

# Emerging technologies, architectural planning and hospitals of the future: the impact of Healthcare 4.0 in Brazilian hospitals

*Tecnologias emergentes, planejamento arquitetônico e hospitais do futuro: impacto da Saúde 4.0 nos hospitais do Brasil*

*Tecnologías emergentes, planificación arquitectónica y hospitales del futuro: el impacto de la Salud 4.0 en los hospitales de Brasil*

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## Abstract

This study aimed to identify the emerging technologies that most impact hospital architectural planning, the hospital sectors most impacted, and the outlook for the hospitals of the future, based on the perceptions of healthcare professionals, architects, and engineers working in the hospital sector in Brazil. An online survey was conducted with 66 participants from different regions; the data were processed using content analysis. The most frequently cited technologies were telehealth, robotics, artificial intelligence, environmental sensors, and augmented/virtual reality. The sectors identified as most impacted were the surgical and obstetric center, diagnostic support, and intensive care unit. For the hospital of the future, trends emerged toward greater patient-centricity, humanization, integrated technologies, dehospitalization, and space optimization, aiming for efficiency, safety, and personalized care. It is concluded that the adoption of these technologies demands physical and organizational reconfigurations and, despite conceptual and infrastructure challenges, the opportunities in terms of care quality and efficiency are promising.

**Keywords:** Emerging technology; Healthcare 4.0; Hospital architecture; Hospital of the future.

## Resumo

Este estudo teve por objetivo identificar as tecnologias emergentes que mais impactam no planejamento arquitetônico dos hospitais, os setores hospitalares mais impactados e as perspectivas para os hospitais do futuro, a partir da percepção de profissionais da saúde, arquitetos e engenheiros que atuam na área hospitalar no Brasil. Realizou-se uma pesquisa através de questionário *on-line* com 66 participantes de diferentes regiões; os dados foram tratados por meio do método de análise de conteúdo. As tecnologias mais citadas foram telessaúde, robótica, inteligência artificial, sensores ambientais e realidade aumentada/virtual. Os setores apontados como mais impactados foram centro cirúrgico e obstétrico, apoio diagnóstico e unidade de terapia intensiva. Para o hospital do futuro emergiram tendências de maior centralidade no paciente, humanização, tecnologias integradas, desospitalização e otimização dos espaços, visando eficiência, segurança e personalização do cuidado. Conclui-se que a adoção dessas tecnologias demanda reconfigurações físicas e organizacionais e apesar de desafios conceituais e de infraestrutura, as oportunidades em qualidade assistencial e eficiência são promissoras.

**Palavras-Chave:** Tecnologia emergente; Saúde 4.0; Arquitetura hospitalar; Hospital do futuro.

## Resumen

Este estudio tuvo como objetivo identificar las tecnologías emergentes que más impactan en la planificación arquitectónica hospitalaria, los sectores hospitalarios más impactados y las perspectivas para los hospitales del futuro, con base en las percepciones de profesionales de la salud, arquitectos e ingenieros que trabajan en el sector hospitalario en Brasil. Se realizó una encuesta en línea con 66 participantes de diferentes regiones; los datos se procesaron mediante análisis de contenido. Las tecnologías más citadas fueron la telesalud, la robótica, la inteligencia artificial, los sensores ambientales y la realidad aumentada/virtual. Los sectores identificados como más impactados fueron el centro quirúrgico y obstétrico, el apoyo diagnóstico y la unidad de cuidados intensivos. Para el hospital del futuro, surgieron tendencias hacia una mayor centralización en el paciente, la humanización, las tecnologías integradas, la deshospitalización y la optimización del espacio, buscando la eficiencia, la seguridad y la atención personalizada. Se concluye que la adopción de estas tecnologías exige reconfiguraciones físicas y organizacionales y, a pesar de los desafíos conceptuales y de infraestructura, las oportunidades en términos de calidad y eficiencia de la atención son prometedoras.

**Palabras-clave:** Tecnología emergente; Salud 4.0; Arquitectura hospitalaria; Hospital del futuro.

## 1 Introduction

Technological development and the consequent progress of emerging technologies have driven significant transformations, providing unprecedented advances in all sectors, including the health sector (Lopes *et al.*, 2019; Schwab, 2016). In the context of Healthcare 4.0, technologies such as Artificial Intelligence (AI), Internet of Things (IoT), 3D printing, and robotics, have modified not only the care and management processes, but also the architectural planning of hospital buildings. These technologies enhance the entire healthcare system, improving processes, reducing medical errors, contributing to decision making, and improving patient care (Al-Jaroodi; Mohamed; Abukhousa, 2020).

Healthcare 4.0 seeks to apply the principles of Industry 4.0 in health systems, having as main characteristic the integration of intelligence into current and future technologies, which allows providing interconnected care and an effectively patient-centered approach. This intelligence is manifested in the ability of systems to process data, adapt to various contexts and support decisions in real time, promoting greater efficiency, personalization, and coordination in health care (Ahmad *et al.*, 2022; Gupta; Singh, 2022; Sony; Antony; McDermott, 2022).

Technological advancement and medical knowledge itself have significantly boosted the entire chain of the health sector. However, not all health systems around the world have reached the Healthcare 4.0 stage. Many still remain at levels 2.0 or 3.0, or are transitioning between these stages. The implementation of Healthcare 4.0 depends on a series of interconnected factors and is strongly influenced by the specific conditions of each country, region and institution. Thus, while some organizations already stand out for adopting cutting-edge technological solutions, others still operate under more traditional health care paradigms, a scenario especially evident in the Brazilian context (Pompermaier; Vergara; Cavalcanti, 2024a).

In this sense, despite the global advancement of emerging technologies and the transformative potential of Healthcare 4.0, this idea is still rather new and not widely known in Brazil (Tortorella *et al.*, 2020). This gap in dissemination and understanding reflects the early stage of adoption of these emerging technologies and can make it difficult to understand their impact on professional practices and the built environment. As a result, many professionals and institutions still have trouble understanding the real impact of these innovations on care practices, management models, and the built environment itself, which needs to keep up with the transformations resulting from digitization in the healthcare sector.

It is relevant to understand how these innovations are perceived and assimilated by professionals who work directly in the healthcare sector, since their adherence, training, and understanding of the impacts of Healthcare 4.0 are determining factors for the success of innovation initiatives in hospital environments.

Given the accelerated and inevitable technological evolution, it is also important to review methods and techniques of architectural design to meet new demands. The challenges presented by society require architects and engineers involved in architectural planning to keep themselves constantly updated and develop skills to deal with the advanced technologies that are promoting global transformations (Góes, 2010). In this sense, this study aims to identify the emerging technologies that impact the most on the architectural

planning of hospitals, the most impacted hospital sectors and the prospects for hospitals of the future, from the perception of health professionals, architects and engineers working in the hospital area in Brazil.

Healthcare buildings are mutable and architects have a key role to minimize and predict problems and maximize the useful life of these spaces. Hospital must stay alive for decades and be prepared for the constant advances in medical knowledge and hospital technology through projects that meet all demands (Karman, 2011). In addition, architects must also “overcome strict professional boundaries and be aware of the impact that hospital design choices have on staff, patient and visitor flows, emergency resilience and technological evolution” (WHO, 2023, p.26).

## 2 Method

The survey was conducted through a Google Forms questionnaire and designed so that participants could have all the information necessary for their participation. In the first section, participants were welcomed and informed about the study's objectives, the structure of the questionnaire and the estimated response time. The second section contained the ethical and legal procedures and the Free and Informed Consent Form (FICF) that had to be accepted to proceed. The third section contained sociodemographic data and two questions that defined the inclusion and exclusion criteria. The fourth section contained six specific questions about emerging technologies and, finally, the fifth section thanked participants for their participation and provided an *email* address for further information. The questions were divided into open-ended and multiple-choice, depending on their nature, and all were mandatory.

The questionnaire was designed based on the information collected through a previously carried out Scoping Review (Pompermaier; Vergara; Cavalcanti, 2024b). The emerging technologies responsible for driving Healthcare 4.0 mapped in the Review were presented to participants so that they could select the five that most directly or indirectly impact the hospital architectural planning, according to their perception. To answer this, participants were provided a glossary in the the Google Form, with the definitions of mentioned technologies, helping participants with any questions or lack of knowledge. Then, considering these technologies, a list of hospital sectors selected from Anvisa's (National Health Surveillance Agency) Collegiate Board Resolution No. 50 (Brazil, 2002) was provided, asking participants to select the three sectors that will be most impacted in terms of architectural planning. The remaining questions, all open-ended, asked for: the main changes that will occur in hospital buildings as a result of the incorporation of emerging technologies; practical examples to illustrate the impact of the incorporation of new technologies in architectural planning; perspectives for the hospitals of the future and; examples of hospitals, in Brazil or abroad, that are great references in incorporating new technologies in the health sector or that embody what would be trends for the architectural planning of the hospital of the future. The questionnaire outline is presented in Table 1.

The Scoping Review carried out shows that the concept of “Healthcare 4.0” is rather new and still not widely known (Pompermaier; Vergara; Cavalcanti, 2024b). Therefore, we sought to avoid the explicit use of the term, preventing incorrect interpretations by participants. To this end, we adopted a language that referred to emerging technologies in health.

**Table 1:** Questionnaire outline.

<b>Part I: Sociodemographic data</b>	
01	State in which you reside ( <i>Acre, Alagoas, Amapá, Amazonas, Bahia, Ceará, Distrito Federal, Espírito Santo, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraíba, Paraná, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Rondônia, Roraima, Santa Catarina, São Paulo, Sergipe, Tocantins</i> )
02	Gender ( <i>Male, Female, other</i> )
03	Age ( <i>20 years or younger, 21 to 30 years, 31 to 40 years, 41 to 50 years, 51 years or older</i> )
04	Education ( <i>Administrator, Architect and Urban Planner, Biomedical Engineer, Civil Engineer, Nurse, Physician, other</i> )
05	Years of professional experience ( <i>up to 5 years, between 5 and 10 years, between 10 and 20 years, between 20 and 30 years, over 30 years</i> )
06	Do you work directly or indirectly in any activity related to the health sector, whether in the development of projects, assistance, care, management, or others? ( <i>yes or no</i> )
07	What is your level of knowledge about health technologies? ( <i>none, basic, moderate, advanced</i> )
<b>Part II: Specific data</b>	
01	Considering your knowledge of health technologies and your professional experience, select 5 (five) technologies listed below that you believe have the most impact, directly or indirectly, on the architectural planning of hospitals? If necessary, use the glossary as a support. ( <i>big data, data analytics and data science; synthetic biology; biosensors and trackers; blockchain and cybersecurity; cloud computing and fog computing; quantum computing; drones; digital twins; genomics; Artificial intelligence (AI), machine learning and deep learning; Internet of Things (IOT), Internet of services (IoS) and Internet of Everything (IoE); additive manufacturing (3D printing); nanotechnology; augmented reality (AR), virtual reality (VR) and mixed reality (MR); robotics; environmental sensors; cyber-physical systems (CPS); 5G technology; telehealth (telemedicine, teleconsultations and teleradiology); wearables</i> )
02	What are the main changes you believe will occur in hospital buildings as a result of the incorporation of the technologies described above?
03	Considering the technologies described above, select 3 (three) hospital sectors that you believe will be the most impacted in terms of architectural planning. ( <i>outpatient care, diagnostic support (clinical pathology, imaging, nuclear medicine), logistical support (linen, cleaning, comfort, maintenance), technical support (nutrition and dietetics, pharmacy, Material and Sterilization Center), therapeutic support (rehabilitation, radiotherapy, chemotherapy, dialysis), surgical and obstetrical center, hospitalization, emergency room (urgency and emergency), Intensive Care Unit (ICU) or Intensive Care Center (ICC), other</i> )
04	Concisely, what do you imagine the hospital of the future will look like?
05	Would you like to make any additional comments that were not addressed in the previous questions?
06	Are you interested in participating in other stages of this research? If so, please leave your email address so we can get in touch.

After the questionnaire was drafted, a pre-test was carried out to identify flaws in the writing and eliminate potential problems. There were three participants who represented part of the diversity of the target population, including an architect and urban planner, a biomedical engineer and a physician. Professionals from other health sectors were included only in the final application of the questionnaire. For the pre-test, the questionnaire was customized so that participants had a space for feedback after each question, where they could make suggestions, ensuring the accuracy of the questionnaire and its validation. The pre-test was conducted online from May 18 to July 05, 2023. After the pre-test, the questionnaire was adapted to its final version, adding two open questions as suggested: a field for additional comments and a field for demonstrating interest in participating in other stages of the research.

The target population, with national coverage, was defined as architects and urban planners, nurses, biomedical/clinical engineers, civil engineers, physicians, among others. The following inclusion criteria were defined: (I) working directly or indirectly in any activity related to the health sector, whether in the development of projects, assistance, care, management, among others; (II) having at least basic knowledge about health technologies.

Participants were recruited using non-probability convenience sampling, aiming to reach professionals from the target population (Gil, 2002). To this end, the invitation to participate in the survey was published and widely shared on social networks such as WhatsApp, Instagram, LinkedIn and by email, allowing any interested and eligible professional to access and respond to the questionnaire.

In addition to open dissemination, the questionnaire was also sent directly to known professionals who are part of the researchers' network of contacts, ensuring the participation of individuals with relevant experience. Additionally, the research was shared by email through the Brazilian Association for the Development of Hospital Buildings (ABDEH) and in some research groups of national relevance in the field of hospital architecture and engineering, further expanding the scope of the study. The questionnaire was administered online from June 6 to July 15, 2023.

After collection, the data were organized and analyzed using the content analysis method as proposed by Bardin (2016). The data obtained through the Google Forms were exported to an *Excel* spreadsheet, allowing the systematic processing of the information. The content analysis was conducted in three steps: (I) Pre-analysis: the data were carefully organized and transcribed, and the corpus of analysis was defined. Then, specific indicators were elaborated to guide the final interpretation; (II) Exploration of the material: the data were explored and categorized into thematic axes, in order to identify the predominant subjects. For this, the responses were manually coded and counted, following previously established rules (III) Treatment of results, inference, and interpretation: in this phase, the categorized data were treated statistically, with the calculation of frequencies, percentages, and trends, when applicable. From these results, inferences were made, that is, logical deductions based on the collected information (Bardin, 2016).

This research was submitted to the Ethics Committee on Research with Human Beings of the Federal University of Santa Catarina (CEPSH-UFSC) (CAAE 68514423.5.0000.0121), approved under Opinion No. 6,073,893. Participants signed the FICF, agreeing to participate in the research voluntarily, anonymously and confidentially.

### **3 Results and Discussion**

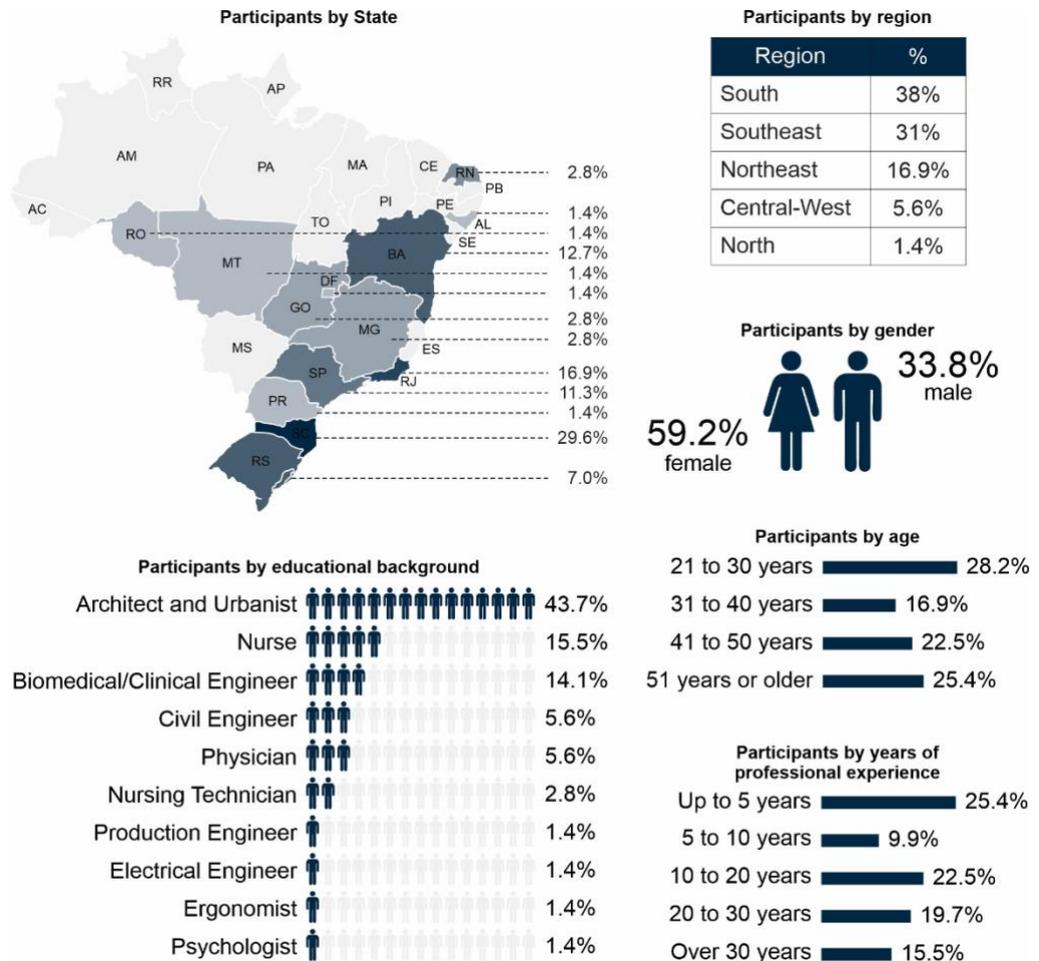
The nationwide questionnaire was completed by 71 participants. To answer specific questions about emerging technologies, participants should meet the following inclusion criteria: (I) working directly or indirectly in any activity related to the health sector, whether in the development of projects, assistance, care, management, among others; (II) having at least basic knowledge about health technologies. Five participants were eliminated for not meeting the inclusion criteria. Four participants did not meet criterion "I" and one participant did not meet criterion "II".

After this filter, 66 participants, from the five geographical regions of Brazil, answered specific questions about emerging technologies in health environments. The states with the highest participation were, in this order: Santa Catarina, Rio de Janeiro, Bahia, São Paulo, Rio Grande do Sul, Rio Grande do Norte, Goiás, Minas Gerais, Alagoas, Distrito Federal, Mato Grosso do Sul, Paraná and Rondônia.

The sample consisted of professionals from different educational backgrounds and levels of experience, allowing a comprehensive view on the investigated topic. The main

sociodemographic characteristics, including gender, age, education and length of professional experience, are summarized in the infographic presented in Figure 1.

**Figure 1:** Sociodemographic infographic of participants.



Source: Pompermaier (2024c).

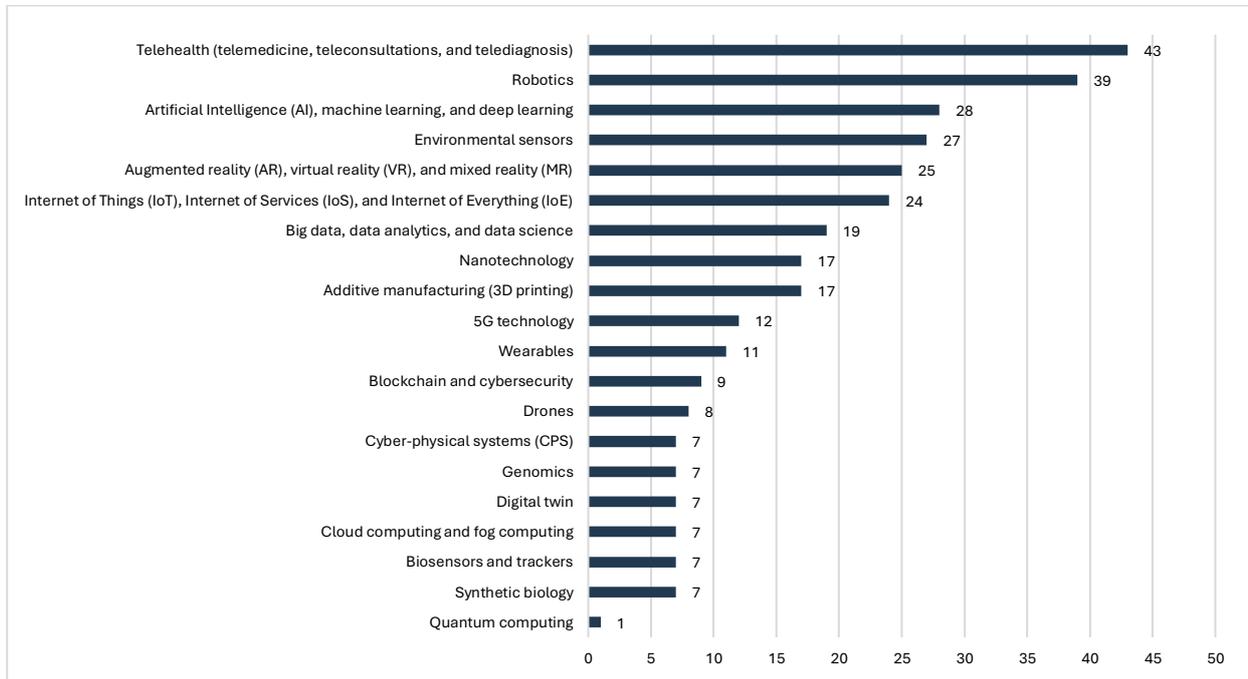
Based on the emerging technologies mapped in the Scoping Review, survey participants were asked the following question: “Considering your knowledge of health technologies and your professional experience, select 5 (five) technologies listed below that you believe have the most impact, directly or indirectly, on the architectural planning of hospitals?”. The following were identified as the main technologies with potential impact: telehealth; robotics; AI, *machine learning* and *deep learning*; environmental sensors; and augmented reality, virtual reality, and mixed reality. All technologies, in descending order, are presented in Figure 2.

These technologies are shaping the future of hospitals and, based on the responses obtained, it is important to consider incorporating them into architectural planning. In addition, the technologies mentioned will bring challenges beyond the physical space, implying organizational, financial, technological and ethical aspects. Oliveira (2014) corroborates this by stating that scientific and technological advances bring solutions while at the same time imposing new challenges on the healthcare sector.

Another relevant aspect to consider is that many of these technologies are integrated into the hospital equipment itself, such as CT scanners, MRI, ultrasound, and x-ray machines, which, due to their size and complexity, have a direct and significant impact on hospital

buildings, influencing the planning, infrastructure and technical requirements of the spaces. This observation leads to reflection on the next question in the questionnaire.

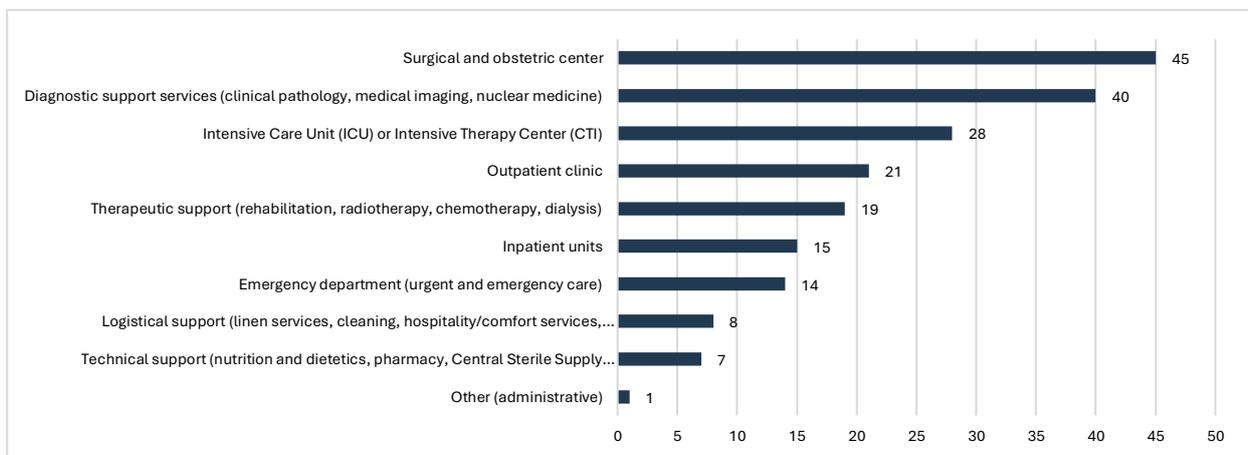
**Figure 2:** Technologies with potential impact on architectural planning.



Source: Pompermaier (2024c).

The participants were asked the following question: “Considering the technologies described above, select 3 (three) hospital sectors that you believe will be the most impacted in terms of architectural planning”. The main sectors identified were, in this order: surgical and obstetrical center; diagnostic support (clinical pathology, imaging, nuclear medicine); and Intensive Care Unit (ICU) or Intensive Care Center (ICC). It is worth mentioning that these results reflect the individual perceptions of the participants and may vary according to the training and area of expertise of each professional. The other sectors, as well as the number of mentions, are shown in Figure 3.

**Figure 3:** Hospital sectors impacted by emerging technologies.



Source: Pompermaier (2024c).

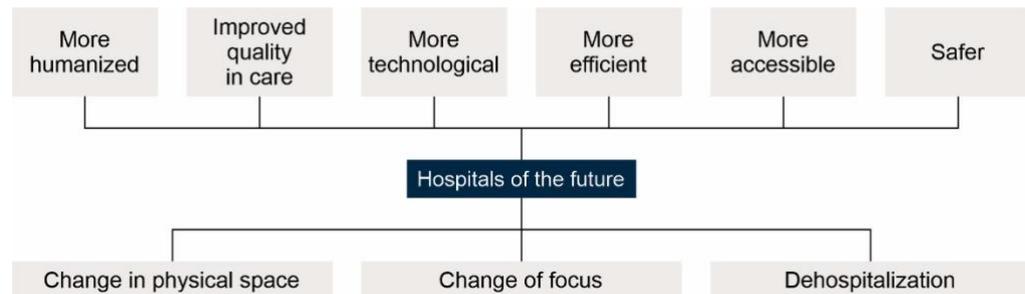
The findings indicate that the sectors most impacted by emerging technologies tend to be those traditionally associated with medical precision, intensive care, and diagnosis and

treatment. These are also sectors where there is already a significant incorporation of biomedical technologies, that is, where equipment, new technologies and forms of treatment are essential for the provision of health care. According to Toledo (2008, p. 105), since the nineteenth century diagnostic support units “[...] have been growing rapidly to meet the incorporation of new diagnostic imaging technologies, and graphic and laboratory methods”. This is just one of the examples. The sectors shown concentrate most of the "hard technologies" of the hospital, that is, complex and high-cost equipment and instruments (Merhy *et al.*, 2006).

This impacts design practices, since, as mentioned earlier, these equipments directly influence the planning, infrastructure, and technical requirements of the spaces. Such influence reinforces the need for architectural solutions that value the flexibility and expandability of the sectors, to allow for constant technological updates and the incorporation of new assistance and operational requirements.

Then the participants were asked about the hospitals of the future through the following question: “Concisely, what do you imagine the hospital of the future will look like?”. Based on the content analysis performed, the data were categorized according to the thematic axis presented in the responses, as represented in Figure 4. This categorization made it possible to identify the prospects for the hospitals of the future.

**Figure 4:** Prospects for the hospitals of the future.



Source: Pompermaier (2024c).

In Table 2, based on the categorization, some answers obtained were organized to exemplify the prospects for the hospitals of the future.

Hospitals of the future will be transformed by emerging technologies, shaped to meet the growing demands created by the growing population, longer life expectancy, and greater incidence of chronic diseases. Perspectives indicate that they will be more complex, technological, sustainable, and patient-centered, enhancing and improving healthcare delivery through more efficient, safe, and personalized processes, based on humanized solutions, both in terms of care and space, promoting well-being during the hospital stay.

Responses obtained indicate a scenario of change in healthcare structures, in which the focus is increasingly shifting toward prevention, a trend that is likely to strengthen in the coming years. The process of dehospitalization, the expansion of specialized medical centers, telehealth and home care, will likely contribute to reinforce the principles of the Unified Health System (SUS): universal access, equity, and comprehensiveness (Brasil, 2023). In addition, technological advances should contribute to reducing the physical stay of patients in the hospital and promote the home environment as part of the care model.

**Table 2:** Answers to the question “What do you imagine the hospital of the future will look like?”.

Category	Mentions
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More humanized	<p><i>"I like to think that it will be technological, but that there will also be more humanized treatment and more welcoming architecture, focused on the well-being of the patient."</i></p> <p><i>"It will track trends in patient well-being, colors, noises, accessibility, access to entertainment, pet interaction, personalized services, decompression spaces, landscaping, and connecting with the city and services in the surroundings. Of course, a lot of technology and comfort for the patient and companions."</i></p> <p><i>"More humanized and welcoming environments with an emphasis on integral health."</i></p>
More quality in care	<p><i>"Fully integrated with the vital parameters of patients, whether or not they are physically within health care facilities."</i></p> <p><i>"Increasingly personalized procedures and drug administration aimed at greater efficiency in all stages of treatment."</i></p> <p><i>"Dynamism, reduction of errors and low contamination rate."</i></p> <p><i>"[...] hospitals will allow patients to receive greater attention and empathy from professionals."</i></p>
More technological	<p><i>"I imagine that test results will be available at the bedside, sensors will be able to report care failures, such failure to change decubitus, artificial intelligence to identify diagnoses, patient conditions and safer treatments."</i></p> <p><i>"Fully connected, fast, without queues, with fast test results and environments suitable for the needs of each patient with the help of technology and humanization itself, light technologies must always walk in parallel with hard technologies."</i></p> <p><i>"The hospital of the future will have different types of material technologies that will support the care of patients, and the entire flow of data is expected to occur digitally."</i></p> <p><i>"Well computerized, in the sense that data on patients and their treatments are passed and treated faster and more efficiently, decreasing noise between therapeutic parties and thus reducing errors."</i></p> <p><i>"Surrounded by many technologies in robotics."</i></p>
More efficient	<p><i>"The hospital of the future must impact on the ease and agility of the care of the teams, where everything must be planned for this purpose."</i></p> <p><i>"[...] more agile maintenance and better-maintained buildings using technology to prevent damage before chaos."</i></p>
More accessible	<p><i>"Autonomous, accessible to all social classes, no queues."</i></p>
Safer	<p><i>"Safer environments and improved working conditions."</i></p> <p><i>"Dynamism, reduction of errors and low contamination rate."</i></p> <p><i>"Health care with safety and confidence in the data of electronic medical records."</i></p>
Change in physical space	<p><i>"More functional areas and greater automation of activities."</i></p> <p><i>"Increased areas of support for diagnosis and therapies and intensive hospitalization."</i></p> <p><i>"Units with smaller floor space and lower flow of outpatients."</i></p> <p><i>"It will be more flexible (the pandemic has shown this need), with spaces that can be rearranged depending on the need."</i></p>
Change of focus	<p><i>"Focused more on prevention than treatment."</i></p> <p><i>"A hybrid environment that uses AI as a way to increase quality of life and longevity."</i></p>
Dehospitalization	<p><i>"Divided into several buildings, said to be 'without walls'. Always safe, efficient and comfortable."</i></p> <p><i>"It will be a hospital where patients will only attend if it is really necessary, getting most of their care at home."</i></p> <p><i>"[...] with care provided online, supported by digital prescriptions."</i></p>

In terms of architectural planning, one can expect an optimization of the physical-spatial structure influenced by dehospitalization, minimally invasive surgical procedures, shorter patient stay and increased outsourcing of services, resulting in smaller areas of administrative, logistical and technical support. On the other hand, the diagnostic and therapy support sectors will need larger physical spaces to accommodate technologies and provide highly complex care support.

Technology will play a key role in how information is collected, processed and stored. Intelligent and integrated solutions based on connectivity and interoperability will drive significant advances and enable faster, more accurate diagnostics and more personalized, safe and effective treatment.

## 4 Conclusion

This study sought to identify the emerging technologies that impact the most on the architectural planning of hospitals, the most impacted hospital sectors and the prospects for hospitals of the future. Based on the analysis of the questionnaire, the results highlighted the centrality of technologies such as telehealth, robotics, AI, machine learning and deep learning, environmental sensors, augmented and virtual reality, IoT, in the transformation of hospital practices and the built environment. The surgical and obstetric center, diagnostic support, and ICU or ICC were identified as the hospital sectors most impacted by technological innovations. These spaces have critical characteristics related to patient safety, operational efficiency and quality of care, becoming strategic points for the incorporation of technological solutions and requiring significant attention during the design process.

Regarding prospects for the hospitals of the future, the responses obtained indicate promising scenarios for health, with more advantages than disadvantages. Although it is not possible to predict the future with precision, studying it allows us to plan and anticipate possible challenges – such as creating favorable conditions for the incorporation of technologies and for the development of health environments that adapt over time, avoiding premature obsolescence. Furthermore, what are treated as emerging and cutting-edge technologies today may no longer be so in 10 or 20 years, or may have been just a means to achieve even more advanced technologies. Without question, there is a need for a fusion between technologies and humanization, providing a more humane hospital environment.

Architects, engineers, and other professionals involved in the design, construction, and operation of hospitals should be aware of trends so that the hospitals of the future are able to meet the needs of the population, ensuring comprehensive healthcare for all. Adopting emerging technologies requires not only adjustments in architectural designs, but also changes in operational flows and staff training in order to ensure efficient implementation aligned with the needs of patients and healthcare professionals.

The technological transition of hospitals in Brazil still faces challenges related to the dissemination of knowledge about Healthcare 4.0 and the adaptation of existing hospital infrastructures. However, the opportunities created by these innovations are promising, especially with regard to improving the quality of care and the efficiency of services.

This study contributes to the field of hospital architecture by providing insights for understanding the current and future demands of the sector, as well as reinforcing the importance of integrating technology and architecture strategically. Future research can deepen the analysis in specific areas of impact, as well as evaluate the practical implementation of these technologies in the Brazilian context, in order to propose more detailed guidelines for smart hospital projects.

Finally, one of the major limitations of the study was the limited sample of professionals who answered the questionnaire in terms of geographical representativeness. Despite the responses obtained in the five geographical regions, the sample disproportion may not comprehensively reflect the diversity of Brazilian hospital contexts, influencing the results. In this sense, future studies should expand the sample with greater representativeness of regions such as the North and Midwest, ensuring a more representative analysis.

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