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Integrative Review about Life-Cycle Cost Approaches in Healthcare Units: Evolution, Limits and Reflections for Public Health in Brazil

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Abstract

The objective of this study is to review the Healthcare Units (HU) life-cycle cost approaches with an emphasis on the project process, life-cycle cost, actors and measures to save resources. It was a systematic integrative review whose search syntax expressed the poles (phenomenon, population and context) of the question. The Virtual Health Library (VHL) portal was used, which gathers 29 databases, with the time limit from 1977 to 2017 and in Portuguese, English and Spanish. All types of manuscripts and methodologies were included. As gray literature, publications from the Ministry of Health of Brazil about the object were collected and the narrative method was used to synthesize the data. A total of 18 texts were included, all foreign, covering different approaches. Case studies predominate, especially in hospitals, with a description of more efficient systems and intervention strategies. The concept of "life-cycle cost" of the building, although explicit in a few texts (22%), guides decisions and interventions aimed at recovering investment in the operation, despite the fact that many are focused on environmental criteria. It was noticed that the economic context is the major driver of measures aimed at operational rationalization in buildings. Only three Brazilian publications are consistent with the evolution of discussions abroad. It was found that the HU life-cycle approach is still mostly restricted to recovering the initial investment in the operation phase. The discussion in the Brazilian Unified Health System (SUS) is incipient and it is necessary to face problems related to the lack of tools and information to the design and management processes of the structure of this equipment.

Keywords

Facility Design and Construction, Brazil, Health Resources, Rationalization, Publications, Health Care Costs, Conservation of Natural Resources, Unified Health System

1. Introduction

Unlike the health area, in which the concept of "life-cycle" refers to living organisms and their "life courses", in civil construction the same term is associated with the various phases related to the life of a building, allowing it to be analyzed them over time, assessing performance and quantifying impacts and costs.

In turn, the Life-cycle Cost (LCC) refers to the total cost of ownership over the entire life of an asset. Typically, the included cost centers refer to planning, projects, land acquisition, construction, operation, maintenance, renovations, recoveries, depreciation, financial cost of capital and disposal (ISO 15686-5, 2017).

When conceptualizing Healthcare Units (HU), it is referring to all the physical structures of the health care units (primary, medium, and high complexity care) of a health system. In this sense, before studying the cost itself of these health units (which vary a lot from the point of view of the care profile, generating comparison problems) it is necessary, first, to understand how the cost of their existence is approached during their useful life, that is, how the life-cycle cost is approached.

The so-called "Sitter's Law" (Sitter, 1984) presents the evolution of costs related to reinforced concrete structures in buildings, allowing the extrapolation of logic to other construction subsystems. According to the aforementioned law, the intervention costs to achieve a certain level of durability and protection increase progressively the later this intervention is. Considering the periods of design, execution, preventive maintenance and corrective maintenance, the cost evolves according to a geometric progression of ratio five at each subsequent stage.

Healthcare units have a peculiar need to continually adapt to technological advances in the sector. Technologies, equipment, and systems incorporated into the building can reflect new spatial dispositions and demands, so that flexibility for future adaptations must be considered in planning. Karman (1995) advocates a vision of predictive architecture that is available for transformations. In this sense, the HU should be designed thinking, also, of future readjustments from the assistance point of view for the execution of public policies in different circumstances.

With the improvement of the architectural design process incorporated into these new guidelines and requirements, buildings now assume their potential to

promote humanization in health, ensuring higher quality of care, favoring good practices and enabling greater efficiency in processes (Figueiredo, 2008). It should be noted that HU are, ultimately, spaces for the production of subjectivities within the scope of health work (Ministério da Saúde, 2010), and, therefore, should also take this aspect into account.

The life-cycle of a building has a strong interaction with the discussion of sustainability, considering the impacts produced throughout its phases, which can be quantified by the methodologies of Life Cycle Assessment (LCA) (Froehlich, 2014; Sampaio, 2005). For this reason, the costs that they mean for health systems in general should be brought to the discussion of HU, especially those that are experiencing moments of disinvestment (Mendes & Carnut, 2019), as in the case of the Unified Health System (SUS) in Brazil.

Some evidence shows that the physical structure of health services in Brazil has some weaknesses. The data systematized by Bousquat et al. (2017) of the National Program for Improving Primary Care Access and Quality (PMAQ-AB) demonstrate that "facilities and supplies" was the worst-assessed dimension. A review conducted by Nascimento, Santos and Carnut (2011) on the difficulties inherent to the operationalization of actions at the level of primary care point out the structure of the units as the main problem.

With regard to secondary and tertiary care, Gusmão-Filho, Carvalho and Araújo-Júnior (2010) realized that the physical structure of hospitals was compromised especially in the absence of support rooms for family members and an ombudsman room. Ribeiro, Gomes and Thofern (2014), on the other hand, regarding the ambience of a pediatric intensive care unit, report how architecture itself should be considered to provide well-being to children.

For these reasons, architecture is relevant in this debate. When it comes to ambience, not only is the perspective of service comfort in terms of sound, color, lighting and aesthetics, but space should also be discussed as a facilitator of the work process, that is, a physical space that provides the meetings in their multiple intentions (Massaro, Barros, & Pessati, 2011; Donabedian, 1988).

Considering the problem of SUS de-financing in Brazil and the need for better application of available resources in the long term through the qualification of investment in the physical structures of the units, the present study aims to raise the state of knowledge related to the theme, reviewing what the literature has produced in recent decades on approaches to the cost of HU throughout its life cycle.

2. Method

2.1. Objective

It is an integrative literature review (Soares et al., 2014) with the objective of raising the state of knowledge regarding the life-cycle cost approaches of HU, reviewing what the literature has produced in recent decades. The definition of

descriptors was made based on the questioning of the research "*What does the scientific literature present about the life-cycle costs approaches of healthcare units* (*HU*)?"

2.2. Data Sources and Research Strategies

The Virtual Health Library (VHL) portal (https://bvsalud.org/) was used as a database. The VHL portal presents 29 indexed databases in the health area with coverage in Latin America, Central America and the Caribbean, as well as some related to North America. Two reviewers conducted the review process.

Several descriptors were grouped related to four thematic poles of interest: 1) costs; 2) life cycle; (phenomenon); 3) healthcare units (HU) (population) and 4) SUS (context). Among the descriptors used, the following descriptors were found in DeCS (http://decs.bvs.br/), which derived from the key items of the question, which after several search strategy designs tested on the VHL Portal, and monthly meetings with the research group to discuss and reformulate the strategies of search, the following final syntax was reached: (*tw*:((*mh*:("*analise de custo em saude*")) *OR* (*mh*:("*investimentos em saude*")) *OR* (*mh*:("*gastos em saude*")) *OR* (*mh*:("*financiamento de construcoes*")) *OR* (*mh*:("*custos e analise de custo*")) *OR* (*mh*:("*organização do financiamento*")) *OR* (*mh*:("*gastos de capital*")) *OR* (*mh*:("*financiamento de capital*")) *OR* (*mh*:("*custos hospitalares*")) *OR* (*mh*:("*reducao de custos*")) *OR* (*mh*:("*economia hospitalar*")))) *AND* (*tw*:((*mh*:("*conservacao dos recursosnaturais*")) *OR* (*mh*:("*conservacao de recursos energeticos*")) *OR* (*mh*:("*consumo de energia*")) *OR* (*mh*:("*energia renovavel*")) *OR* (*mh*:("*ar condicionado*")) *OR* (*mh*:("*uso eficiente da agua*")) *OR* (*mh*:("*indicadores de desenvolvimento sustentavel*")) *OR* (*tw*:("*ciclo de vida*")) *OR* (*tw*:("*life-cycle*")) *OR* (*tw*:("*life cycle*")))) *AND* (*tw*:((*mh*:("*arquitetura hospitalar*")) *OR* (*mh*:("*arquitetura de instituicoes de saude*")) *OR* (*mh*:("*arquitetura*")) *OR* (*mh*:("*construcao de instituicoes de saude*")) *OR* (*mh*:("*edificios*")) *OR* (*mh*:("*construcao*")) *OR* (*mh*:("*tamanho das instituicoes de saude*")) *OR* (*mh*:("*instalacoes de saude*")))).

When working with the final syntax described above, 76 studies were identified (tested at Sept.19th of 2020), all foreign, produced between 1977 to 2017. From available titles and abstracts, it was found that several were not of the theme (63 publications). It is also noteworthy that several texts had no summary, despite having titles related to the topic. For these reasons, it was decided to check the availability of the results, online and in the physical collection of the Faculty of Public Health of the University of São Paulo, prior to the application of exclusion criteria (unavailability open access), obtaining 36 results (**Chart 1**).

Of these, peer review was carried out through a consensus meeting between the two independent reviewers on whether or not to include the 36 studies. After this analysis, of the 36 studies, 17 of these had a summary and the other 19 studies only had the full text for evaluation. The inclusion of the research theme and the possibility of answering the question was a condition for inclusion. Due

Chart 1. Remaining studies identified after the exclusion criterion was applied. 2019.

N.	Authors	Year	Title	Journal
1	Vick, JHI	2017	Solar power reduces operational cost for medical office buildings	MGMA connexion
2	Van der Zwart, J; Van der Voordt, TJM	2016	Adding Value by Hospital Real Estate: An Exploration of Dutch Practice	Health Environments Research & Design Journal
3	Thompson, JE; Ferenc, J	2014	A sustainable mission: Gundersen nears total energy independence	Health facilities management
4	Lorenzi, N	2014	Light wave: energy savings, long life and quality of light drive LED adoption	Health facilities management
5	Carvalho, M; Lozano, MA; Ramos, J; Serra, LM	2013	Synthesis of trigeneration systems: sensitivity analyses and resilience	The Scientific World Journal
6	Ferenc, J	2012	The incentives continue to grow for hospitals to reduce their impact on the environment.	Health facilities management
7	Lorenzi, N	2012	Lighting it up. LED fixture manufacturers target health care facilities	Health facilities management
8	García Sanz-Calcedo, J; Cuadros, F; López Rodríguez, F	2011	La auditoría energética: una herramienta de gestiónenatención primaria	Gacetasanitaria
9	Mróz, TM	2010	Multicriteria aided design of integrated heating-cooling energy systems in buildings	Journal of the Air & Waste Management Association
10	Ivy, R	2009	What will happen to Charity Hospital and other endangered projects? A fresh look at the state of historic preservation.	Architectural Record
11	Houghton, A; Vittori, G; Guenther, R	2009	Demystifying first-cost green building premiums in healthcare	Health Environments Research & Design Journal
12	Kahn, N	2009	Healthcare-tides of change	Health Environments Research & Design Journal
13	Vernon, WN	2009	Keeping green: reducing energy consumption without harming the budget	Journal of healthcare management
14	Serb, C	2008	Think green	Hospitals and health networks
15	Schulte, MF	2008	Green hospitals: Improving the workplace, saving money, and healing the earth	Frontiers of health services management
16	Hospitals and health networks [Editorial Team]	2007	Infection prevention, energy savings top construction trends.	Hospitals and health networks
17	Romano, M	2007	Good as gold. Fort Knox military hospital sees strong return on investment from its focus on energy conservation, facility modernization	Modern healthcare
18	Tsilemou, K; Panagiotakopoulos, D	2006	Approximate cost functions for solid waste treatment facilities.	Waste management & research
19	Williams, CJ; Lerouge, F	2005	Elegant solution. Chiller project addresses capacity and aesthetic concerns	Health facilities management

Continued

20	Wang, JY; Touran, A; Christoforou, C; Fadlalla, H	2004	A systems analysis tool for construction and demolition wastes management	Waste management
21	Swenson, G	2004	Energy demand: a facility manager tells how he is complying with a state energy mandate	Health facilities management
22	Christen, K	2004	Federal buildings increasingly going green.	Environmental science & technology
23	Lanser, EG	2003	Maximizing the value of your facilities projects. Focusing on life-cycle costs will benefit your organization long-term	Healthcare Executive
24	Basdere, B; Seliger, G	2003	Disassembly factories for electrical and electronic products to recover resources in product and material cycles.	Environmental science & technology
25	Runy, LA	2003	The data page. Heavy user	Hospitals and health networks
26	Halim, I; Srinivasan, R	2002	Integrated decision support system for waste minimization analysis in chemical processes	Environmental science & technology
27	Najm, MA; El-Fadel, M; Ayoub, G; El-Taha, M; Al-Awar, F	2002	An optimisation model for regional integrated solid waste management I. Model formulation	Waste management & research
28	Mancl, K	2002	Model for success in on-site wastewater management	Journal of environmental health
29	Akbari, H	2002	Shade trees reduce building energy use and CO_2 emissions from power plants	Environmental pollution
30	Quayle, C	1998	It's easy being green. Need an energy-saving partner? Call the EPA.	Health facilities management
31	Dix, A	1998	Buildings. More bricks than kicks	Health service journal
32	Crawford, G	1995	Steel can recycling: how to cut costs and support the environment	Healthcare Foodservice
33	Mullen, P D	1983	Implementing asthma self-management education in medical care settings-issues and strategies	Journal of allergy and clinical immunology
34	Hall, B G; Stauffer, H	1980	HCA uses team to cut energy costs	Hospitals
35	Hospital [Editorial Team]	1977	Hospital meets criteria for phased growth, low life-cycle costs, operational flexibility	Hospitals
36	Duffie, JA	1976	Solar heating and cooling	ISA Transactions

Source: Authors themselves.

to the characteristics of publications in the area of architecture, many articles did not have abstracts. If we excluded articles for lack of abstracts, we would have a huge loss of material for analysis. In addition, we would go against the tradition of research in the field of architecture. With these requirements, at the end 18 results were included in the review. The literature selection process is described in a PRISMA flowchart (**Figure 1**). No contact was made with the study authors to identify additional studies.

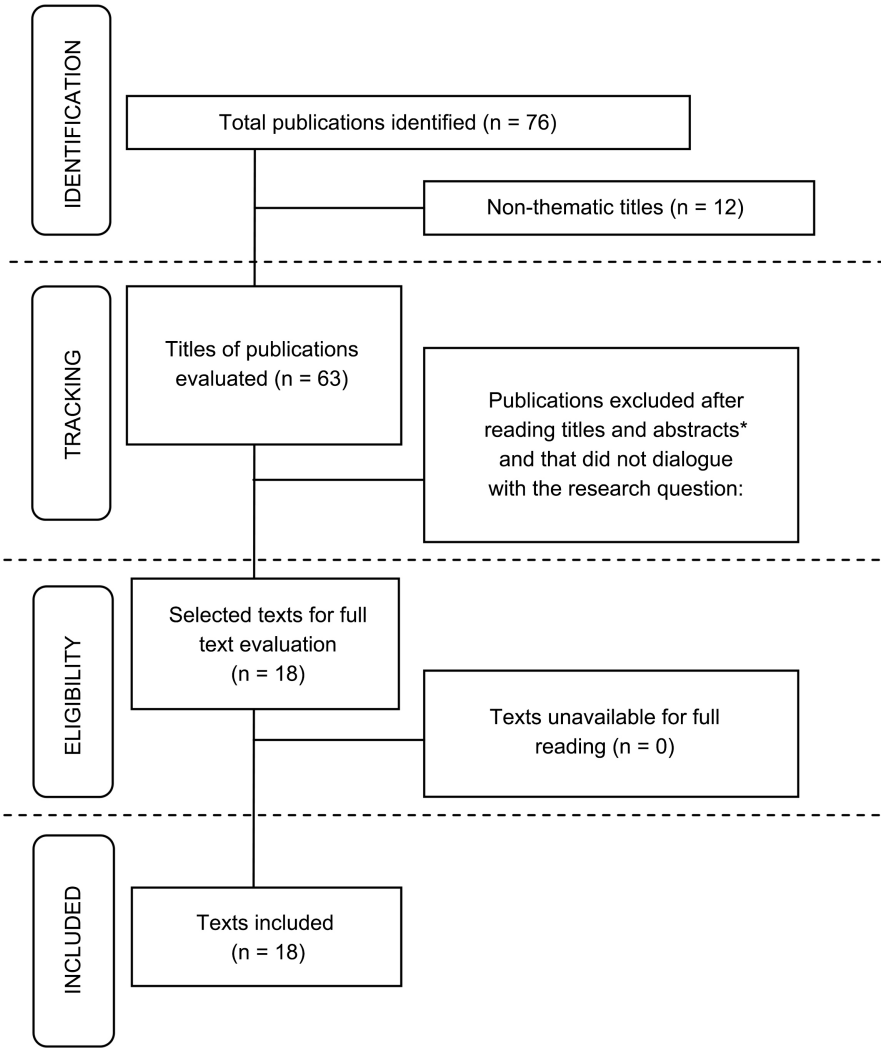

Figure 1. Flowchart of the selection process of the articles included in the review on the approaches to the cost of the life cycle of Healthcare Units. *We included studies that did not present an abstract, reading them in full (when the title was not self-explanatory).

In an attempt to articulate the knowledge reviewed in this study with its possibility of application in SUS in Brazil, the collection of gray literature was carried out on the website of the Ministry of Health of Brazil that presented a relation as a theme. Thus, three publications of the Ministry of Health were identified, located in their thematic virtual libraries, so all the means of search to identify the texts related to the research question were used within the proposed scope.

2.3. Data Analysis

The data analysis process followed the update of the integrative review method, including the steps of data extraction, display, comparison and conclusions. Data extraction was completed independently by 2 reviewers (E.R.S. and L.C). The data extraction form was designed based on the research questions. The ex-

tracted data include the author (year of publication), structure and methodology used, main points, approaches to costs, projects, actors and ways of saving (Chart 2). The data synthesis was presented narratively. This modality was chosen because the typology of the manuscript, the research methods and results presented were quite different and also applied to different types of HU. The de-standardization of the included articles was a consequence of the writing format of the interface between three fields (architecture, economics and health), which made it impossible, therefore, to analyze biases and methodological quality, making this procedure not applicable. The strength and quality of the evidence also suffered from the same problem previously mentioned.

3. Results and Discussion

3.1. Evolution of the Theme and Its Limits

All texts are foreign, produced between 1977 and 2017. Sixteen were published in the United States, one in Spain and the other in the Netherlands. Regarding the means of publication, with the exception of the Spanish text, which was published in a scientific journal, the others come from journals specialized in hospital management or in the real estate sector focused on health. Thus, 83% (15) of the included studies are in the form of reports and only 17% (3) are surveys that explain the methodology employed, whether performing energy audits in HU based on a script (Sanz-Calcedo, Cuadros, & Rodríguez, 2011), combining the literature review related to theme with project assessment (Houghton, Vittori, & Guenther, 2009) or interviews with those responsible for the construction and operation of a set of HU (Van der Zwart & Van der Voordt, 2016).

As for the type of HU, with the exception of one study that addresses the level of primary care (Sanz-Calcedo, Cuadros, & Rodríguez, 2011), all texts refer to hospitals, with only one of them highlighting that the sector covers a variety of types of construction, with differences in size, intensity of consumption of resources and program complexities (Houghton, Vittori, & Guenther, 2009).

Some authors present a traditional view of the hospital as equipment unrelated to sustainable principles, due to the intense consumption of resources and impacts on the environment and the local community. A survey (Ruby, 2003) on energy consumption in different types of buildings in the USA (measured in trillions of BTU) shows that the total of HU accounts for the fourth largest consumption in the country (515), behind office buildings (1089), commercial (724) and educational (649). When the total consumption is divided by the number of existing establishments (in millions of BTU), the HU with hospitalizations largely exceed any other type of building (35.8), such as commercial buildings (3.49). Another article (Serb, 2008) highlights the impact caused by the operation of air conditioning systems and equipment 24 hours a day, intensive use of plastic and disposable packaging, incinerators, waste and contaminating substances.

Chart 2. Characterization of manuscripts included by article structure, method used, life cycle approaches and main measures to resources savings in HU. 2019.

Authors - Year	Structure and methodology used	Main points	Project process approach	Life-cycle Cost approach	Actors approach (patients, workers and community)	Main measures to save resources
Van der Zwart J; Van der Voordt TJ, 2016	Study. Interviews with hospital project directors and leaders regarding a set of values present in HU projects, previously extracted from the literature.	How hospital properties can add value to the healthcare organization, which values are prioritized in practice and why.	Survey of guiding values in decision making and how they are physically reflected in the project.	The prioritized values proved to be different in the different phases of the life cycle, that is, between the phases of initiation, design and use of the building.	Support for the patient's needs and well-being, facilitated health processes, productivity and team satisfaction, support for the multidisciplinary organizational culture and work processes focused on the patient.	Based on the interviews, it presents an impact matrix with design decisions for saving water and energy; alternative energy sources; greater efficiency in air conditioning and material specification.
Lorenzi, 2014	Article. Describes the operation and benefits of LED lighting technology.	Energy efficiency, light quality, installation and maintenance flexibility and infection control.	-	Restricted to recover the initial investment in the operation phase.	Patient satisfaction and well-being, greater efficiency in tasks	Replacement of other LED lighting systems, combined with drive controls and sensors.
Thompson JE, Ferenc J, 2014	Article. Interview CEO of a hospital. Description of an intervention case and interviewee's reports.	Energy efficiency, with reduced consumption and local generation with renewable sources.	Restricted to investment in the technical engineering team and evaluation of alternatives.	Restricted to recover the initial investment in the operation phase.	Excellence in patient care. Hospital's role focused on community education and well-being.	More efficient design and construction; energy conservation using renewable sources and selling the surplus produced.
Ferenc J, 2012	Article. Interviews experts and managers, citing studies and programs from third parties.	Sustainability. Measurement of the quality of cost decisions.	As a requirement to achieve aggressive sustainable goals, aimed at more efficient systems and the adoption of passive strategies.	Restricted to recover the initial investment in the operation phase.	Portrait of the hospital's mission, focused on the well-being of the patient, workers and community.	Passive design strategies in the building envelope, reducing the need for artificial lighting and air conditioning; alternative energy sources, with the sale of the surplus.
Lorenzi, 2012	Article. Describes the operation and benefits of LED lighting technology.	Energy efficiency; better color reproduction; adjustment to the circadian cycle; less toxicity; installation and maintenance flexibility.	-	Restricted to recover the initial investment in the operation phase.	Patient well-being with the adaptation of lighting throughout the day and by environments.	Replacement of other LED lighting systems, combined with drive controls and sensors.
Sanz-Calcedo JG; Cuadros F; Rodríguez FL, 2011	Study. Assessment of the feasibility of energy auditing as a management strategy. Methodology: data collection; device location, inspection and analysis; quantification of total investment and payback period; and final report.	Audits in Spanish primary Healthcare Unit between 2005 and 2010, identifying concrete measures for intervention in order to reduce energy consumption.	It does not address directly. The description of intervention measures is restricted.	Restricted to recover the initial investment in the operation phase.	Internal management based on team awareness is seen as a zero-cost measure with the potential for savings.	Review of contractual conditions with the concessionaire; installation of power capacitors; updating of hot water, lighting, and air conditioning systems; adequacy of the envelope; adoption of renewable energies; and internal management.

Continued

Houghton A; Vittori G; Guenther R, 2009	Literature review on the cost of construction of "green" buildings. Survey of how much is spent on these projects. Due to the scarcity of specific studies in the health area, other types are used.	Incremental cost in the construction of "green" buildings in the health area.	With the sustainable objectives considered from the beginning, there is a tendency for costs to remain within budget; team with experience in the area to avoid higher initial costs.	Greater efficiency in the use of energy, water and materials, through better location, design, construction, operation, maintenance and removal. Reduction of impacts on environmental health.	Correlation between the "green" health project and the reduction in the patient's stay; greater productivity and staff retention; better perception and benefits to the community.	Use of wastewater and rainwater; more efficient air conditioning equipment; alternative energy sources; higher energy performance; sustainable materials; climate-appropriate wraps.
Vernon W, 2009	Article. Reports sustainability strategies.	Practical and low-cost measures for sustainability for implementation in hospitals, considering the reality of several institutions in the USA.	It does not address directly. It mentions operational monitoring and identification of areas for intervention.	Restricted to recover the initial investment in the operation phase.	Greater patient satisfaction and safety; better health results and professional retention; demanding users and community regarding the environmental responsibility of organizations.	Monitoring of consumption and comparison with *benchmarks*; optimization of operation and replacement of building systems; use of renewable energy; goal of reducing gas emissions.
Serb C, 2008	Article. Discusses sustainability and main strategies, presents the pointed barriers that discourage these measures and benefits identified in the organizations that incorporated the concept. It presents three cases of hospitals and indicates five strategies with generic application.	Sustainability as a guiding concept. Orientation of new projects based on savings obtained. Increasing costs and new technologies to be installed were catalysts for this movement, such as competitive advantage and market positioning.	Little emphasis. Projects inserted in the context of technological updating and in the identification of systems subject to greater energy efficiency.	Restricted to recover the initial investment in the operation phase.	Hospital as an educational space in the environment for workers and patients served; environmental quality for workers; leadership before the community.	Energy is strategic due to the possibility of expressive results even with smaller investments; alternative sources; efficiency in water consumption and air conditioning; materials less harmful to the environment, with simpler and more economical cleaning; reuse of demolition waste.
Schulte, MF, 2008	Editorial of a periodical written in first person. Author's position on the theme of sustainability.	Return on investments in sustainability as a means to its viability.	Radical changes in planning and projects in several phases. New BIM design tools.	Restricted to recover the initial investment in the operation phase.	-	-
Hospitals & Health Networks, 2007	Article. It addresses major trends in construction in the health area. Cites quantitative reports from third parties, briefly reporting on measures taken in four cases.	Projects with investments in sustainability and focused on infection control, marking a trend in the health area.	Decisions based on environmental certification criteria, process flows and financial performance.	Restricted to recover the initial investment in the operation phase. He argues that investments are profitable and paid for in a short time.	Expected improvement in processes and patient health. Search for evidence to validate strategies.	Motion sensors in taps, lighting and doors, combining savings and infection control; materials with antimicrobial surfaces.
Romano M, 2007	Article. It addresses the reform carried out in a hospital. When presenting national data, it positions the specific case in relation to the USA panorama at the time.	Cost reduction through energy efficiency.	It does not detail the design process. It highlights that at that time there was no LEED sustainability certification category for requalifications.	Restricted to recover the initial investment in the operation phase.	Priority of investments in operational efficiency in relation to the North American trend, at that time, of prioritizing amenities and technologies in environments.	Improvements in energy efficiency, air conditioning and envelope materials.

Continued

Swenson G, 2004	Article written by hospital director, reporting the experience in the organization. It presents a graph with results obtained and spreadsheets to calculate savings obtained used with employees.	Interventions to reduce energy consumption in existing buildings. Gradual investments and reinvestment of savings obtained.	It only mentions the management of improvement opportunities in existing buildings, with monitoring of results.	Restricted to recover the initial investment in the operation phase.	Raising workers' awareness of energy savings, data usage, customized calculation tools. Potentially benefited community through the reproduction of learning.	Technological update of the boiler, air conditioning and lighting systems. Window replacement as a passive strategy. In old buildings, adoption of more efficient solutions according to the need for maintenance and adaptations.
Lanser EG, 2003	Article. Interview with building systems specialist. Provides an approach to improve the organization's financial and operational performance.	Building systems design, with emphasis on operating costs.	Long-term evaluation should guide the project. This should be linked to the facilities master plan and integrated with strategic planning.	The concept should guide the project, with the evaluation guiding the decisions. It presents the information that 75% of the cost is in the operation phase.	-	Long-term plans, avoiding fragmented and reactive maintenance; greater control over costs and risks in contracts with third-party providers; results-based agreements.
Ruby, 2003	Article. Highlights the impact of HU energy consumption. It uses quantitative data and comparison with other types of buildings.	Possibility of reducing energy consumption by joining a government program.	-	-	-	Reduction of energy consumption; greater systems efficiency; adherence to the government's *Energy Star* program.
Quayle C, 1998	Article. Reports hospital adherence to an energy conservation program. It presents consumption reduction data and a simplified methodology for calculating the internal rate of return on investments.	Gradual upgrade of systems. Measures in line with the US Environmental Protection Agency's *Energy Star Building* program. Saving financial resources and reducing environmental impacts.	Intervention planning in five phases, with gradual disbursements, with a return on investments. Focus on decision makers based on the attractiveness of return estimates.	Restricted to recover the initial investment in the operation phase. Provides estimates of internal rates of return and risk factor.	-	Digital climate control; more efficient building systems; lighting as an initial target. Sequence of interventions initiated by the least costly, aimed at reducing the thermal load, finally updating air conditioning equipment.
Hall BG; Stauffer H, 1980	Article. Case report with company energy conservation strategy that controlled more than 170 hospitals of the USA. Displays consumption indicators per unit of floor area.	Reduced energy consumption for lower operating costs. Adoption of innovative solutions, some of which are not yet viable or have operational problems.	Internal team of professionals to identify needs and project guidance activities. Control and evaluation of construction quality, performed by third parties.	The evaluation of alternatives by the internal team and representatives of the architecture, engineering and construction companies occurs based on the life-cycle cost.	Highlights the support of management and workers to the team responsible for maintenance as a key point.	More efficient lighting, considering the work surfaces and coating materials of the environments; thermal insulation of the envelope; solar energy; harnessing the heat from incinerators.
Hospitals, 1977	Article. Reports characteristics and design strategies of a hospital completed in 1975.	Project methodology based on life-cycle cost assessment and operational flexibility.	Environment layout, possibility of modifications and resizing, according to flow criteria and specifications based on the life-cycle cost assessment.	Explicit concept in the text. Evaluation to specify materials, systems and components, aiming at lower operational cost, despite the higher initial cost reported.	Comfort and convenience for the patient; objective location criteria as a facilitator of work processes; good relationship with the community.	Streamlined construction with panels and *shafts* for installations independent of the structure; durable materials with low maintenance cost; greater efficiency of the heating system.

Source: Authors themselves.

The editorial of one of the magazines (Schulte, 2008) highlights that, in the same way that these HU have a negative impact, there is great potential to have a positive impact, pointing to the urgency for this change. From the various results raised, it is clear that over time the characteristics of HU, especially those of greater complexity, end up being taken as a justification for not advancing efficiency in building operations, considering solutions in this sense as well as complex and with restrictive costs.

Still in relation to energy consumption (measured per unit of built area), another author, when comparing two types of HU with office buildings, found that outpatient care has a demand similar to the latter, while in the hospital it was found twice as much, indicating the need to establish a basis of comparison based on programs and services (Houghton, Vittori, & Guenther, 2009). Another article presents this same relationship between consumption of hospital buildings and offices (Quayle, 1998).

It was possible to identify how certain issues have evolved over these decades. It is observed that the cost of energy was the first major driver of improvements and new practices aimed at greater economic efficiency in buildings. The first references raised are from the 1970s, in the context of the oil crisis (Hall & Stauffer, 1980). There are later references on the rising cost of energy (Serb, 2008; Hospitals & Health Networks, 2007) as well as the rising cost of the health sector (Schulte, 2008; Hospitals & Health Networks, 2007) and, even more specifically, the cost of incorporating new technologies (Serb, 2008). In the 2000s, an increase in the number of healthcare projects in the USA was identified, with large investments in construction starting in 2003 (Romano, 2007), extending until the crisis of 2008 (Schulte, 2008). This increase may reflect the end of the health facilities' useful life built between the 1950s and 1960s, in need of replacement or extensive requalification (Houghton, Vittori, & Guenther, 2009). After the 2008 crisis, incentives were identified through the allocation of billions of dollars in energy and environmental projects in the North American economic stimulus package (Vernon, 2009).

It can be observed, through the texts, that these economic aspects described start to be gradually articulated in the growing environmental and corporate responsibility discourse and that these principles start to guide projects. Other concerns such as saving water and improving aspects of environmental comfort in the project through materials and wrapping suited to the local climate are expressive, with a relevant impact on HVAC systems (Ferenc, 2012).

One of the studies (Houghton, Vittori, & Guenther, 2009) raises the fact that, despite the significant impact generated by the hospital operation, the concern with sustainability in the HU initially had a slower pace compared to other sectors, such as office buildings and other types of services. This same study identified a jump in the number of companies in the health area that would meet a criterion to focus on this type of project (minimum 30% of "green" projects), with a jump from 4% to 19% in works started between 2006 and 2008.

An article (Serb, 2008) investigates the factors identified by managers as barriers to the implementation of sustainable measures. It was identified that those related to impeding costs were the most mentioned, such as high initial costs (78%), higher costs in relation to traditional buildings (73%), other investment priorities (72%) and deadline for their return (47%).

One of the studies (Houghton, Vittori, & Guenther, 2009), when carrying out a bibliographic review regarding the construction costs of "green" buildings and comparing projects from different years, identified evidence that over time there is a tendency to reduce incremental costs linked to sustainable techniques, among other reasons by reducing the price of new materials and systems. Other evidence indicates that for buildings in general, not necessarily HU, there is an increase in the cost of about 2% when incorporating ecological solutions, arguing that only the return obtained with energy savings would already make the investment feasible. In hospitals (Hall & Satuffer, 1980; Thompson & Ferenc, 2014) with conventional characteristics, there is a result of up to 39% less energy without resorting to cutting-edge devices (Lanser, 2003). The application of proven systems engineering design techniques would have been the solution.

Two articles specifically address LED (Lorenzi, 2012) lighting technology. The LED is highlighted as a more energy efficient system, with longer life and less maintenance. Even so, its combination with presence monitoring and automation measures is seen as a means to expand the benefits of the economy (Lorenzi, 2014).

Regarding HU in operation with obsolete systems, one author (Swenson, 2004) reports the strategy of identifying and managing possibilities for improvements such as sustainability and conservation of resources and energy audit (Thompson & Ferenc, 2014), identifying potential high impact and low cost strategies (Serb, 2008) and that their periodic performance is a managerial element that allows systematization and continuous knowledge of the functioning of HU (Sanz-Calcedo, Cuadros, & Rodríguez, 2011).

The Spanish study (Sanz-Calcedo, Cuadros, & Rodríguez, 2011) points out that the energy audit helped to identify that air conditioning absorbs 52% of the annual energy demand, lighting 30%, hot water 8% and other equipment 10%. Eight concrete measures for intervention were identified, ranging from contractual renegotiation with the energy concessionaire and internal management with employees, without requiring investments.

Unlike most recent results, the two articles from the 1970s and 1980s are more restricted to economic and operational aspects, not yet marked by the "sustainable approach" present in most texts. One of them (Quayle, 1998) reports difficulties in the incorporation of technologies considered eccentric at the time: production of solar energy and use of the heat generated in incinerators. These were applied only punctually to the network of 170 North American hospitals controlled by an organization, with a long period of return on investment (20 years) for solar energy and operational problems in the incinerator.

In a more recent Dutch study (Van der Zwart & Van der Voordt, 2016), flexibility is still presented as an important project requirement, considering expansions and relocations throughout the operation. It is noteworthy the difficulty of the architectural project to strictly express the organization's vision, considering the passage of time, since over the period for which the building was designed, there will probably be changes in the management structure and style, objectives and vision on how to organize processes.

Back to the operation phase, an article (Lanser, 2003) highlights the importance and impact of building systems in HU. According to the author, 75% of the expenses occur right after the construction of the building, which is why it emphasizes the great importance of due planning and evaluation, since decision making based on initial costs is common, which adopted in a restricted way can lead to greater expense throughout the operation.

Some articles stand up for the articulation of operational aspects of buildings with the more general strategies of health organizations. For building systems, an assessment approach focused on the long term is presented, which starts from a master plan integrated with planning (Lanser, 2003; Ferenc, 2012), including at its strategic level (Serb, 2008; Hall & Stauffer, 1980; Thompson & Ferenc, 2014).

Some authors highlight the social dimension related to the hospital, with its role before the community, starting from the mission of providing well-being (Ferenc, 2012; Thompson & Ferenc, 2014), improving the perception of the benefits generated (Houghton, Vittori, & Guenther, 2009) and even the possibility of exercising local leadership in the environment from example (Serb, 2008). In addition to the discourse of organizations and concepts incorporated by senior management, some authors reveal that the present issues are reflected with health professionals as gains in the organization and facilitation of processes (Van der Zwart & Van der Voordt, 2016; Hospitals, 2007), greater productivity and staff retention (Houghton, Vittori, & Guenther, 2009), well-being (Ferenc, 2012) and going a little further, as an educational space in the environment, both for professionals and for assisted patients (Serb, 2008).

When mentioning the relationship between architectural design and patients, some articles deal with aspects more linked to comfort and convenience (Hospitals, 2007), the consideration of their circadian rhythm for adjusting lighting (Lorenzi, 2012), the focus on patient health and well-being as an objective to be achieved, this arising from the mission of these institutions (Ferenc, 2012), and the possibility of obtaining positive impacts on work processes as a way to better serve you (Van der Zwart & Van der Voordt, 2016; Hospitals & Health Networks, 2007).

One author (Romano, 2007) stands out in the group for presenting a counterpoint to the trend of investments aimed at amenities and technologies in the accommodation of patients, in a context of overvaluation of hospital hotels and expansions, in the boom of the sector in mid-2006, reporting energy efficiency as north in the requalification of a hospital.

In general, articles that do not explicitly bring the term "life-cycle cost" end up dialoguing with the concept, albeit superficially, by pointing to the projection of lower expenses in the operation of buildings based on more efficient project decisions from the point of view, economic view, often more costly, with recovery of initial investment.

Another approach to the issue, more focused on convincing decision makers, is presented by one of the authors through a simplified calculation to estimate the internal rate of return on investment in energy efficiency. It points to rates varying between 20 and 30% and a risk factor of around 0.75, comparing them to those of investments in government bonds and stock exchanges (Quayle, 1998). The synthesis of these elements is summarized in **Chart 3**.

3.2. Reflections for Public Health in Brazil

To complement the foreign texts recovered in the systematized search, the Ministry of Health's production focused on the aspects of costs, efficiency and life cycle of HU that could help to think how these data, from different socioeconomic contexts, can dialogue with the approaches of HU in SUS.

Chart 3. Details of the measures adopted or described in the manuscripts to save over the life cycle of the HU. 2019.

Author, Year	Measures adopted or described						
	Water	Energy	Acclimatization	Waste	Alternative energy sources	Construction material	Building envelope
Van der Zwart J; Van der Voordt TJ, 2016	Yes. In the impact matrix.	Yes. In the impact matrix.	Yes. In the impact matrix.	Yes. In the impact matrix.	Yes. In the impact matrix.	Yes. In the impact matrix.	Do not quote.
Lorenzi, 2014	-*	Yes**	-	-	Yes	-	
Ferenc J, 2012	Yes. The main way to save money is to reduce the need for heating, in addition to reuse and rainwater, low-flow taps.	Yes. Efficient lighting, high efficiency electric motors, occupancy sensors.	Yes.	Yes. Selective collection and composting of organics.	Yes. Solar. Produce and even sell surplus to the network.	Yes.	Yes, mass and orientation to obtain natural light. Passive design strategies.
Houghton A; Vittori G; Guenther R, 2009	Yes. Water reuse, more efficient equipment. Rainwater harvesting.	Energy efficiency. Usually the first place that building owners - including healthcare executives - look for a measurable return on investment in green building strategies.	Yes.	-	Yes.	More sustainable.	Yes.

Continued

Serb C, 2008	Just quote.	Yes. Strategic point to save and be more sustainable and can be understood as a starting point. Expressive results can be achieved even with smaller investments, such as equipment maintenance and presence monitoring. Achieved savings can be reinvested in further improvements.	Yes.	Recycling and demolition waste.	Yes, wind, geothermal and hydroelectric.	Specification of less toxic. In addition to easier and more economical cleaning materials.	No.***
Hospitals & Health Networks, 2007	Yes. Associated with infection control.	Yes. Associated with infection control.	No.	No.	No.	Yes, development of PVC-free carpet. And antimicrobial surfaces for the purpose of educing infections.	No.
Romano M, 2007	?****	Yes.	Yes.	No.	No.	No.	Yes.
Lanser EG, 2003	Yes.	Yes.	Yes.	No.	No.	No.	No.
Hall BG; Stauffer H, 1980	Not directly	Yes. Task-focused lighting, more luminous efficiency systems	Yes. Higher efficiency in HVAC, and in the envelope. Turning off ventilation after hours of use.	No.	Yes. Solar energy and heat recovery from waste incinerators are examples of other more exotic ways of conserving energy that have been tried on an individual hospital basis. The measured results of the solar energy system show savings of 3.500 gallons of fuel oil per year.	Yes. Internal wall and floor coverings were selected to improve reflection and light distribution.	Yes. Wall and roof insulation, window sizes, detachable panels
Hospitals, 1977	No.	Yes.	Yes.	No.	No.	Yes.	Yes.

Source: Authors' elaboration. *-: does not present the information in the manuscript; **Yes: it just signals that this measure is important or should be considered; ***No: does not signal that this measure is important or should be considered; ****?: information is doubtful.

Regarding the dissemination of information in Brazil by the Ministry of Health, it is worth mentioning the existence of a relevant information bank, SOMASUS (System of Support for the Elaboration of Investment Projects in Healthcare) (Brasil, 2018), with contributions more focused on dimensioning environments and services, specification of equipment, furniture and permanent materials and operational flows.

The ministry also provides thematic areas of Architecture and Engineering in Health at the Virtual Health Library (VHL), with its own and third-party publications. Despite having the same name and the identification of the VHL, different forms of access were identified, from the SOMASUS (BVS, 2018a) page, with 58 titles, and from the main VHL page of the Ministry of Health (BVS, 2018b), with 276 titles. It was found that the titles differ between both and that the latest updates were carried out respectively in 2013 and 2015, not following the pace of evolution verified by the integrative review.

It is noteworthy that, despite the studies of Architecture and Engineering in Health being in the thematic area of the Ministry of Health in the VHL, the publications are not indexed in the Regional Portal of the VHL, while the studies in the thematic area of Health Economics have not been recovered in the systematic search due to the descriptors used (lack of descriptors in the "costs" or "life cycle" hubs).

In relation to the hypothesis that national studies in this area would still be incipient, the oldest publication raised, from 1995, is introduced pointing out the objective of "filling a large gap in the specialized bibliography available for architectural projects in complex functions, specific to the area of health." (Brasil, 1995: p. 5). This study focuses on the impact of architectural decisions on costs in hospital projects, through the author's previous experiences in the area of costs. From this study, the author makes considerations about the costs, mainly of construction, resulting from the arrangement of the vertical, horizontal plans, heights, dimensioning and format of environments and circulations, making some considerations on operational costs.

By subdividing hospital buildings into two basic parts, one corresponding to the built spaces and the other to the equipment necessary for the building to fulfill its function, it highlights the great impact of the facilities on the total costs, affecting, on average, 40% of the construction cost, being even more relevant in the maintenance cost, pointed, on average, as 70%. It highlights the fact that the maintenance of these systems is usually corrective, and, therefore, additional design care must be taken. It is observed that despite the focus on hospitals, the applicability of the concepts presented is valid for other HU programs.

Other ministerial publications on the subject are more recent and were found in the virtual library of Health Economics (VHL) (BVS, 2018c). Among a set of publications focused on Health Economics for SUS Management (ECOS Series), texts were identified that address operational aspects of HU. One of the publication's chapters on diagnostic tools for investment qualification is dedicated to

the indirect costs of physical infrastructure in primary care (Brasil, 2015a). The text adopts a methodology whose initial reference was the minimum structure for Size I BHU projects.

From SOMASUS, equipment were collected, including air conditioning in some environments, water and lighting points, establishing a profile of electricity and water consumption based on the expected number of services. Average data on the cost of electricity (R$/kWh) and water (R$/m^3) were collected at the national level and by Brazilian region between the years 2010 and 2011. Among these two items, it was found that energy has a greater weight, 86.94%, and water represented the remaining 13.06%. It is noteworthy that despite the differentiated tariff survey, for the establishment of the consumption profile, regional aspects were not considered, which may affect more or less intensity of use of air conditioning, artificial lighting, and water, for example.

Another publication of the ECOS Series is focused on the qualification and sustainability of HU (Brasil, 2015b) constructions, with a focus on efficiency in energy consumption, natural resources and waste production. In addition to sustainability, the publication highlights the emergence over the last two decades of new issues such as the humanization policy, the incorporation of the concern with the accessibility of physical spaces and the accreditation process of the units, emphasizing that the biggest challenge would be in quality investments, so that it is not enough to have sufficient resources for the construction of HU if care is not taken to ensure the sustainability, humanization and maintenance of these spaces.

The publication highlights an initiative to evaluate project proposals submitted to the Ministry of Health between 2010 and 2011. During this period, approximately 950 projects financed by the National Health Fund were analyzed to see if they followed any type of sustainability concept and whether its structure contributed to the economy of the resources invested in the maintenance of buildings. It was found that most of the projects analyzed were not in accordance with the applicable standards and that, in general, they did not foresee the adoption of sustainable solutions, even with the growing trend of their incorporation in the constructions, a fact that supported the presentation of the information.

In the specific context of SUS, understanding health care as a social right, one can dialogue with the concept of viability, less as a condition and more as an objective to be pursued for the sustainability of the system, facing the existing barriers related to the lack of financing and weak management, identified in the lack of coordination between managers, technical bodies, planning and decision-making. As the planning approach that considers HU throughout its life cycle is quite incipient, the question arises: to what extent budget constraints in the context of the Brazilian public system drive investment qualification, as defended and reported as "opportunity" by some authors in foreign systems, or further compromise the application of resources, given the lack/failure of tools,

information and design and management processes, reinforcing their focus on disconnected, emergency and unplanned activities? This appears to be an open research agenda.

3.3. Implications for Public Policy

Despite the fact that building life cycle cost approaches are a recurring theme in the engineering and architecture literature, little is produced with regard to Healthcare Units (HU). The state of science has made few contributions in this regard, which makes the topic a gap in knowledge in the area of health economics to be investigated.

The life cycle, like this procedure of formally analyzing the complex interaction of a system—which can be a material, a component or a set of components—is still restricted. Considering how the environment throughout its life cycle, characterizing what has become known as the "cradle-to-grave" approach is not recurrent, which characterizes yet another challenge to this theme.

From the point of view of the implications for public policies, this study consolidates important evidence to think about how the approach to the life cycle cost of these buildings is still restricted to the recovery of the initial investment in the operation phase and largely disregards the quantification of uses of energy and matter and environmental emissions; the environmental impact of these uses of energy and matter and emissions; opportunities to make environmental improvements; the extraction and processing of raw materials; manufacturing, transportation and distribution; use, reuse, maintenance; recycling and final disposal (demolition).

In this sense, it is worth mentioning that, for the better use of Healthcare Units, the practice of the public manager must recommend the life-cycle cost as an important information in budget planning, especially when it is intended to expand the health service network. Estimating these costs is not just an academic exercise, but allows us to have a long-term view of the physical structures of the services, helping to re-adapt them from the point of view of their care profile and their economic sustainability during various political moments of health policies in different governments.

3.4. Limitations

The limitations of this review are the relatively low level of evidence in most studies, which were case report studies, interviews or reports (level 5) (Souza, Silva, & Carvalho, 2010). Although the methods are adequate to answer the questions of the integrative review, the methodological characteristics of the reviewed studies have implications for the results presented. In addition, the way the results are presented by the reviewed studies affects the integration of the conclusions in this study. This generated a level of disaggregation that hindered the synthesis of these studies.

3.5. Advances of This Research

Still, it is pertinent to remember that the great novelty of the study is related to the fact that the literature on collective health has not focused on the study of the architectural elements of the Healthcare Units and, very little on their costs. It is no wonder that, in Brazil, this study complies with the National Agenda of Priorities in Health Research (ANPPS) which in its axis 7 (Economics and health management) has item 7.3 Costing assessment, technical feasibility and sustainability of Assistance Establishments as a priority research topic and which has no direct precedent in editions of this agenda in previous years.

It is important to note that this study, as it is a synthesis of international studies, its finding also applies to several countries. However, when interpreting its results, it is necessary to rethink the measures in each local context. From the point of view of implications for future research, this study presents a gap, especially on primary care services, which seems to be a way to advance this theme.

Thus, we can summarize the main contributions of this study in the following findings: 1) the concept of "life-cycle cost" of the building guides decisions and interventions aimed at recovering investment in the operation of the construction of Healthcare Units (HU), 2) the economic context is the major driver of measures aimed at operational rationalization in HU, 3) the approach to the life-cycle of HU is still mostly restricted to the recovery of initial investment in the operation phase, and 4) the discussion on the topic in the Brazilian Unified Health System (SUS) is incipient.

4. Final Considerations

According to the results of this review, it can be said that the cost of HU is more analyzed for hospitals, to the detriment of basic and medium complexity units (which is considered an important gap in the literature that was found systematically).

The concept of "life-cycle cost" of the building, although explicit in a few texts, guides decisions and interventions aimed at recovering investment in the operation and, although many are focused on environmental criteria, the economic context was perceived as a major driver measures aimed at operational rationalization in buildings.

Among the Brazilian publications located on the studies on the life cycle of HU, it can be said that they are consistent with the evolution of discussions abroad, with due regard for the limits in the transposition of international findings to the Brazilian Unified Health System. These findings are essential to redirect research on HU to strengthen Primary Health Care, and also to guide managers in the decision to open new hospitals and the consideration of financial resources and solutions through more sustainable and inexpensive environmental approaches.

It is important to bear in mind the methodological limitations of this study.

From the point of view of the use of the portal (which aggregates many databases), in one hand, it may have facilitated the retrieval and design of the search strategy; in the other hand, it leaves the search strategy susceptible to a number variation of identified studies. This is because some databases are discredited on this portal while other new databases are accredited. In addition, from the point of view of the level of evidence, it is important to remember that the studies reviewed (due to the characteristic of the area of architecture) do not have methodological characteristics in the field of public health. This required the integration of several types of texts (such as essays, interviews and reports) that do not represent a study with scientific approach. Finally, it is important to be careful when extrapolating these results to other scenarios.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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