The Future of Hospitals: A Systematic Review in the Field of Architectural Design with a Disruptive Research and Development Approach

María Araya Léon, Ainoa Abella, Aura Murillo, Ricardo Guasch, Laura Clèries

Abstract—This article aims to examine scientific theory framed within the term hospitals of the future from a multidisciplinary and cross-sectional perspective. To understand the connection that the various cross-sectional areas, we studied have with architectural spaces and to determine the future outlook of the works examined and how they can be classified into the categories of *need/solution, evolution/revolution, collective/individual,* and *preventive/corrective.* The changes currently taking place within the context of healthcare demonstrate how important these projects are and the need for companies to face future changes. A systematic review has been carried out focused on what will the hospitals of the future be like in relation to the elements that form part of their use, design, and architectural space experience, using the WOS database from 2016 to 2019. The large number of works about sensoring & big data and the scarce amount related to the area of materials is worth highlighting. Furthermore, no growth concerning future issues is envisaged over time. Regarding classifications, the articles we reviewed address *evolutionary and collective solutions* more, and in terms of *preventive and corrective solutions*, they were found at a similar level. Although our research focused on the future of hospitals, there is little evidence representing this approach. We also detected that, given the relevance of the research on how the built environment influences human health and well-being, these studies should be promoted within the context of healthcare. This article allows to find evidence on the future perspective from within the domain of hospital architecture, in order to create bridges between the productive sector of architecture and scientific theory. This will make it possible to detect R&D opportunities in each analyzed cross-section.

Keywords—Hospitals, trends, architectural space, disruptive approach.

I. INTRODUCTION

TODAY more than ever, healthcare is facing significant challenges that it must address whether due to emergencies and urgent adaptation, the new paradigms of habitability associated with healthcare and well-being, or to the rapid advances in technology. These new pressing scenarios have impulse preconceived notions about the future reality today.

With the foregoing in mind, the architecture studio PMMT in Barcelona, which specializes in healthcare designs/ buildings or proposals, aims to answer these questions, through joint work with the research department at Elisava Research.

The two entities have addressed the challenges of research through their interdisciplinary network with a methodological path approach that begun by investigating the mega and macro trends related to the healthcare sector, a vision of experts on the aforementioned topics, and the development of expert toolkits and evidence walls produced in two days of workshops. All of the above made it possible to define various action scenarios.

The mega and macro trends have been defined as:
- Hard (technical, 3D, numbers, laboratory) to Soft (flexible, emotional, bio, intelligent, social, human).
- Ephemeral (take and discard) to Resilient (modular, interactive, ...)
- Individual to Shared (collective, public system, collaborative...)
- Machine (Artificial Intelligence, AI) to Human (Cultural Intelligence (CI), creative skills).
- Physical to Phygital (AR, VR...).
- One or the other to both
- Certainty to Probability (serendipity, imperfection...)
- Wise to Critical (ethics, gender...).
- Strong to Light (mobility, nomads).

The Evidence Walls (Fig. 1) created by the experts, have allowed the clustering of various concepts, always related to the research question about the hospitals of the future. From that clustering process, key concepts have been extracted afterwards for both sessions.

The evidence wall allowed the expert to cluster all concepts and define the following scenarios:
1. Empowerment: #The system as a service; #Pedagogical environments; #Collective intelligence; #Personalization of the experience; #Opensource.
2. Kindness: #Human being and environment, receiver and emitter; #Haptic responsive environment; #Environment communicates, informs and guides in an intuitive and friendly way; #Emotional material configuration.
3. Augmented: #Artificial intelligence and sensoring; #Hyper technification; #Human disqualification; #Building as a cognitive prosthesis.
4. Nomad: #Climate change; #Catastrophe scenarios; #evolutionary design; #Adaptive and homeostatic spaces; #Transformative architecture; #Recovery of uninhabited wild territories.
5. Branded detox: #Lifestyle coaching; #Healing spaces; #Health, wellness and positive aging.

María Araya*, Ainoa Abella, Aura Murillo, Ricardo Guasch, and Laura Clèries are with Elisava, Barcelona School of Design and Engineering (UVic-UCC), Spain (*corresponding author, e-mail: maraya@elisava.net, aabella@elisava.net, auramurillop@gmail.com, rguasch@elisava.net, lcleries@elisava.net).

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Fig. 1 Evidence wall for the clustering of concepts

6. Pure luxury: #Basic needs of human beings as a matter of luxury; #Breathe clean air and oxygen; #Drink water and eat toxic-free food; #Develop in the living space.

In a second-round clustering, two large scenarios are defined, encompassing the previous concepts, which will be the basis for addressing this research. These correspond to:

- "Branded Wellthy" #Individual Resilience and #Brand Confidence. This is the result of the connection and hybridization of these four initial scenarios: Augmented, Nomad, Branded detox and Pure luxury.
- "Collective Empowerment" #Collective Resilience and #Trust in the system. This came from the connection and hybridization of the initial scenarios Empowerment and Kindness.

Finally, with the aim of relating everything extracted from the experts, the theory and the two defined scenarios, a cross-sectional matrix has been developed with the following concepts:

- Inclusion
- Materials
- Sensoring & Big Data
- Communication
- Ethics
- User experience
- Sustainability

From the information obtained from this matrix, the key concepts that are the basis of this systematic review are extracted.

The objective of this research is to create the scientific theoretical framework to support the conceptual path defined in the initial phase of this project on hospitals of the future, through the review detailed below.

II. METHOD

The method we applied is a systematic review to address the research question: what will the hospitals of the future be in relation to the elements that form part of their use, design, and architectural space experience? We carried out the literature review using the Web of Science (WOS) database in English, from 2016 to 2019.

Based on the question, the target population of the review was determined, as well as the intervention, comparison, and expected outcomes, according to the PICO format: **P**: Inclusion (older people, gender perspective); **I**: hospital space, telemedicine, outdoor environment; **C**: not applicable; **O**: Level of innovation and perspective for the future, applications in architectural space, in an evolutionary and disruptive level.

Systematic Procedure

Creating the Taxonomy

To define the key words or concepts to use in the search engine, we developed a taxonomy that begins with the extraction of a cross-sectional and scenario-based concepts, already defined in the introduction to this paper. These have been verified in two thesaurus search engines, both in Spanish and in English.

The thesauri consulted for this systematic procedure were TA&A – Art & Architecture Thesaurus [1] and DeCS [2] – Health Sciences Descriptors.

Definition of the Search Terms and Engines

We defined the search terms to guide the present system based on the final concepts we would employ. Each word in a topic or title was paired with the concept *"Future Hospitals,"* yielding a total of 18 search terms.

TABLE I
FUTURE HOSPITALS + TAXONOMY CONCEPTS

Future Hospital +	Aging	Trust
	Diversity	Empathy
	Inclusion	Ethics
	Materials	Monitoring
	Emotions	Mental Health
	Predictive modeling	Empowerment for
	Participatory action research	Health
		Sustainability
	Big Data	Materials environment
	Communication	

Filters, Inclusion and Exclusion Criteria, Selection and Discarding Process

For the process of selecting and discarding the titles and articles defined in the different filters, "built environment", "services", "systems", "innovation", and "policy" were defined as inclusion criteria, whereas laboratory research and/or research on very specific diseases were used as exclusion criteria.

We applied the following filters: titles (relation and relevance

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to the topic), abstract overview (related to the selected titles were read), open access articles, a complete overview of the article, to end up with a final analysis.

III. RESULTS OF THE SYSTEMATIC PROCEDURE

Once the systematic procedure (Fig. 2) was carried out with the search terms, and the inclusion and exclusion criteria were applied, the following results were obtained: after having as an input a total of 1,540 articles, 334 passed the title filter, 191 passed the second filter of abstracts, 131 passed the third filter of open access, and 91 passed the fourth filter for full overview and reading. Subsequently, 83 articles were selected for a final analysis.
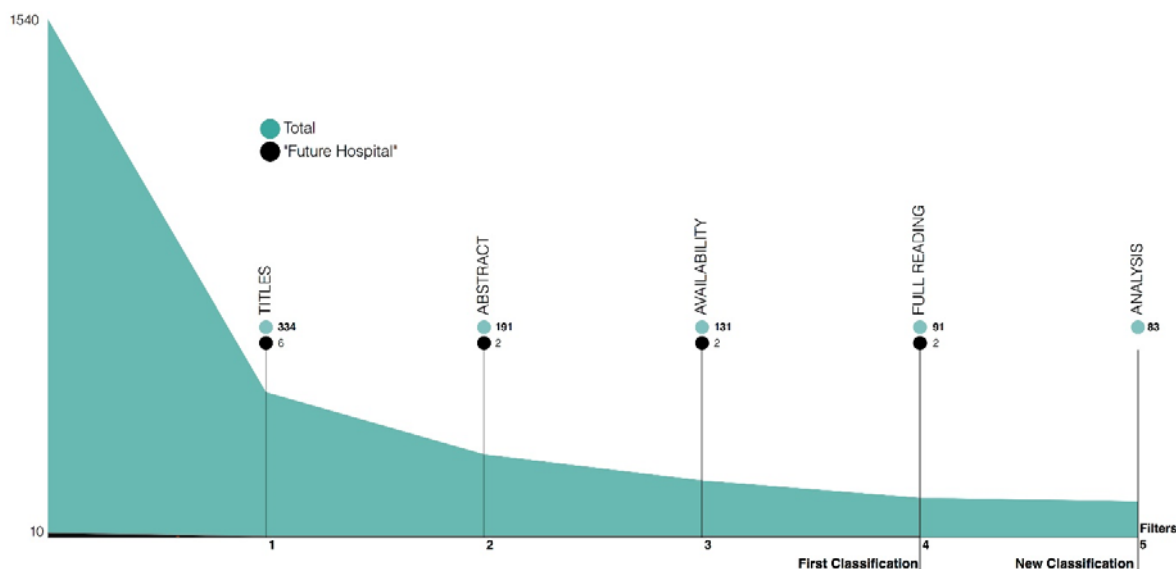

Fig. 2 Systematic review, hospitals of the future, filters, and selection of scientific evidence
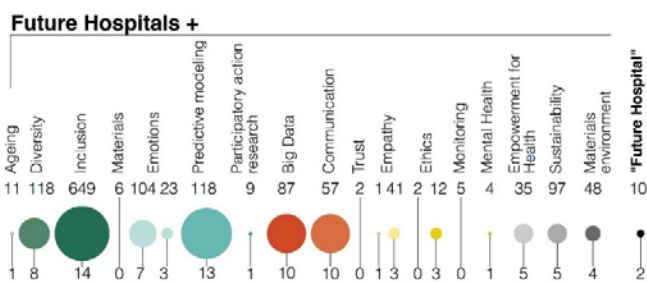

Fig. 3 Totals selected by search term up to filter 4

In terms of the topic availability, there is a concentration concerning topics of diversity, inclusion, predictive models, big data, and communication. On the opposite side, there is a reduced amount on confidence, mental health, aging, and participatory action research (Fig. 3).

A. Bibliometric Analysis

For better comprehension, we developed an initial classification in filter 4 -full reading- according to the different *Branded Wellthy* and *Co-healthy* scenarios and the cross sections inclusion, materials, sensoring & big data, communications, ethics, user experience (UX), and sustainability (see Fig. 4).

The scientific evidence focuses on areas related to "sensoring & big data," from a more social and collaborative perspective, with a total of 15 articles. This was followed by "inclusion" and "communication," both more concentrated in collaborative and social areas, with 8 in inclusion and 12 in communication. Conversely, fewer results were found in "materials," with one article in the case of the Co-Healthy scenario. Furthermore, we observed that "ethics" and "sustainability" are concentrated in the *Co-Healthy* scenario, with four articles in ethics and five in sustainability. In the case of "UX" the evidence was concentrated in the *Branded Wellthy* scenario, with seven articles.

For the final analysis of the articles selected for full reading, we developed an analysis guideline to enable systematizing the analyzed information from each one into two dimensions:
1. Quantitative data for a descriptive analysis of the information: Country – context in which the research was carried out; Impact – the value assigned to the source (scientific journal); year and keywords for each article.
2. Qualitative information focused on: Need –Solution; Evolution – Revolution; Individual approach – Collective approach; Preventive approach – Corrective approach; and Architectural space relationship.

1. Final Classification

In parallel to the analysis, we produced a final classification with the 83 articles selected based on the analysis process. With the aim of providing a more general framework in which materials were expanded to the term "built environment," sensoring & big data to "technology," UX to "experience," while "prediction models" and "others" were also incorporated (see Fig. 5).

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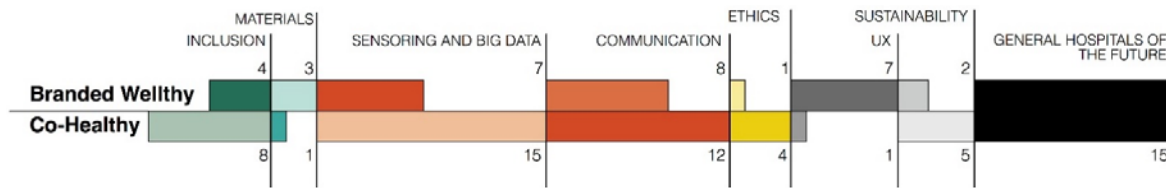Vol:17, No:7, 2023
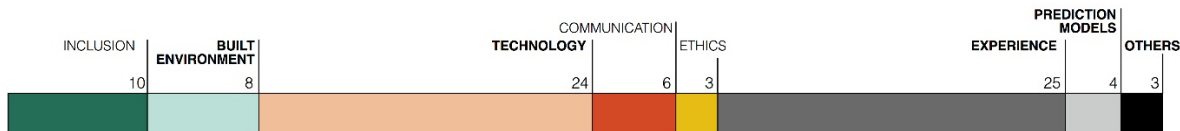
Fig. 4 Classification 1, filter 4

Fig. 5 New classification made after applying analysis filter 5

Fig. 6 Tag cloud – keywords

TABLE II
IMPACT AND YEARS BY CONTEXT

Countries	Total	Q1	Q2	Q3	Q4	-	2019	2018	2017	2016
USA	23	11	5	6	0	1	3	6	8	6
UK	12	6	3	2	1	0	2	6	0	4
Australia	9	7	1	1	0	0	1	3	2	3
Canada	5	3	2	0	0	0	1	1	0	3
Europe	18	5	4	5	3	1	7	5	3	3
Other countries	16	7	3	3	2	1	2	5	6	3
TOTAL	**83**	**39**	**18**	**17**	**6**	**3**	**16**	**26**	**19**	**22**
Percentages %		47	21.7	20.5	7.2	3.6	19.2	31.3	23	26.5

Note: the cases with the most results were left as countries and the most isolated cases were grouped by continent and in "others"

We observed that the highest concentration of articles concerned technology and experience, with 24 and 25 examples respectively. These were followed by inclusion with ten, built environment with eight, and communication with six. The categories that contained the fewest articles were predictive models, ethics, and others with four, three, and three respectively.

2. Quantitative Analysis

Subsequently, we clustered the data on years, contexts (country), and the impact of the publication (see Table II). Regarding the countries, the ones with the greatest amount were the United States, the United Kingdom, Australia, and Canada. These countries were followed by Europe, and the "Other" category, that group together all the other countries with less representation (Table II).

As a general observation, in relation to Table II, the general distribution of the articles over the years is proportionate, as only 2018 stands out slightly with 31.3% of the results. Regarding impact, the Q1 publications stand out, with 47% of the total articles.

A tag cloud was developed afterwards to visually represent the keywords in the articles.

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The concepts *Hospital, Health, Care,* and *Patient* are repeated the most. Other words of interest were notable: *Social care, Emotion, Caring, Communication, Sustainability, Machine, Hotel, Palliative, Dehumanization,* and *Older.* Finally, the least mentioned, yet still present, words were *Experience, Environmental, Aged, Home, Culture, Ethics,* and *Telemedicine*, among others.

It is worth mentioning that although the concept of "Future Hospitals" was the basis for all searches, the word "Future" was not repeated much.

3. Qualitative Analysis

Fig. 7 shows a trend towards current and social aspects, with most of the results clustered in studies that address issues of need, with an evolutionary, collective, and corrective approach.
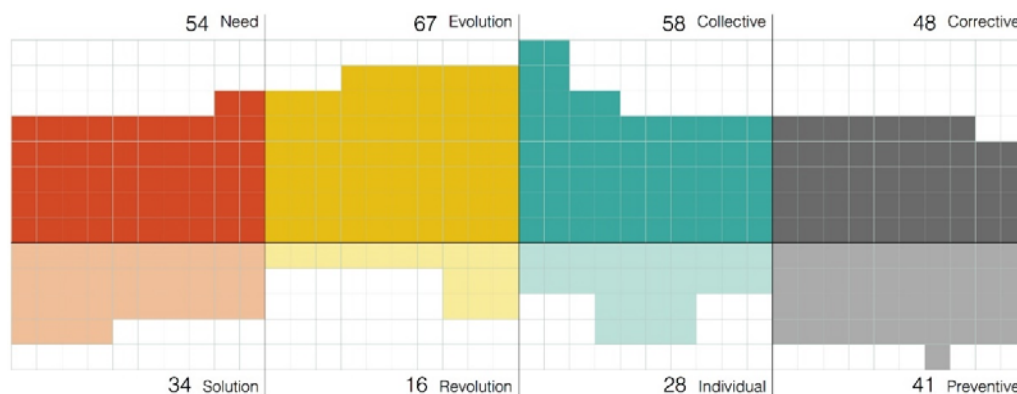

Fig. 7 Qualitative information – Approaches

The revolution indicator appeared the least, perhaps due to the qualitative process of information analysis, as well as the profiles that scientific articles may have, especially in the field of health sciences. Many of the articles address preventive and corrective approaches simultaneously. Based on the above, we should note that some of the articles we analyzed address several indicators at the same time.

Architectural Space or Built Environment Connection

Although this article focuses the future of hospitals in terms of physical space, only 36.1% of the articles we analyzed address this connection, while the remaining 63.9% do not address it. This also takes into account research that could have an impact on the use of space or, for example, efficiency in hospitalization times as a connection. For this reason, other complementary analysis units have been added to the systematic review, which are detailed in the following section.

IV. DISCUSSION

This section presents the units of analysis that do not fall under the previous classifications but present a panorama of scientific evidence linked to the built environment.

A. Analysis Units

The final analysis is grouped into six themes, drawn mainly from the final classification, plus the other units of analysis: inclusion, built environment, communication, ethics, technology, experience, and other units.

1. Inclusion

One of the recurring themes related to inclusion lies in ethnic differences and how minority groups are important to consider when understanding hospital care and quality [3]-[5]. These groups often face hospital readmission within 30 days, along with the elderly population, which has an impact on the excessive use of hospital spaces [6]. If the elderly population has supportive social networks, hospital use may decrease [7]. Concerning aging and cultural differences, the limited healthcare literacy present among patients [8], and the language used [9], should be taken into account.

Dehumanization and even concepts such as infrahumanization were observed in the analysis, related to stigmatized segments of the population such as gender groups [10].

As a positive exploratory pathway, art was found as a therapeutic process in aging populations [11] and as an improvement for rehabilitation processes, increased well-being, and productivity [12].

2. Built Environment

The built environment in hospitals positively and/or negatively affects people's well-being and health through the parameters that form part of it. Although materials are an important element, they are not what we primarily analyzed in the literature.

The importance of the indoor environment in the healing processes for patients is one of the main issues that must be faced when shaping hospital spaces. Multiple factors must be taken into account such as room size, privacy, atmosphere, sound, music, lighting, exposure to sunlight, windows with views towards nature, pollutants in the ventilation system, humidity and temperature, and other environmental stimuli such as furniture, art, colors, smell, materials, and more. These factors have both a psychological and a physiological impact on patients [13]. Furthermore, spatial organization and the use of spaces also have an impact on recovery [14].

Temperature and humidity are extremely relevant as they

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affect air quality and the presence of bacteria and viruses [13]. The spread of bacteria between healthcare personnel, patients, and the external environment remains a critical issue despite hygiene protocols.

Another parameter deemed negative was sound and noise as they can create physiological and psychological issues in hospitalized patients [15]-[17].

Developing and innovating with materials provides an opportunity to address many of the highlighted issues [18].

3. Technology

Technology is advancing exponentially and affects healthcare. The articles focus on how Big Data [19] is increasingly used in prediction and personalization issues, in data quality, machine learning [20]-[24], and in improving image quality for remote surgeries [25]. Regardless of the topic, all research projects share that data privacy is a constant challenge that must be improved [26], [27]. Moreover, sensor technology is taking a leading role in the same prediction and health control models [28], both individually and collectively. Hopefully, progress will be made in smart health current issues through sensor technologies [26], [29]. It would be possible thanks to real-time data collection from different human responses. These digital and monitoring technologies facilitate progress in services such as telemedicine and telehealth for groups and individuals with greater ethical rigor [30]-[33].

Other avenues such as ICTs (Information and Communication Technologies) are presented as ways to aid individuals who are caretakers for critically ill patients. The effects that such care could have ranged from physical, emotional, and social burdens to isolation [34].

Affective and emotional aspects are fundamental dimensions in the humanization of technology considering the rejection that technology produces in patients [35], [36]. With the aim of improving the quality and emotional closeness of robots, there are studies that show a reverse engineering method for learning emotional expressions in social robots [35]. Examples of these explorations of robot therapies that try to humanize the experience through animals are the case of the PARO robot, a therapeutic robot baby, intended to have a calming effect and provoke emotional responses in hospital patients [36].

Another important field of knowledge concerning emotions falls within home health monitoring, especially for the elderly. To analyze the conditions of the elderly, their emotional state is one of the factors that reflects mental states and can have a great impact on decision making. Sensor technology is a tool that makes it possible to detect these emotional states, although the main problem lies in invasiveness [37].

Finally, regarding the problems that technology and Big Data entail, beyond privacy and data protection, there is limited economic accessibility [3] in addition to the threat of deskilling that all this entails [38].

4. Communication

Exchanging information within the healthcare field is a fundamental action for the performance of the system, which covers and involves different media and actors. The quality of communication in this environment is something that must be improved since it contributes positively to palliative care, providing more security, and less loneliness [39] through more effective information

Psychological and social factors in communication are aspects that could be improved, especially in the final stages of life and in cases of serious diseases [40] where empathy becomes one of the most important focuses on an emotional level and doctors also become key actors and a primary point of contact in communication processes with the patient [41].

5. Ethics

Ethics is cross-sectional in all areas of healthcare, and a filter in many decisions, research projects, applications, and more. However, the small number of articles in this category concerning hospitals of the future is striking.

From a general perspective, we have noted a clash between an individualistic understanding of rights, freedom, and privacy and, on the other hand, the common good in health and well-being. One of the concepts addressed in the scientific literature is relational bioethics [42]. Furthermore, technology and digital transformation have led to devising hyper-connected spaces and smart cities that entail bioethical problems along with an increase in the notion of commodification, human obsolescence, and a wider economic gap [43].

6. Experience

Experience in every area of healthcare is a subject that has been widely studied and addressed.

One of the most studied areas is the emotional dimension, considering the large number of traumatic experiences that are experienced within hospitals [44], [45]. Emotions are also important for the employees in healthcare settings as in many cases they risk their lives [46] and experience "compassion fatigue" while working, an emotional, physical and physiological impact experienced by helping others in situations of trauma and stress. Thus, it is important to protect both their emotional and physical well-being [47].

Empathy is a common denominator in the studies we analyzed, where person-centered care promotes an attentive environment that is respectful, compassionate, and sensitive to the needs of users [48]-[50] and must be present at all levels of the healthcare environment [51].

The perception of quality that a hospital reflects [52], [53], which also affects the well-being and satisfaction of patients [54], [55], is related to the feelings that positively influence patients [56], collaborative work between patients, staff, and families in emergency situations [57], [58], the physical facilities at hospitals and their visual appeal [52], and the service and cultural competence of the healthcare workers [52], [59].

There are works that highlight the concept of Medical Tourism. This concept makes reference to the increasing circumstance of patients moving voluntarily to a different country to receive a specific medical treatment [60], [61] as well as the concept of the Patient Hotel [62].

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7. Others

Considering the scarce number of articles that do not correspond with the above classifications, classifications have been made for other topics related to social sustainability, the low amount of Gross Domestic Product invested in the healthcare sector, analogous predictive models [63], [64], articles related to self-report techniques (PROMs), and the importance of these models [64], in hospital occupancy [63].

Regarding social sustainability, mentions are made on how this is becoming a key objective within the healthcare field and how it is opening up opportunities for preventive behavior and well-being [65].

B. Other Units of Analysis

The built environment affects people's well-being and health and also affects recovery experiences and outcomes. The psychological aspects of the relationship between the physical environment and human health and well-being are also known as "Environmental Psychology" [66].

There is evidence regarding the benefits of therapeutic design for patients, staff well-being, and the length of stay. Issues related to security and privacy, lighting, green spaces, the impact of architecture on mental health outcomes, interior design, art, and aesthetics stand out [67], [68].

Design aspects, sound, colors, and biophilia [66] in the built environment positively influence health and reduce patient anxiety, pain, and stress levels [69] and treatment times due to a space's enhanced quality [70].

V. CONCLUSIONS

Scientific evidence on the impact that the built environment has on human beings is increasing. However, this is occurring with greater intensity in other types of contexts, which may be due to the difficulties inherent in the healthcare environment when conducting research that is not in the medical field.

These findings are also impacting evidence-based design methods, which constitute a series of architectural actions that seek harmony and balance between the environment and the individuals inhabiting it. However, there is still no adequate methodology available to address the different environmental aspects in a holistic way [71], although progress has been made on issues regarding accreditation and certification for this methodology. Holistic methodology enables an architect to evaluate and design in order to contribute to human well-being [72]. Furthermore, it is worth noting that, although our search focused on the concept of the future, it is striking how most of the articles we analyzed address aspects that are more concerned with the present or near future. From the articles analyzed, most of them concern the built environment in a time frame of the present and the near future. This highlights an opportunity/need to address the relationship further.

Due to the importance of the effect of the built environment on human beings and the scientific advance that this implies, it is essential to tackle the disciplinary gap that exists between the different areas of knowledge.

VI. LIMITATIONS

Innovations and changes published as a result of the COVID-19 pandemic have not been included in this article as the systematic review work was conducted beforehand. Therefore, this could represent an opportunity of continuation for this research.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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