainable-oriented approach toward a more health-related one. Health is considered here with the wider definition of the World Health Organization (WHO) "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" [76] (p.1).

Sustainable buildings, or at least buildings with environmentally sustainable certification, are considered as better quality, receiving on average better economic evaluations [77]. Moreover, especially in complex high-performance facilities such as hospital buildings that have a significant impact on the environment, sustainability represents a challenge to face and a valuable target to achieve. Since the Bruntland report on sustainability, several steps have been taken and scholars reported that sustainable development is an important prerequisite for guaranteeing health, touching on the social, economic, and ecological (environmental) dimensions of sustainability [78]. In addition to this, it is important to design healthy environments able to support and improve occupants' health and wellbeing and human factors [79,80]. As EBD theory and several studies demonstrate (i.e., [18,81]), built environment has impacts on occupants' health and wellbeing and therefore it is important to implement these issues in existing or future POE assessment tools.

The growing attention on health-related issues and the reduction of sustainability-related issues may lead to consideration of environmental sustainability and energy performance as topics covered by regulations, guidelines, and prescriptive tools, while the health impacts area is a growing topic to explore when dealing with POE assessment, especially in hospital environments.

5.1. Innovation/Originality

Several articles have been published about the comparison of different tools in various settings [13,21,24,58,59,82,83] but this is the first time a sample of tools have been appraised from an EBD perspective and considerations about the presence of sustainable and/or health related indicators have been provided.

5.2. Impacts for Research

This research contributes to enriching the current body of knowledge about POE tools through the lens of EBD and provides a collection of instruments, criteria, and indicators. This forms a preliminary collection of a dispersed and scattered information about hospital built environment evaluation due to the poor indexing and the very specific area of research.

5.3. Future Development

The results show several promising research topics that can be further investigated through different research lines. We suggest three possibilities: first, to test the effectiveness of each different tool and compare the certified buildings through concrete case studies and applications, instead of the instrument of measurement. Comparisons between several type of hospitals, date of construction, planimetric development, etc., are encouraged. This first line of research will be particularly important in terms of dissemination and will make the results accessible to a broad audience. Second, the most recurrent topics throughout the literature might be investigated to test whether they are able to objectively increase the sustainability or the health-related outcomes in several empirical settings. Finally, similar inquiries might be conducted on other high-performance environments, such as office

buildings or residential or commercial spaces. These three research lines will be followed by the authors in the near future.

5.4. Limitations

The research has limitations. First, this review did not use two independent reviewers to conduct the study search, selection, and evaluation, but only one researcher, supervised by a doctoral advisor, who is an expert on the topic. Then, the selection of this period of time is intentional but might have led to exclusion of relevant contributions, as well as the inclusion of POE protocols, LCA tools, or other instruments that might have led to different results.

Finally, the analysis has been conducted at the indicator level, but deeper considerations might emerge when approaching single items of measurement, or even case study applications.

Approaching this topic is challenging because it touches very different fields of study, i.e., POE, IEQ, EBD, sustainability, architecture, Project Appraisal (PA), Real Estate (RE), Facility Management (FM) Environmental Psychology, and Usability. Although this multidisciplinarity might lead to missing of relevant contributions, we do think that the methodology adopted in the search phase is structured enough to overcome this potential problem.

Supplementary Materials: The following are available online at http://www.mdpi.com/2075-5309/9/4/76/s1, Table S1: List of POE studies on healthcare facilities, Table S2: List of the 44 tools found in the review, Table S3: List of the 13 tools included in the review and their main characteristics, Table S4: Relationship between EBD dimensions and tools' indicators, Table S5: Indicators divided per categories and subcategories.

Author Contributions: A.B. and S.C. planned the investigation. A.B. conducted the literature search and the instruments collection and drafted the manuscript. S.C. supervised the whole process, reviewed the collected instruments, and critically reviewed the content of the manuscript. Both approved the final submitted version.

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