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SMART CAMPUS: possible paths for Brazilian universities

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ABSTRACT

Over the last two decades, various studies have been undertaken with a view to making cities more adaptable to the massive introduction of Digital Information and Communication Technologies (DICTs). Thus, in the field of urban planning, the term Smart Cities was coined. Over the years, research has expanded and reached the educational context, giving rise to Smart Campuses, due to the similarities between university campuses and cities. The Smart Campus is an environment where there is remarkable efficiency in areas such as infrastructure, security, health and notably education. With this in mind, the aim of this study was to systematically analyze scientific articles linked to the term Smart Campus. This is therefore a study using a systematic review methodology, with a meta-analytical approach, of a qualitative and quantitative nature derived from the use of the Parsifal software. The results point to a lack of consensus on the concept of a Smart Campus, but converge on the understanding that TDIC are essential for carrying out projects aimed at being smart. Finally, a framework methodology proposed by the University of Sapienza is presented as a suggested model for prospecting projects at universities in Brazil. It is hoped that this study will contribute to the creation of new projects that will lead to the construction of Smart Campuses in Brazil.

Keywords: Smart universities; Digital Information and Communication Technology; Internet of Things.

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SMART CAMPUS: caminhos possíveis para universidades brasileiras

RESUMO

Nas últimas duas décadas diversos estudos têm sido empreendidos na perspectiva de tornar as cidades mais adaptáveis à maciça inserção de Tecnologias Digitais de Informação e Comunicação (TDIC). Assim, no campo do planejamento urbano, foi criado o termo Smart Cities. Com o passar dos anos, as pesquisas foram se expandindo e atingindo o contexto educacional, fazendo surgir então, os Smart Campus, em virtude das semelhanças que os campi universitários e as cidades possuem entre si. O Smart Campus parte do princípio de ser um ambiente onde há uma notável eficiência em áreas como infraestrutura, segurança, saúde e notadamente educação. Nesse sentido, este estudo teve por objetivo analisar de forma sistemática artigos científicos ligados ao termo de Smart Campus. Trata-se, portanto, de uma pesquisa com uso metodológico de revisão sistemática, com enfoque meta-analítico, de caráter qualitativo e quantitativo derivado do uso do software Parsifal. Os resultados apontam um dissenso a respeito do conceito de Smart Campus, no entanto, convergem para o entendimento de que as TDIC são primordiais para a realização de projetos visando o "ser inteligente". Por fim, apresenta-se uma metodologia de framework proposto pela Universidade de Sapienza como uma sugestão de modelo para a prospecção de projetos em universidades do Brasil. Espera-se assim, que este estudo contribua para suscitar novos trabalhos que levem a construção de Campi Inteligentes no Brasil.

Palavras-chave: Universidades inteligentes; Tecnologia Digital de Informação e Comunicação; Internet das Coisas.

SMART CAMPUS: posibles caminos para las universidades brasileñas

RESUMEN

A lo largo de las dos últimas décadas se han llevado a cabo diversos estudios con vistas a lograr que las ciudades se adapten mejor a la introducción masiva de las Tecnologías Digitales de la Información y la Comunicación (TDIC). Así, en el ámbito del urbanismo, se acuñó el término «Smart Cities» (ciudades inteligentes). Con el paso de los años, la investigación se ha ampliado y ha llegado al contexto educativo, dando lugar a los «Smart Campuses», debido a las similitudes entre los campus universitarios y las ciudades. El Campus Inteligente es un entorno en el que existe una notable eficiencia en ámbitos como las infraestructuras, la seguridad, la sanidad y, en particular, la educación. Teniendo esto en cuenta, el objetivo de este estudio era analizar sistemáticamente los artículos científicos relacionados

con el término «Smart Campus». Se trata, por tanto, de un estudio metodológico mediante una revisión sistemática, con un enfoque meta-analítico, de carácter cualitativo y cuantitativo derivado del uso del software Parsifal. Los resultados apuntan a una falta de consenso sobre el concepto de Campus Inteligente, pero convergen en el entendimiento de que las Tecnologías de la Información y la Comunicación son esenciales para la realización de proyectos encaminados a «ser inteligentes». Por último, se presenta una metodología marco propuesta por la Universidad de la Sapienza como modelo sugerido para la prospección de proyectos en universidades de Brasil. Se espera que este estudio contribuya a nuevos trabajos dirigidos a la construcción de Smart Campuses en Brasil.

Palabras clave: universidades inteligentes; tecnologías digitales de la información y la comunicación; Internet de los objetos.

1. INTRODUCTION

The transformations resulting from the incorporation of Information and Communication Technologies (ICTs) have become increasingly evident over the years. These transformations have impacted various sectors of society, including education, labor, healthcare, public administration, communication, and culture, thereby introducing numerous forms of organization within societies embedded in what is referred to as "late modernity." The outcome of these changes is a significant acceleration in social transformations (Giddens, 1997).

Key transformations resulting from the integration of ICTs include expanded access to education through distance learning platforms, online courses, and digital educational resources; the rise of remote work, particularly during the pandemic, which has altered the dynamics of the workplace; the growth of digital platforms such as e-commerce and fintechs; the increased use of telemedicine for medical consultations; as well as other issues such as the digitalization of public services and the rise of social media.

In addition to this context of social transformations, there is the continued growth of the global population, which is expected to reach 10.4 billion by the 2080s (UNFPA[1], 2022). A similar trend is observed in Brazil, which recorded a population growth of 6.5%, or an increase of 12,306,713 people, from 2010 to August 2022, resulting in an annual growth rate of 0.52%. Although this is the lowest growth rate observed since the beginning of the historical series in 1872, it still holds significance for the country's demographic landscape (IBGE, 2023).

In light of this scenario, one concept in particular has gained significant attention: Smart Cities. This concept emerged with the aim of providing solutions to address the challenges resulting from concentrated urbanization (Neves et al., 2017). Although there is no consensus on a single definition of Smart Cities, it can be understood as a city that leverages advanced technologies and innovative solutions to improve the quality of life for its citizens, enhance the efficiency of urban services, and promote sustainability (Jesus; Pereira; Santiago, 2018).

1 United Nations Population Fund (UNFPA): www.unfpa.org

Subsequently, the concept of Smart Campus emerges as a derivative of Smart Cities, given the similarities between university campuses and cities. Both integrate into this context through their significant potential to stimulate interactions within the spaces of universities (Jesus; Pereira; Santiago, 2018).

Based on this context, the general objective of this article is to analyze, through a systematic literature review, the main concepts associated with the term *Smart Campus*, and to outline some technological possibilities currently being developed by educational institutions both nationally and internationally, based on the aforementioned term. The aim is to suggest pathways for the transition from a traditional university model to a Smart Campus.

2. THEORETICAL ASPECTS

It is indisputable that Information and Communication Technologies (ICTs) have transformed education by facilitating access to knowledge, promoting collaborative learning, and personalizing teaching. One of the key examples of this transformation in the educational field is the advancement of Distance Education, which has, to some extent, democratized access to education, making it more accessible and adaptable to individual needs.

The latest Higher Education Census published by the National Institute for Educational Studies and Research Anísio Teixeira (INEP, 2023) for the year 2022 supports the aforementioned information, as it indicated a 139.5% increase in the number of vacancies offered in undergraduate courses in the EaD modality between 2018 and 2022. Year after year, society faces significant transformations in terms of educational innovations, such as the integration of artificial intelligences like ChatGPT.

The emergence of disruptive technologies, such as artificial intelligence (AI), and their rapid integration into educational processes has sparked extensive debate within academic circles. This scenario, marked by the convergence of digital technology, educational innovation, and the need for more efficient learning environments, has paved the way for the advent of so-called Smart Universities or Smart Campuses. Smart Universities aim to integrate technologies such as AI, IoT, and big data to enhance both the academic and administrative experience, fostering more personalized and collaborative learning.

However, according to Roth-Berghofer (2013), several aspects must be considered for a university to be classified as "smart." For him, a Smart University is described as a platform for the acquisition and delivery of data, aimed at driving the analysis and improvement of the teaching and learning environment.

According to Ferreira and Araújo (2018), a Smart Campus can be understood as a collaborative ecosystem enriched with technology, capable of quickly responding to the demands of stakeholders, with the goal of enhancing the quality of life on campus, delivering value, and balancing interests. For the authors, the main characteristic of a Smart Campus is the rapid adaptation of the environment to various demands, which may originate from different sources and contexts.

According to these authors, the technologies integrated into Smart Universities facilitate collaboration among educational institutions, researchers, and students worldwide, promoting a more diverse and interconnected learning environment. It is also important to highlight that this university model supports the practice of open education, providing open educational resources (OERs) that allow anyone to access high-quality learning materials (Freitas, 2019).

The research was motivated by the reality of Brazilian universities in relation to this institutional model. According to the Higher Education Census (INEP, 2023), Brazil currently has 2,595 higher education institutions (HEIs), with 2,283 private and 312 public institutions. However, according to a study conducted by Bandeira, L.; Bandeira, B.; Neto, and Casimiro (2022), only nine Smart Campuses were identified in the country, six of which are in public institutions and three in private institutions.

In this sense, the premise of this research was to bring greater visibility to the topic at hand, given the importance of developing projects that monitor and incorporate available technological possibilities, aiming at promoting balanced development alongside the enhancement of quality of life.

3. METODOLOGIA

To achieve the proposed objective, a Systematic Literature Review (SLR) with a meta-analytic approach was used as the methodological resource. This procedure combines meta-analysis, which seeks knowledge through secondary empirical data, with the systematization of bibliographic selection (Mariano; Rocha, 2017).

For the conduct of the SLR, the software Parsifal[2] v2.2.0 was used, in accordance with the Literature Review Protocol described in the section. A Systematic Literature Review is a method for evaluating and interpreting all relevant research on a specific question, topic, or phenomenon of interest. The SLR allows for the analysis of a defined set of studies, considering the specific objectives it has, thereby focusing on deepening the knowledge already addressed on a given topic (Kitchenham et al., 2009).

The objective of this systematic review was to identify concepts of Smart Campus and to list potential projects, considering the perspective of a smart campus. The development of the Review Protocol followed the PICOC criteria, which is one of the most commonly used methods in systematic reviews. In this approach, the researcher must define the Population, Intervention, Comparison, Outcomes, and Context based on their research questions. For this study, the following parameters were used:

- **Population:** Publications focused on the context of universities.
- **Intervention:** "Smart Campus," Smart Universities.
- **Comparison:** Not applicable.

2 Parsifal (http://parsif.al) is an online tool designed to assist researchers in conducting systematic literature reviews. It enables geographically dispersed researchers to work together within a shared space, designing the protocol and conducting the research collaboratively.

- **Outcomes:** Concepts of "Smart Campus," ongoing projects related to this term, and the challenges of these projects from the perspective of the smart university.
- **Context:** Primary Studies.

The search sources used were Scopus and IEEE Xplore. The choice of these databases was made due to their relevance for accessing publications that support researchers both in the development of studies and within academia. The search sequence was specified considering the key terms related to the phenomena under investigation. Pilot searches were conducted to refine the search string. After three attempts, the following search sequence (Search String) was defined and used to search within keywords, titles, abstracts, and full texts of the publications:

("Smart Campus" or "Smart University") and ("Concepts" or "applications" or "projects") and ("main challenges" or "key challenges").

The summarized inclusion and exclusion criteria are presented in Table 1. However, in general, for the analysis conducted, only primary studies published between 2019 and 2023 were considered valid, provided they offered some contribution to the concept of Smart Campus, examples of projects, and the challenges of implementing them in a university campus.

Table 1. Inclusion and exclusion criteria

N	INCLUSION CRITERIA
1	Publication year between 2019 and 2023
2	Presents the concept of "Smart Campus"
3	Provides examples or models of Smart Campus projects
4	Discusses the challenges of Smart Campus projects
5	Published in English or Portuguese
N	**EXCLUSION CRITERIA**
1	Study outside the scope of the review
2	Duplicate studies
3	Publication year before 2019
4	Books, theses, or dissertations
5	Not written in English or Portuguese
6	Does not allow free access to the full text
7	Short papers (4 pages or fewer)
8	Full texts unavailable due to technical issues with the database

Source: Original data from the research, 2024.

3.1 Criteria for Study Selection

The study selection procedure consisted of four main steps. In Step 1, a preliminary selection of articles was made using the search string. The application of the search sequence resulted in 280 scientific texts, with 101 from the IEEE Digital Library (36.1%) and 179 from Scopus (63.9%).

These studies were imported into the Parsifal platform to begin the first filtering procedure, which aimed to exclude duplicate works. To identify duplicates, the "find duplicates" option was used, allowing the application to detect texts with the same title and authors. The result of this action was the identification of 47 duplicate studies.

From this initial pre-selection, 233 studies were considered eligible to proceed to the next stage. The second step in the selection process involved reading the abstracts. During this process, 3 studies were excluded due to content duplication (despite having different titles), and another 155 were rejected for not aligning with the scope of the proposal, being outside the chosen time frame (2019–2023), or classified as books, theses, dissertations, or short papers. No studies written in languages other than the pre-selected ones (English or Portuguese) were identified.

The result of this second stage was the selection of 75 studies deemed suitable for full reading, based on the criteria described in the Protocol. These studies were then cataloged in a spreadsheet. At this stage, the feasibility of open access to all materials was verified. However, 12 studies were not freely available through the CAPES Periodicals Portal, five (05) encountered access errors, five (05) were short papers, and three (03) were excluded as they were books or systematic reviews (since the study only accepts primary research), thus preventing their inclusion in the review. After all these procedures, 49 studies remained, considered relevant for the review.

3.2 Quality Assessment

The quality of scientific research is directly influenced by the methodological rigor employed, with internal validity being one of the key criteria for assessing the reliability of the results (Richardson, 2011). This understanding is supported by Kitchenham and Charters (2007), who argue that quality relates to the extent to which a study minimizes bias and maximizes both internal and external validity (Vilela et al., 2017).

Thus, to assess the quality of the selected studies, a checklist consisting of six questions was created. The answers to these questions were classified as "Yes," "Partially," or "No." Each of these responses was assigned a different weight, with a maximum score of 6 and a cutoff score of 3.5 for a study to be accepted, as shown in Table 1.

Table 1. Quality Index

DESCRIPTION	WEIGHTING
Yes	1.0
Partially	0.5
No	0.0

Source: Original data from the research, 2024.

All analysis was conducted on the Parsifal platform. As the articles were evaluated, a summary list was generated for a more comprehensive view of the works considered essential for the intended study.

4. RESULTS AND DISCUSSIONS

It is a fact that over the past 20 years, many studies have been conducted with the aim of presenting concepts related to *Smart Campus*. However, what is observed is a limited consensus on what this term actually means. In addition to the concept itself, there is also a lack of systematic documentation regarding examples or models of technological projects implemented in smart universities. Given this context, the relevance of conducting a systematic literature review became evident.

The quality assessment of the articles resulted in the approval of 22 studies, which, based on the proposed questions, received a score equal to or greater than the cutoff of 3.5. The questions used for the evaluation are presented in Table 2.

Table 2. Quality Assessment Criteria

N	QUESTIONS
1	Does the study define the concept of "Smart Campus" clearly?
2	Does the study present examples or models of Smart Campus projects?
3	Does the study address the main challenges for implementing Smart Campus projects?
4	Has the study conducted a well-described experiment to evaluate the proposal?
5	Is the research objective clearly described?
6	Do the authors discuss the limitations of the study?

Source: Original data from the research, 2024.

The results of the evaluation criteria are presented in the following sections, divided into three parts: 1) Concepts of *Smart Campus*; 2) Examples or Models of *Smart Campus* Projects; and 3) Main Challenges Encountered in Implementing *Smart Campus* Projects. To meet the objectives of the

article, it was essential to focus exclusively on these three areas.

4.1 Concepts of Smart Campus

As predicted in the introduction of this paper, the term *Smart Campus* emerges in the academic literature as a derivation of the concept of *Smart City*. The similarities between university campuses and urban structures have transformed universities into laboratories where multiple researchers can "test" their projects with the expectation of making these spaces increasingly efficient in terms of the use of natural and technological resources.

In the context of the conception of what constitutes a *Smart Campus*, several authors argue that its development is aimed at providing a comfortable environment for its users through the extensive use of Information and Communication Technologies (ICT). In Table 3, the concepts/approaches of *Smart Campus* identified in the systematic literature review (SLR) are presented.

Table 3. Concepts of Smart Campus

N	Author(s) and Year	Identified Concepts
1	Cibilić; Poslončec-Petrić; Matošić (2023)	The fundamental idea is to create a campus that makes the most efficient use of its resources, provides high-quality services to the campus community, and does so while spending less money on operations.
2	Kou; Park (2023)	A Smart Campus is characterized by a comfortable, energy-efficient, and safe environment that effectively contributes to the growth of education on campus and administrative management.
3	Nóbrega; Miki; Palacio (2022)	We define a Smart Campus as a higher education institution that creates an ecosystem using ICT to achieve sustainability through a governance-based, collaborative, and adaptive learning model, aimed at promoting better livability for its stakeholders.
4	Huang; Su; Pao (2019)	The Smart Campus is a concept of upgrading the campus environment in various aspects through emerging technologies.
5	Samancioglu; Nuere (2023)	The central concept of a Smart Campus is to combine a variety of advanced technologies to achieve high educational performance, provide comfort to users, and be environmentally sustainable, according to various definitions and characteristics.
6	Zabalos *et al.* (2020)	Smart Campuses (SCs) are universities where devices and technological applications create new experiences or services and facilitate operational efficiency.
7	Zarpellon *et al.* (2023)	An educational environment that is infused with enabling technologies for smart services to enhance educational performance, while addressing the interests of stakeholders, with extensive interactions with other interdisciplinary domains within the context of the Smart City.
8	Opranescu; Nedelcu; Ionita (2023)	A Smart Campus can be defined as an achievable goal of digitized support, utilizing the right technologies and leveraging resources offered by IoT (Internet of Things) services and cloud providers, in order to integrate them and develop an interconnected system.
9	Pham *et al.* (2020)	A platform that acquires and provides essential data to drive the analysis and improvement of the teaching and learning environment, or alternatively, as a concept that encompasses a comprehensive modernization of all educational processes.

10	Wahid *et al.* (2021)	In terms of the Smart Campus concept, it refers to a campus that implements and integrates learning systems through information technology.
11	Lobato *et al.* (2021)	The concept of Smart Campus is situated within the academic sphere, much like Smart Cities, with the aim of improving the quality of life for its population.
12	Fernandez *et al.* (2023)	An open, connected, adaptable, and sustainable environment.
13	Valks; Arkesteijn; Heijer (2019)	In this research, the systems or services that measure space usage in real-time and provide this information to users or campus administrators are referred to as "Smart Campus tools."
14	Min-Allah; aAlrashed (2020)	A Smart Campus is considered the integration of cloud computing and IoT, which aids in the management, teaching, research, and other activities of universities. A Smart Campus adheres to the concepts of Smart Cities and addresses the same challenges.
15	Mustafa *et al.* (2021)	A *Smart Campus* is the updated version of a digital university, providing a better academic environment for both faculty and students.
16	Fortes *et al.* (2019)	The concept of Smart Campus derives from the concept of Smart City, which emerged as the application of automatic collection of environmental data and its processing to achieve efficient management of urban areas, as well as their resources and assets. This approach is supported by the massive application of information and communication technologies (ICTs) and the Internet of Things (IoT) paradigm.
17	Sui; Xie (2023)	The *Smart Campus* is a set of technical solutions for intelligent education based on the development and construction of information technology. A *Smart Campus* can be considered a campus management model based on information technology to integrate and optimize campus resources for the delivery of smart services.
18	Blazevic; Riehle (2023)	A Smart Campus can be considered part of a Smart City. Both share a similar structure; a Smart Campus can be seen as a small-scale Smart City.

Source: Original data from the research, 2024.

When analyzing Table 3, the following convergences in the conceptualization of *Smart Campus* are observed:

- The development of a *Smart Campus* is based on the intensive use of Information and Communication Technologies (ICTs);
- The goal of creating a *Smart Campus* is grounded in the ability to provide the public with a more comfortable, sustainable, and efficient environment;
- The primary purpose of a *Smart Campus* is the improvement of teaching and learning processes.

4.2 Technological Solutions in *Smart Campus*

The technological solutions that can be applied in Smart Campus are diverse and are primarily related to resources that support administrative decision-making, aiming to transform the campus into a more efficient and productive environment. With the advent of the Internet of Things, projects related to wearable technologies, smart agriculture, smart transportation, and efficient and sustainable energy have become increasingly widespread. In Table 4, we present examples of proposed projects

for Smart Campus.

Table 4. Examples of Projects for Smart Campus

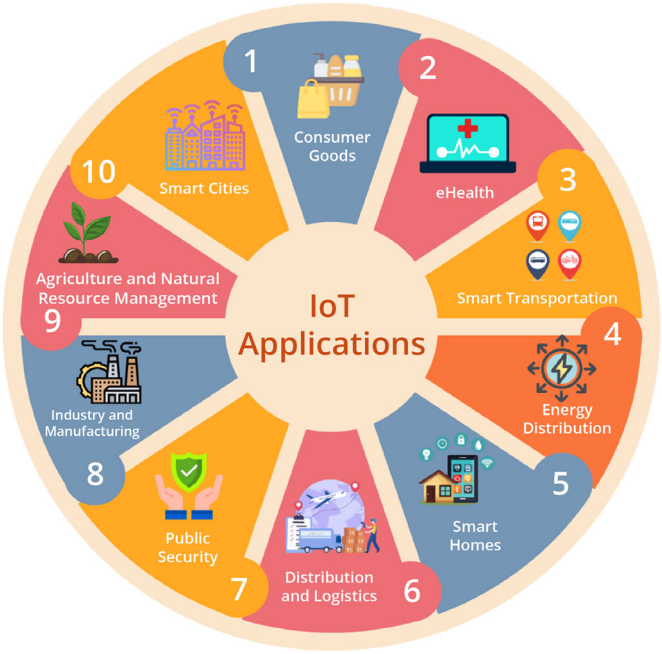
N	Author(s) and Year	Identified Concepts
1	Cibilić; Poslončec-Petrić; Matošić (2023)	Drones and Unmanned Aerial Vehicles (UAVs)
2	Kou; Park (2023)	Automatic Demand Response (Auto-DR)
3	Huang; Su; Pao (2019)	Smart Classrooms
4	Zabalos *et al.* (2020)	Interdisciplinary modeling of digital twins that can be integrated with existing decision support systems, providing quantitative insights and suggestions on sustainable architecture and ICT engineering policies, such as environmental monitoring.
5	Zarpellon *et al.* (2023)	IoT architecture for electrical energy management and water consumption.
6	Chakal *et al.* (2023)	Augmented Reality (AR) and Virtual Reality (VR) technologies to provide a more comprehensive understanding of the campus environment.
7	Opranescu; Nedelcu; Ionita (2023)	Automation of administrative processes and student decision-making processes through the importation of personalized schedules for students and faculty, generation of personalized calendars, virtual assistant recommendation services for students, and automated course exchange processes.
8	Chen *et al.* (2022)	Development of architecture focused on Multi-Access Edge Computing (MEC) for remote areas, where there is limited or no connectivity to a centralized environment.
9	Pham *et al.* (2020)	Living Lab
10	Wahid *et al.* (2021)	Synchronous hybrid learning through videoconferencing for online learning systems; Smart Equipment Solution – based on Internet of Things devices for controlling lighting, air conditioning, LCD projectors, and classroom switches.
11	Lobato *et al.* (2021)	Electric Mobility – Intelligent Multimodal Electric Mobility Management System project for electric bus and boat modes.
12	Fernandez *et al.* (2023)	Digital Twin
13	Min-Allah; Alrashed (2020)	RFID, IoT, cloud computing, 3D visualization technology (augmented reality), sensor technology (motion, temperature, light, humidity), mobile technology (including NFC, QR codes, GPS), and web services.
14	Oberascher *et al.* (2022)	'Smart Water' Project – installation of digital water meters and valves to monitor and control the water distribution network (WD).
15	Mustafa *et al.* (2021)	Smart Classrooms; Smart Laboratories; IoT in Waste and Water Management; IoT for a Safer Campus; Video Surveillance; Smart Locks and Access Control; Asset Tracking; People Tracking; IoT in Energy Efficiency and Cost Savings; IoT in Mobile Applications; Intelligent Service System; QR Code; Occupancy Detection and Tracking; Efficient Parking; IoT in the Smart Library.
16	Fortes *et al.* (2019)	Green Islands
17	Sui; Xie (2023)	Online Learning Platforms
18	Abdullah *et al.* (2019)	Construction of Smart Buildings; Campus Smart Grid.
19	Blazevic.; Riehle (2023)	IoT Sensors for User Monitoring

Fonte: Resultados originais da pesquisa, 2024.

The analysis of Table 4 reveals that the use of sensors for environmental control is one of the most common resources in projects under development with a focus on Smart Campus. It is also evident that the efficient management of water and energy are essential components for determining whether an environment can be considered, or is capable of becoming, "smart."

Almost all of the solutions presented rely on IoT to function. In brief, the Internet of Things (IoT) refers to a network of interconnected physical objects that, through sensors, software, and other technologies, are capable of collecting, processing, and exchanging information over the internet, enabling the integration and automation of devices in various contexts (Ashton, 2009; Bassi & Horn, 2008). According to Atzori, Iera, and Morisio (2010), the IoT has roots dating back to the 1990s, with pioneering projects that already explored device connectivity and data collection. This long history explains the current diversity and scope of IoT applications, which has become a versatile and multifunctional technology present in various sectors of society, as can be observed in Figure 1.

Figure 1. IoT Applications



Source: Adapted from Freitas, 2016.

This series of applications is summarized by Mustafa et al. (2021), who highlight the following technological possibilities: IoT in Waste and Water Management; IoT for a Safer Campus; IoT in Efficiency; IoT in Mobile Applications; and IoT in the Smart Library. Thus, through IoT, it is possible to modernize, optimize, and automate cities, and similarly, university campuses, through the use of technological objects.

4.3 Main Challenges for Implementing Smart Campus Projects

The results presented up to this point can be understood as guidelines for planning a Smart Campus. However, it is important to consider the challenges that arise when working with technologies that primarily involve data management, whether for a population in a municipality or in a more confined, yet more complex environment, such as a university campus. Thus, in Table 5, we present the main challenges identified in the Systematic Literature Review (SLR).

Table 5. Main Challenges for Implementing Smart Campus Projects

N	Author and Date	Main Challenges
1	Kou; Park (2023)	High costs with connectivity and computing; Data confidentiality.
2	Nóbrega; Miki; Palacio (2022)	Data security.
3	Samancioglu; Nuere (2023)	Despite the fact that the transition to Smart Campus development is still ongoing, there is little evidence that user opinions are considered in decision-making processes. Additionally, there is a focus on systems with technologies that are poorly suited to the environments, as well as neglect of outdoor spaces on campuses.
4	Zabalos *et al.* (2020)	The concept of campus intelligence still needs to be thoroughly tested, primarily due to the numerous types of systems, technologies, and smart devices available to students, faculty, and academic institutions.
5	Zarpellon *et al.* (2023)	- The challenge of enabling different systems to communicate with each other in a simple and direct manner, as data are generated in different ways, and their storage may not be standardized. - The structure of the database can be built in various ways, leading to inconsistencies when attempting to integrate data from different databases, even if they store the same data. - Data from multiple sources can only be integrated when this semantic heterogeneity is resolved. - Difficulties related to the willingness of individuals involved in the system to share their data for integration, as well as reluctance to provide the necessary data for such integration.
6	Chakal *et al.* (2023)	The domain of applications related to Augmented Reality (AR) for vertical cybersecurity.
7	Chen *et al.* (2022)	- Traditional information infrastructures on campus may not support latency-sensitive and computationally intensive smart applications. - A mix of legacy and new applications, isolated data silos, and heterogeneous management.
8	Pham *et al.* (2020)	Security, privacy, interoperability, standardization, and configuration, along with political issues.
9	Fernandez *et al.* (2023)	Data management, data acquisition, advanced processing resources, trained personnel, data storage, standardized data-sharing frameworks, lack of open data, accessibility for the public and other stakeholders, interoperability between platforms, digital privacy, and scaling pilot projects to city-wide levels.
10	Valks; Arkesteijn; Heijer (2019)	Systems are still primarily evaluated from a technical perspective rather than a functional one.
11	Min-Allah; Alrashed (2020)	- Security / privacy. - There is currently a lack of comprehensive interoperability standards to integrate various devices.

12	Oberascher *et al.* (2022)	- Sufficient IT knowledge; - Integration of different participants in the project (diversity of professionals); - High investment costs; - Environmental impacts (e.g., use of batteries in projects).
13	Fortes *et al.* (2019)	The final coexistence of highly heterogeneous ICT elements represents a challenge in maintaining proper integration of all the different devices.
14	Sui; Xie (2023)	- Limited knowledge within the academic community about what constitutes a Smart Campus; - Information security.
15	Abdullah *et al.* (2019)	- Technical barriers observed from the following perspectives: security, privacy, and configuration; - Financial difficulties due to the limited resources of universities; - Political obstacles related to privacy restrictions.
16	Blazevic; Riehle (2023)	- Government support; - Privacy concerns; - Social influence and collaboration in services.

Source: Original data from the research, 2024.

The term *Smart Cities*, from which intelligent universities derive, was coined in the 1990s, primarily focusing on the new information and communication technologies being integrated into urban infrastructure (Lopes; Leite, 2021). It is clear that significant progress has been made in the areas related to the implementation of projects aimed at this concept. However, it is also evident that, even today, three decades later, many challenges remain in the deployment of technologies that embrace the term "smart."

It is a consensus among the authors identified in the Systematic Literature Review (SLR) that data security and privacy is the main challenge to be addressed. We also draw attention to the limited knowledge within the academic community about what constitutes a Smart Campus and, consequently, its benefits for optimizing university life. This prompts us to reflect on the strategies that could be adopted to mitigate obstacles related to the resistance of many individuals when it comes to their involvement in decision-making processes aimed at improving the university environment.

Therefore, this study considers it of substantial importance to analyze the challenges involved in the creation of a Smart Campus, given the financial expenditure that is commonly required for technological projects. Thus, anticipating potential obstacles is relevant to prevent the loss of human and economic capital for the state or for the institution itself, which aims to implement a Smart Campus.

4.4 Conceptual Framework for Smart Campus

The term "Smart," according to Alves et al. (2019), cited by Lopes and Leite (2021, p.5), is related to two major areas: "on one hand, it brings a logic of technopolis with the use of new technologies (such as IoT, big data, algorithmic governance, etc.), and on the other, the idea of an innovative city with citizen inclusion and participation in urban governance." In this sense, it is important to emphasize that the concept of "being smart" is not limited to the diffusion of ICTs (Information and Communication

Technologies), but encompasses a broader set of needs, infrastructures, and sustainable concepts.

The Smart Campus can thus be understood as a new phase in the development of information technology in universities. Although research on the topic tends to focus on the field of Computer Science, it is clear from the Systematic Literature Review (SLR) that management can contribute significantly to this model transition.

The evolution of Brazilian Higher Education Institutions (HEIs) is both necessary and urgent, especially when considering a study presented by Reinsel, Gantz, and Rydning (2018) from the International Data Corporation (IDC), which forecasts an alarming increase in data interaction: by 2025, approximately 75% of the global population will be connected and interacting with data every 18 seconds, with a significant portion of this interaction originating from Internet of Things (IoT) devices (Bandeira, L.; Bandeira, B.; Neto, and Casimiro, 2022).

Considering this context and the current state of Brazilian universities, it is possible to suggest the adoption of the conceptual framework methodology defined by the Sapienza University of Rome, Italy (Pagliaro et al., 2016), which, when adapted, can serve as a possible pathway for the development of projects aimed at improving quality of life and sustainability on campus, towards the Smart Campus model. The framework developed by the University of Rome is divided into six stages:

1. Preliminary Planning – This stage involves an exploratory study of the university, aimed at identifying the challenges and potential of the site, defining the areas to be investigated, and determining the beneficiaries of the projects. During this phase, the methods for data collection and the feasibility of the projects are also analyzed;
2. Identification of Action Areas – This stage involves filtering the areas pre-selected in the first phase;
3. Data Acquisition – This stage is characterized by the collection of data to build the foundation. Methods such as surveys, interviews, public consultations with communities, among others, can be used;
4. Data Analysis – This stage involves the tabulation and evaluation of the collected data;
5. Categorization of Issues – This stage involves identifying the deficiencies in each area;
6. Definition of Strategies – This stage involves selecting the most appropriate strategy according to the action area. The process is carried out in three stages: construction of Incidence Matrices (actions x areas); weighting of actions, where scores are assigned to each action based on the following criteria: user rating, feasibility rating, and time rating. Finally, the winning actions are chosen based on the highest total scores.

Considering the profile of national universities, the application of the aforementioned methodology is suggestive for experimenting with technological projects that promote sustainability, which could also be scaled to cities, thereby contributing to the creation of more sustainable spaces.

It is worth noting, however, that the proposed framework takes into account a reality that differs

from that of universities, as well as from their technical and technological infrastructure. Therefore, its implementation requires careful planning, investment in appropriate technologies, and an integrated approach to ensure that all components function harmoniously to achieve the goals of sustainability and efficiency.

Therefore, it is essential to invest in specialized professionals to define the execution paths for the proposal, considering that it requires coordination across various technical and organizational aspects. The approach must be adaptable and iterative to respond to evolving needs and ensure the achievement of the campus transformation objectives.

5. FINAL CONSIDERATIONS

This study primarily aimed to identify concepts, technological solutions, and challenges related to Smart Campus. Although there has been a substantial body of scientific literature and the development of projects based on the conception discussed here in recent years, this study identified a lack of consensus regarding its definition. This disagreement suggests the possibility of further investigations in the field, as the Smart Campus, in its practical sense, holds considerable dynamic and adaptive potential.

In this sense, it is emphasized that the proposed framework should also be adaptive, meaning it must keep pace with ongoing technological and academic transformations, so that the Smart Campus model does not quickly become outdated or obsolete, thus failing to meet the needs of the student community.

The intention of this research was to highlight the importance of developing projects aligned with the well-being and improvement of teaching and learning processes in universities, as well as the possibilities offered by the concept of Smart Campus to achieve these goals. Thus, this study aims to make a small referential contribution to the perspectives of intelligent solutions covered by the proposed theme.

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