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A Smart Campus Framework: Challenges and Opportunities for Education Based on the Sustainable Development Goals

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Abstract: Although technology improvements boosted the digital transition of universities, which built a path for smart campuses, the smartization process is more than simply promoting digitalization. This research aims to identify the essential elements and the most significant deficiencies in the smart campus dimensions and its variables from the user's viewpoint to offer a list of priorities for decision-makers. Through an importance-performance analysis (IPA) performed using IBP SPSS 26, we tested an integrative smart campus framework in a Brazilian university, previously validated with Latin American experts. This research confirmed that eight dimensions are important for a smart campus evaluation and provided a list of priorities for academic managers. The results indicated the main gaps among importance and performance. This research concluded that the smartization process could not rely on technology attributes only. Universities should meet the modern society's present and emerging needs and the labor market in a sustainable, social, and technological manner. Smart campuses in developing countries may prioritize different components than developed countries, such as infrastructure. We propose that more studies should apply the framework in more universities.

Keywords: smart campus; sustainable development goals; higher education; smart university; Brazil; importance–performance analysis

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1. Introduction

For many centuries, universities have changed realities through education and critical thinking. Since scholasticism in medieval European monasteries, universities had become a significant component of societal change, sustainability, and digital transitions [1,2]. They have had a crucial role in recent matters, such as fighting the COVID-19 pandemic, through partnerships and support of governments and civil society [3].

Change and freedom highlight the history of universities with diverse roles to ensure the institution is fresh and aware of novelties. Technology is a fundamental tool in replacing classical education with smart education led by industry 4.0, technical innovations, and socioeconomic challenges [4,5]. In this way, universities are leaning toward the smartization process, that is, becoming smart campuses.

The smartization process of universities aims to change the current framework to evolve an open university concept. It aims to adapt the management model, infrastructures, and relationships with the community toward a common goal: sustainability and quality of life [6].

To understand a holistic and multidimensional perspective of development, the United Nations proposed the Sustainable Development Goals (SDGs). It connects countries, cities, regions, companies, and people to embrace all 17 objectives and promote human well-being, economic prosperity, and environmental protection [7]. It is not legally binding, but the global framework effectively applies to local realities.

Smart initiatives promote sustainable development as a crucial component. Smart cities use models and tools to improve access of citizens to municipal services and facilities along with high levels of technology advancements [8], such as providing solutions for the COVID-19 pandemic [9]. Smart cooperatives also employ technologies and sustainable development for value creation in this sector [10].

Smart campuses use information and communication technologies (ICT) to interact with stakeholders to create an ecosystem that integrates physical and digital spaces. It establishes responsive, intelligent, and improved services to create a productive, creative, and sustainable environment [11,12].

Open and integrative participation of stakeholders is part of the smart campus' primary purpose to achieve sustainability and quality of life. Therefore, it is necessary to assess how university stakeholders evaluate the smart campus dimensions and its variables. Studies from the user's viewpoint can provide a map for academic managers to optimize the smartization process and improve the users' satisfaction level. Thus, this study contributes with an educational management tool, a list of prioritization items for decision makers.

Smart campus is a recent approach, and the prioritization order of its elements varies according to the cultural, social, and economic context. Thus, our research question is: "What should be the decision-making priorities in the smartization process of a Brazilian university?"

This research aims to identify the essential elements and the most significant deficiencies in the smart campus dimensions and its variables from the user's viewpoint to offer a list of priorities to decision makers. We used a quantitative descriptive–exploratory approach through an importance–performance analysis (IPA) to accomplish our goal with a sample of students from the Federal University of Campina Grande, located at the Paraiba State in Brazil. After this Introduction section, we present a literature review section with a background of university history and smart campus. Then, we present the Methodology, Results, Discussions, and Conclusions sections.

2. Theoretical Background

Universities emerged in the Western world through European Christian monasteries by the 11th century. At first, universities had an academic structure composed of theology, arts, law, and medicine [1,13]. Teaching in the first universities followed scholasticism. Which is a scientific practice or method based on the rigorous conception of different positions through the analysis of authorized texts in a phase of *Lectio*, followed by a step of debates, namely *disputatio* [1,2,14].

Universities remained under the responsibility of the Christian church for centuries [1], although, the Protestant reform and its political and cultural changes in the 16th century affected the university curricula, systems, and frameworks [15]. New universities were instituted to spread the reformed faith throughout Europe. Lutherans and sovereigns made universities a territorial state and a confessional formation [15,16].

The university conception remained the same until the French Revolution, which also marked the decline of universities and the appearance of vocational schools, such as the *École Polytechnique*, with a focus on engineering [1,13]. Meanwhile in Germany, a new type of university introduced teaching and research as the inseparable core responsibilities of professors, committed to a humanistic education, which became the classic university of the 19th and 20th centuries [13,15].

The development of universities continued to follow state and political directives, structuring new pedagogical landscapes and founding new kinds of universities, such as the technical university, focused on business and commerce in France and later in the United States [1,13,15]. World War I also changed universities, introducing new courses, alterations of subjects, and ways of research, including the curtailment of academic freedom by the Soviets and the destructive ideology by the Nazi Party [13].

After World War II, universities increased the applied sciences and interdisciplinarity, such as game theory and operational research [13]. Also, student movements paved the way for building a contemporary university that focuses on methods, research paradigms, disciplines, institutions, and epistemologies. New universities are transdisciplinary with an active role in society [13].

2.1. Latin American Universities

The first Latin American universities appeared in the 16th century with the Spanish colonization as a copy of the medieval model subordinated to the crown and the church [17]. After the independence of Hispano-American countries, a new kind of university emerged: the republican university inspired by the Napoleonic model, connected with professional schools [17,18].

Those Latin American universities had the same structure and aimed at an intellectual elite and classical studies until the beginning of the 20th century when the University Reform Movement or Cordoba Reform took place in 1918 [17–20]. The University Reform started as a student protest against the old universities' regime controlled by traditional oligarchies in Córdoba University in Argentina. This thinking quickly spread throughout Latin America and became one of the most important social movements of the continent [17–19].

The Cordoba Reform also became the starting point for Latin America to mark the history of universities with its original contribution [17]. The movement had broad goals related to political, cultural, economic, and social demands. However, the most relevant point was democratizing universities through autonomy, co-governance, and outreach or extension [17,18,20].

The social engagement brought by the Reform changed the ethos of Latin American universities by the inclusion of outreach as the third mission of universities along with teaching and research [17,18]. Currently, the profile of Latin American universities includes autonomy and governance with professors, students, and other stakeholders. Additionally, outreach activities are conducted toward the community or disadvantaged sectors of society through technical assistance and projects, which is the most prominent characteristic of public Latin American universities [17,20].

With a different history from its neighboring countries, Brazilian universities only emerged in the early 1920s [17,21]. However, movements demanding the democratization of society from the Cordoba Reform and student protests against the military dictatorship, also marked the history of universities in the country [17,21]. Those social movements mainly contributed to the legal binding of the integration and inseparability of teaching, research, and outreach as the mission of universities, consecrated by the Brazilian constitution of 1988 [17,21].

2.2. Smart Campus

The digital transition of universities accelerated in 2020 due to the COVID-19 pandemic and restrictions, through ICT, digital management, and distance teaching [22]. Along with technology, the future university needs to sustainably attend to the needs and promote better livability and quality of life for its stakeholders, which is the goal of smart campuses [23–25].

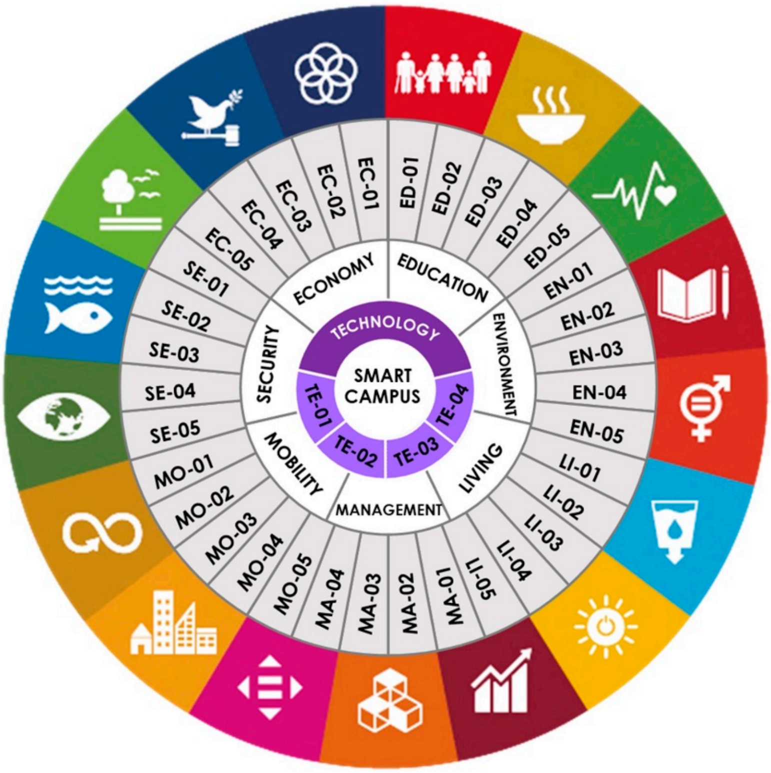
Starting in 2000 [26], the smart campus concept is still at the exploratory stage, with no common agreement on the definition, dimensions, or characteristics [12,27,28]. However, three different perspectives conceptualize smart campus based on a (1) technology-driven approach, (2) organizational process-driven approach, and (3) smart-city-driven approach [27,29,30].

Technology is the driver of smart campuses, mainly through the Internet of Things (IoT) and ICT to enhance the informatization level in colleges and universities [31–36]. The wide range of technologies supports and digitalizes processes, teaching, research, and services rapidly and harmoniously [35–41].

The organizational process perspective focuses on replacing old manual services with smart ones to optimize processes through information sharing mechanisms [37,42]. The management should also provide personalized guidance and assistance for specific tasks based on user requirements to achieve the smart management and service on campus [43–45].

The smart city promotes the integration of social, economic, and environmental awareness into a well-performing city, mainly based on smart dimensions (economy, people, governance, mobility, environment, and living) to optimize the citizens' quality of life through cutting-edge technologies, such as ICT and IoT [46–49]. The smart campus is part of smart city movements that use technologies and sustainability to improve universities as an advanced pattern of digital and sustainable universities [50]. Sharing a similar structure, smart campuses may be used as a small-scale city for smart city projects [51–55].

Despite different perspectives, we define a smart campus as a higher education institution that creates an ecosystem using ICT to achieve sustainability using a governance-based, collaborative, and adaptive learning model to promote better livability for its stakeholders. Based on the goal of sustainability, we proposed a framework with dimensions connected to the SDGs, namely economy, education, environment, living, management, mobility, security, and technology, which is a transversal one, i.e., present in all dimensions (Figure 1).



DIMENSION	CODE	VARIABLE
Smart Economy	EC-01	Electronic services
	EC-02	Entrepreneur and innovation support
	EC-03	Collaborative Economy
	EC-04	Local development
	EC-05	Employability
Smart Education	ED-01	Smart Education Technologies
	ED-02	Internet access
	ED-03	Community needs awareness
	ED-04	Satisfaction
	ED-05	Results-based learning
Smart Environment	EN-01	SDGs
	EN-02	Biodiversity
	EN-03	Eco-friendly resources
	EN-04	Smart Buildings
	EN-05	Recycling
Smart Living	LI-01	Quality of Life
	LI-02	Health
	LI-03	Social Inclusion
	LI-04	Leisure
	LI-05	Extracurricular activities
Smart Management	MA-01	Sustainable management
	MA-02	Transparency
	MA-03	Participation
	MA-04	Process efficiency
Smart Mobility	MO-01	Accessibility
	MO-02	Signaling
	MO-03	Sustainable transport
	MO-04	Collaborative economy
	MO-05	Eco-friendly transport
Smart Security	SE-01	Security
	SE02	Biosecurity
	SE-03	Smart Technologies
	SE-04	Cybersecurity
	SE-05	Disaster prevention
Smart Technology	TE-01	Internet technologies
	TE-02	Data management
	TE-03	Information Systems
	TE-04	Internet Technologies

Figure 1. Smart campus framework.

According to the SDGs and a smart city perspective [47], our model proposes variables to each smart dimension. As the university becomes more sustainable, achieving the SDGs, it introduces or improves the smartization process. It can be a monitor for both perspectives, selecting how the university activities connect with whichever dimension.

3. Methodology

The goal of this study was to identify the essential elements and the most significant deficiencies in the smart campus dimensions and its variables from the user's viewpoint to offer a list of priorities for decision makers. We conducted a quantitative descriptive–exploratory approach through an IPA based on the smart campus framework previously validated.

The IPA technique was proposed by Ref [56] to develop more effective marketing feedback from consumers and help decision makers better manage resources and strategies through the service/product performance and importance. It diagnoses the performance of attributes and promotes prioritization for the optimal allocation of resources, improving customer satisfaction [57]. Currently, it is employed in research in other areas, such as smart cities [49], tourism [58], service satisfaction [59], and higher education [60].

3.1. Data Collection

Although the case choice was intentional, we established the following criteria for the university selection: (i) The university should present standard Brazilian universities' characteristics, i.e., to be a public institution with different undergraduate and graduate programs; (ii) The university should have a smart campus project or an intention to start one; (iii) The university should have some recognition at the national level. Thus, we chose the Federal University of Campina Grande (UFCG) located in the northeast of Brazil, which has approximately 20,000 students, 124 degree programs (undergraduate, master, and Ph.D.), 1500 professors, and 1400 employees [61]. Besides, UFCG has seven campuses, and it recently created the Smart Campus Project on its main campus. Additionally, in 2020, UFCG was highlighted in the national media for leading in the National Ranking of Resident Depositors of Invention Patents, released by the National Institute of Industrial Property [62,63].

Data collection was conducted in November 2021 through an online survey hosted on Google Forms sent to UFCG students. The university has 20,427 students [61], thus, considering a random sample with a 95% confidence level and 5% error, this should amount to 378 respondents. The questions are from a previous framework pre-validated by a Latin American experts' panel. Validation occurred through online focus group sessions composed of 10 participants from different scientific backgrounds, such as management, architecture, and technology, from Brazil, Colombia, Cuba, Ecuador, England, Mexico, and Spain.

The IPA results rely on the attributes' perception, so it is crucial to appropriately select each indicator and use the same set in both importance and performance. For this reason, we used a framework previously validated by international experts on smart campus (Table 1).

Table 1. Smart campus indicators.

Dimension	Indicators	Variable
Smart Economy (EC)	On my campus, it is possible to perform electronic transactions, such as paying university fees or making payments in stores.	Electronic services
	My campus supports business ideas through entrepreneurship centers, innovation centers, entrepreneur incubators, specialized centers, etc.	Entrepreneur and innovation support
	My campus has collaborative economy networks or actions of shared economy.	Collaborative economy
	My campus supports local economic development with projects and actions toward the community.	Local development
	My campus has a department or sector to support employability.	Employability

Table 1. *Cont.*

Dimension	Indicators	Variable
Smart Education (ED)	My campus uses smart technologies for teaching, for example, cloud computing, IoT, IA, big data, etc.	Smart education technologies
	My campus has open and available internet bandwidth for all.	Internet access
	My campus consults the community about its educational needs (e.g., course availability).	Community needs awareness
	My campus monitors the satisfaction level of students and staff.	Satisfaction
	On my campus, the teaching methodology is results-based learning.	Results-based learning
Smart Environment (EN)	My campus develops actions toward the Sustainable Development Goals (SDGs).	SDGs
	On my campus, there are actions to protect the local biodiversity.	Biodiversity
	My campus uses bioenergy and smart technologies to manage energy and water resources, such as automatic lighting.	Eco-friendly resources
	My campus has smart buildings, e.g., buildings with automated management of resources.	Smart buildings
	My campus recycles residues.	Recycling
Smart Living (LI)	On my campus, there is quality-of-life and well-being monitoring.	Quality of life
	My campus implements occupational health and wellness programs.	Health
	My campus measures the level of social inclusion among students.	Social inclusion
	My campus has adequate leisure spaces.	Leisure
	On my campus, there are extracurricular activities for the community.	Extracurricular activities
Smart Management (MA)	My campus has a management focused on the sustainable use of resources.	Sustainable management
	My campus publishes the accountability annually.	Transparency
	My campus performs participatory strategic planning.	Participation
	My campus has an online process management platform.	Process efficiency
Smart Mobility (MO)	There is adequate public transport to access my campus.	Accessibility
	There is traffic signaling on campus.	Signaling
	My campus encourages or uses low-carbon transport.	Sustainable transport
	My campus encourages collaborative transport, such as rides.	Collaborative economy
	My campus has support facilities for bikes.	Eco-friendly transport
Smart Security (SE)	My campus ensures physical and material security.	Security
	My campus has biosafety protocols.	Biosecurity
	My campus has technological systems to support security (e.g., facial recognition system).	Smart technologies
	My campus has protection from cyber attacks.	Cybersecurity
	My campus has protocols for the prevention and management of risks and disasters.	Disaster prevention
Smart Technology (TE)	My campus uses internet technologies, such as the Internet of Things.	Internet technologies
	My campus has systems for data management and interconnection.	Data management
	My campus has technological control systems, such as sensors.	Information systems
	My campus has systems (e.g., webpage) to offer and manage services to its stakeholders.	Internet technologies

Note: SD—Standard Deviation; I–P—Importance–Performance.

We conducted a content validity test with Brazilian undergraduate and graduate students and professors to improve the questions' reliability. We requested them to evaluate and suggest improvements related to each item's clarity and adequacy. We analyzed and changed the queries according to all suggestions. Additionally, we performed a pilot test in October 2021 with UFCG's undergraduate and graduate students.

The questionnaire was promoted through emails to academic secretaries and professors, as well as social networks, namely Instagram, Facebook, WhatsApp, and Telegram, to reach a broader range of students. However, to ensure that only UFCG's students would answer the survey, we included a filter question, asking the respondent what connection they had with the university. They had three options: (1) undergraduate student, (2) graduate student, or (3) no connection with the university. The questionnaire opened only if the student answered the first and second options. Additionally, we assured anonymity in completing the questionnaire, since no email or identification data were collected.

Firstly, the questionnaire presented the smart campus concept. Second, we asked the respondents for a two-fold evaluation of 38 indicators (Table 1). On the one hand, they indicated the importance of each attribute to a smart campus. On the other hand, they evaluated the indicator performance. We chose a 5-point Likert scale, of which one was equal to the lowest level on both importance and performance, and five was the highest. Finally, there were demographic questions, such as sex and age.

3.2. Data Analysis

On IBM SPSS 26, we performed data analysis through the IPA matrix, composed of four quadrants (Figure 2). The first quadrant comprises the most important variables but with low satisfaction, meaning that managers should prioritize those; the second quadrant indicates items with good performance and importance, therefore the managers should keep up the good work on those; the third quadrant gathers underperforming and non-important items, which are low priority; and the fourth quadrant comprises items with high performance but low importance, indicating a possible overkill of resources [56].

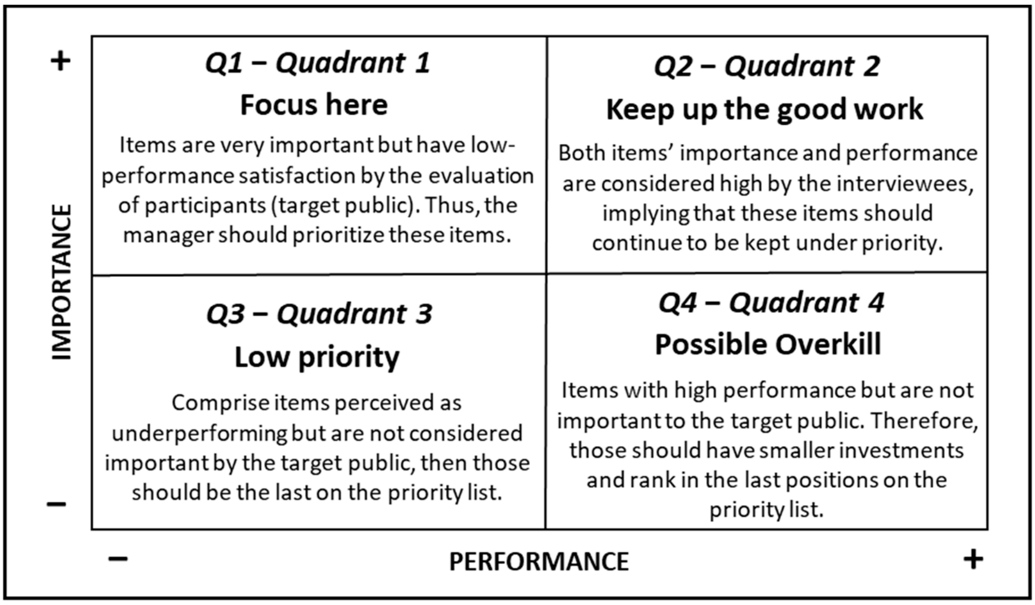


Figure 2. IPA matrix.

Selecting the optimal cut-off points in IPA is one of the biggest issues in this method [57]. We chose the data-centered method to discriminate the IPA thresholds, since it is the most applied method and has higher discriminative power than the scale-centered method [57,64,65]. Thus, our IPA uses the mean values to specify the threshold.

4. Results and Analysis

We obtained 450 answers, but only 379 were valid because 45 respondents were not UFCG students, and 26 questionnaires had missing data. The main sample characteristics were 54.8% female in an age range of 18–30 years old (79.8%) from undergraduate courses (80.2%) in the main campus in Campina Grande city (76.4%), as shown in Table 2.

Table 2. Demographics.

Characteristic	Number of Respondents	Percentage (%)
Sex		
Female	213	56.2
Male	166	43.8
Age		
Less than 18 years old	2	0.5
Between 18 and 30 years old	315	83.1
Between 31 and 40 years old	40	10.6
Between 41 and 50 years old	15	4.0
Between 51 and 60 years old	5	1.3
More than 61 years old	2	0.5
Course type		
Undergraduate	304	80.2
Graduate and Postgraduate	75	19.8
Campus		
Campina Grande city	291	76.8
Cajazeiras city	10	2.6
Cuite city	16	4.2
Patos city	13	3.4
Pombal city	10	2.6
Sousa city	29	7.7
Sume city	10	2.6

4.1. Descriptive Analysis

Descriptive statistics quickly describe the data characteristics through a simplified set of values [66]. To graphically summarize our results, we chose [67]'s boxplot, one of the most used techniques for displaying and summarizing univariate data [66–69]. It mainly uses the data median and quartiles that compose the 5-number summary: minimum and maximum range values, marking the interval length by putting whiskers as the lines. Thus, it draws a box from the first to the third quartile that equals in the interquartile range (IQR = Q3 − Q1) and puts a line at the median (Q2) [66,68,69].

The left side of Figure 3 summarizes the descriptive data for importance scores with a 1-point scale (4–5). The respondents majorly considered all attributes as very important to measure a smart campus, as the range of 93% of the data were between 4.49 and 4.84. Even the farthest outliers, which compose 7% of data, at the graph's lower end scored 4.30, indicating a high level of importance. The interquartile range representing 50% of scores is relatively short, comprising a 0.13-point difference. Additionally, the median is closer to the boxplot's upper end, with half the scores grouped higher than the mean. This result indicates that students have a high level of agreement with each other.

Additionally, the right side of Figure 3 shows the descriptive data of performance scores with a 3-point scale (1–4). Students considered that the university underperformed as a smart campus, since the overall data ranged between 2.23 and 2.86. The interquartile representing 50% of the data is relatively short, as it ranges between 2.86 and 2.23, resulting in a 0.63-point difference. It points out a high level of agreement among respondents. However, the upper whisker is more prolonged than the lower one, which means that opinions varied in the most positive quartile. Meanwhile, in the most negative quartile, represented by the lower whisker, the views were more similar, which is also indicated by the median's position closer to the box's lower end.

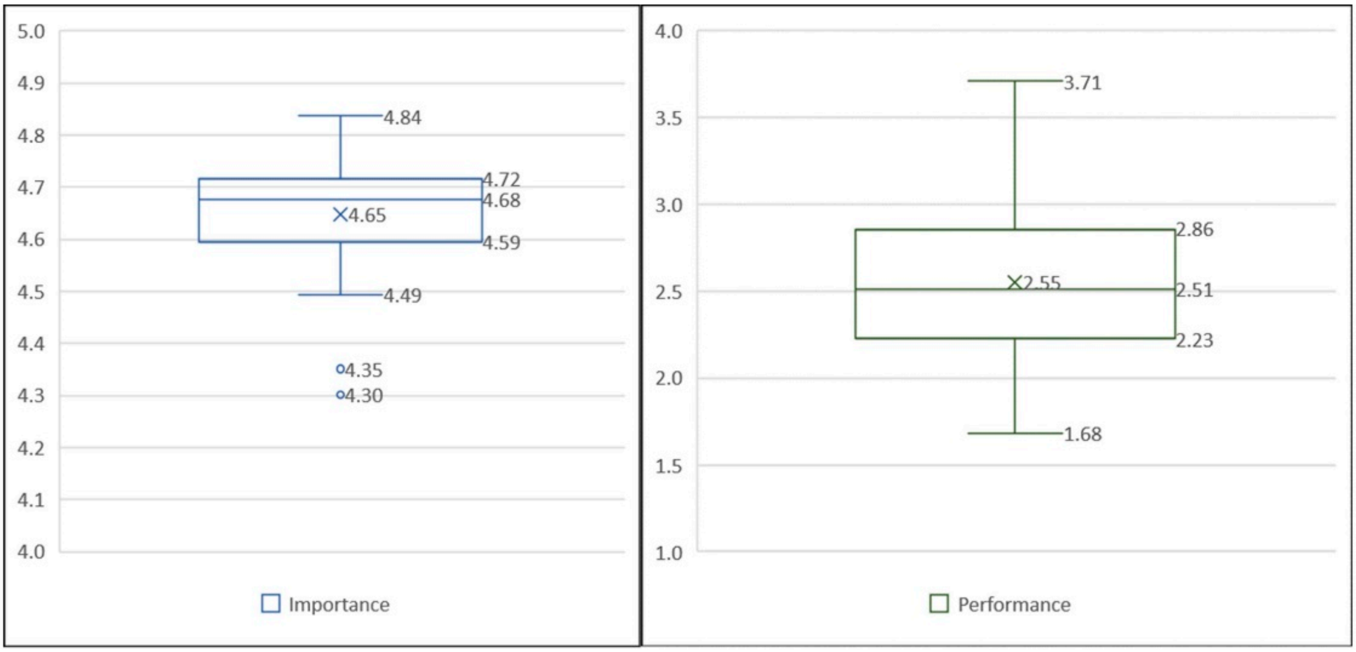


Figure 3. Importance and performance boxplots in different scales.

When compared using the same scale (Figure 4), the difference between importance and performance scores is clear. While respondents majorly agreed that all items are important to evaluate a smart campus, as indicated by the higher and shorter boxplot, the university had a mild to bad performance, with students holding different opinions, as represented by the lower and taller boxplot.

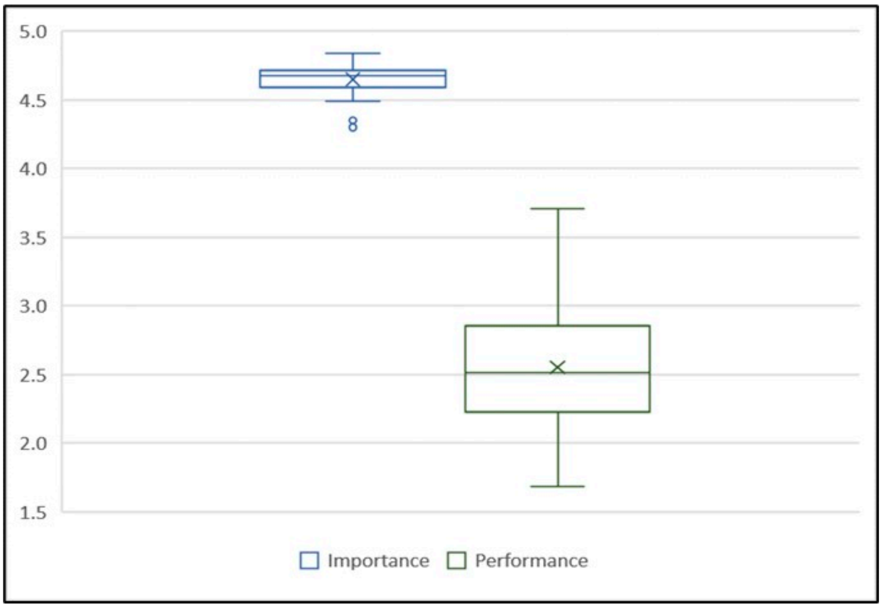


Figure 4. Importance and performance boxplots.

4.2. IPA Analysis

We extracted the Cronbach's alpha coefficient for both importance and performance samples before conducting the IPA to ensure data reliability. All dimensions scored higher than 0.7, which is considered reliable and indicates adequate internal consistency of the dataset [65]. Table 3 presents the scale indices and the general score by dimension.

Table 3. Dimensions statistics.

Ranking	Importance				Performance				GAP	
	Dimension	Mean	SD	Alpha	Dimension	Mean	SD	Alpha	Dimension	I–P
1	LI	4.713	0.024	0.911	MA	2.898	0.578	0.737	MA	1.779
2	TE	4.710	0.082	0.845	TE	2.783	0.657	0.754	EC	1.878
3	SE	4.707	0.077	0.916	EC	2.562	0.289	0.775	TE	1.927
4	MA	4.677	0.042	0.907	ED	2.527	0.234	0.779	ED	2.122
5	EN	4.672	0.086	0.924	EN	2.495	0.484	0.815	EN	2.177
6	ED	4.649	0.040	0.887	LI	2.473	0.129	0.839	MO	2.221
7	MO	4.633	0.135	0.898	MO	2.412	0.726	0.745	LI	2.240
8	EC	4.440	0.107	0.893	SE	2.382	0.463	0.818	SE	2.325
-	TOTAL	4.650	0.074	0.976	TOTAL	2.566	0.445	0.950	TOTAL	2.08

Note: SD—Standard Deviation; I–P—Importance–Performance.

The most important dimension is smart living with a mean of 4.713 and a standard deviation of 0.024 (Table 3). These results suggest that students regard highly the issues relating to their quality of life in a smart campus, such as health, leisure, and well-being. On the other hand, the less important dimension for students was smart economy, with a mean of 4.44 and a standard deviation of 0.107. However, we note EC is less important but did not have a low score (4.44). Thus, students value entrepreneurship, economic innovation, electronic payment systems, and other economy-related issues.

Regarding the performance results, the best dimension in UFCG is smart management, with a mean of 2.898 and a standard deviation of 0.578 (Table 3). However, the score attributed is medium, not high. This dimension includes process efficiency, sustainable management, transparency, and participation. The worst performance relates to the smart security dimension with a mean of 2.382 and a standard deviation of 0.463. Thereby, students consider that UFCG underperforms in disaster prevention, biosecurity, cybersecurity, and other issues associated with this dimension. Despite the position in the performance ranking, all dimensions indicate low functioning, as mentioned before.

Furthermore, we found considerable gaps between the expectation of a smart campus and the reality in UFCG in all dimensions. The I–P gaps vary between 1779 to 2.325 on a scale of 1–5 points (Table 3).

Table 4 summarizes the average scores of indicators. It presents mean and standard deviation results, as well as the ranking for higher values for importance and performance. It also shows the gaps between importance and performance that represent unsatisfaction levels among respondents. The gaps point out the faultiest items to achieve the status of a smart campus and the way to guide academic managers toward a smartization process. In this case, the interpretation of gap ranking is for lower values, since the smaller the gap, the better the quality of that attribute from the respondent's perspective.

The results indicated that the most important items for a smart campus are accessibility (4.84), security (4.83), and internet technologies (4.79), while the less important attributes are electronic services (4.30), collaborative economy (4.35), and entrepreneur and innovation support (4.49), all from the economy dimension. However, as previously mentioned, all items are considered important. They have a score above 4, a mean of 4.65, and a standard deviation of 0.7.

The responses may represent low discriminant power, since all items are important. Nevertheless, these results support our proposition that a smart campus needs an integrative model and a balance among technology and other dimensions. It confirms that universities need to sustainably attend to their stakeholders' needs and promote better livability and quality of life, which is the primary goal of smart campuses [23–25].

Table 4. IPA results.

Variables		Importance			Performance			Gap	
	Code	Mean	SD	Rank	Mean	SD	Rank	I–P	Rank
Electronic services	EC-01	4.30	0.92	38	2.78	1.31	13	1.52	3
Entrepreneur and innovation support	EC-02	4.49	0.83	36	2.64	1.18	16	1.85	11
Collaborative economy	EC-03	4.35	0.90	37	2.28	1.19	26	2.07	17
Local development	EC-04	4.53	0.77	32	2.87	1.24	9	1.66	6
Employability	EC-05	4.52	0.86	34	2.23	1.11	28	2.29	26
Smart education technologies	ED-01	4.64	0.68	25	2.72	1.16	15	1.92	15
Internet access	ED-02	4.70	0.70	13	2.21	1.19	30	2.49	30
Community needs awareness	ED-03	4.61	0.74	27	2.46	1.12	21	2.16	20
Satisfaction	ED-04	4.68	0.64	19	2.45	1.21	23	2.23	24
Results-based learning	ED-05	4.61	0.69	28	2.80	1.17	12	1.81	9
SDGs	EN-01	4.75	0.61	5	2.93	1.10	7	1.81	10
Biodiversity	EN-02	4.72	0.61	10	2.85	1.29	10	1.86	12
Eco-friendly resources	EN-03	4.65	0.70	22	2.12	1.15	32	2.53	32
Smart buildings	EN-04	4.53	0.81	33	1.84	1.01	37	2.69	37
Recycling	EN-05	4.71	0.67	11	2.72	1.21	14	1.99	16
Quality of life	LI-01	4.69	0.65	18	2.27	1.18	27	2.41	28
Health	LI-02	4.70	0.65	12	2.43	1.15	24	2.28	25
Social inclusion	LI-03	4.70	0.65	14	2.50	1.23	20	2.20	23
Leisure	LI-04	4.75	0.59	6	2.57	1.27	18	2.18	21
Extracurricular activities	LI-05	4.73	0.62	8	2.59	1.23	17	2.13	18
Sustainable management	MA-01	4.65	0.72	24	2.45	1.16	22	2.20	22
Transparency	MA-02	4.67	0.68	21	2.91	1.29	8	1.75	8
Participation	MA-03	4.65	0.70	23	2.52	1.21	19	2.13	19
Process efficiency	MA-04	4.74	0.63	7	3.71	1.24	1	1.03	1
Accessibility	MO-01	4.84	0.51	1	3.22	1.34	3	1.62	5
Signaling	MO-02	4.70	0.68	15	3.17	1.35	4	1.53	4
Sustainable transport	MO-03	4.55	0.87	31	1.68	0.97	38	2.87	38
Collaborative economy	MO-04	4.51	0.87	35	1.98	1.20	35	2.53	33
Eco-friendly transport	MO-05	4.57	0.83	30	2.01	1.15	34	2.56	34
Security	SE-01	4.83	0.48	2	2.95	1.28	6	1.88	13
Biosecurity	SE-02	4.72	0.67	9	2.81	1.28	11	1.91	14
Smart technologies	SE-03	4.63	0.72	26	1.96	1.18	36	2.67	36
Cybersecurity	SE-04	4.67	0.76	20	2.17	1.16	31	2.51	31
Disaster prevention	SE-05	4.69	0.73	16	2.03	1.10	33	2.66	35
Internet technologies	TE-01	4.76	0.60	4	2.30	1.19	25	2.47	29
Data management	TE-02	4.69	0.64	17	2.98	1.24	5	1.71	7
Information systems	TE-03	4.60	0.74	29	2.23	1.20	29	2.37	27
Internet technologies	TE-04	4.79	0.52	3	3.63	1.29	2	1.16	2
AVERAGE	-	4.65	0.70	-	2.55	1.20	-	2.10	-

Note: SD—Standard Deviation; I–P—Importance–Performance.

Regarding performance, the most prominent items are process efficiency (3.71), internet technologies (3.63), and accessibility (3.22). The worst performing variables are sustainable transport (1.68), smart buildings (1.84), and smart technologies (1.96). Indeed, all items presented low regular performance, since they scored under 3, with a mean of 2.55 and a standard deviation of 1.2 (Table 4).

On the other hand, the best levels of student satisfaction are related to process efficiency (1.03), internet technologies (1.16), and electronic services (1.52), as noted by the lowest gap between importance and performance. By comparison, the worst levels of satisfaction belong to sustainable transport (2.87), smart buildings (2.69), and smart technologies (2.67).

Those higher results in technology-related attributes indicate that UFCG follows the smart campus technology-driven approach. In this view, a university enhances its informatization level through an interconnection of physical and virtual systems, characterized as an advanced digital campus [38,42,50,70]. However, recent smart campus perspectives promote new educational paradigms and improvements in different dimensions to better meet the stakeholders' needs [11,12,71]. Thus, our results indicate that UFCG needs to amplify its perspective about what a smart campus is.

Additionally, it shows the difference, from the Brazilian perspective, from developed countries, since basic infrastructure items are still not satisfied, such as accessibility, transport, and buildings. Indeed, developed countries build technology and network frameworks on established institutions and infrastructures, while developing countries suffer from deficient public services, lack of resources, and weaker institutions [72,73].

Figure 5 presents the IPA matrix with all quadrants to provide the priorities for UFCG toward the smartization process. The first quadrant gathered 28.9% of the attributes (11), indicating that they are important to respondents but should receive more attention from decision makers to improve their low performance. The most relevant attribute is internet technologies (TE-01), which is also fourth in the general ranking, but its performance is ranked at 25 and satisfaction at 29. Quadrant 1 has variables of six different dimensions: education (ED-02, ED-04), environment (EN-03), living (LI-02, LI-02, LI-03), management (MA-01, MA-03), security (SE-04, SE-05), and technology (TE-01).

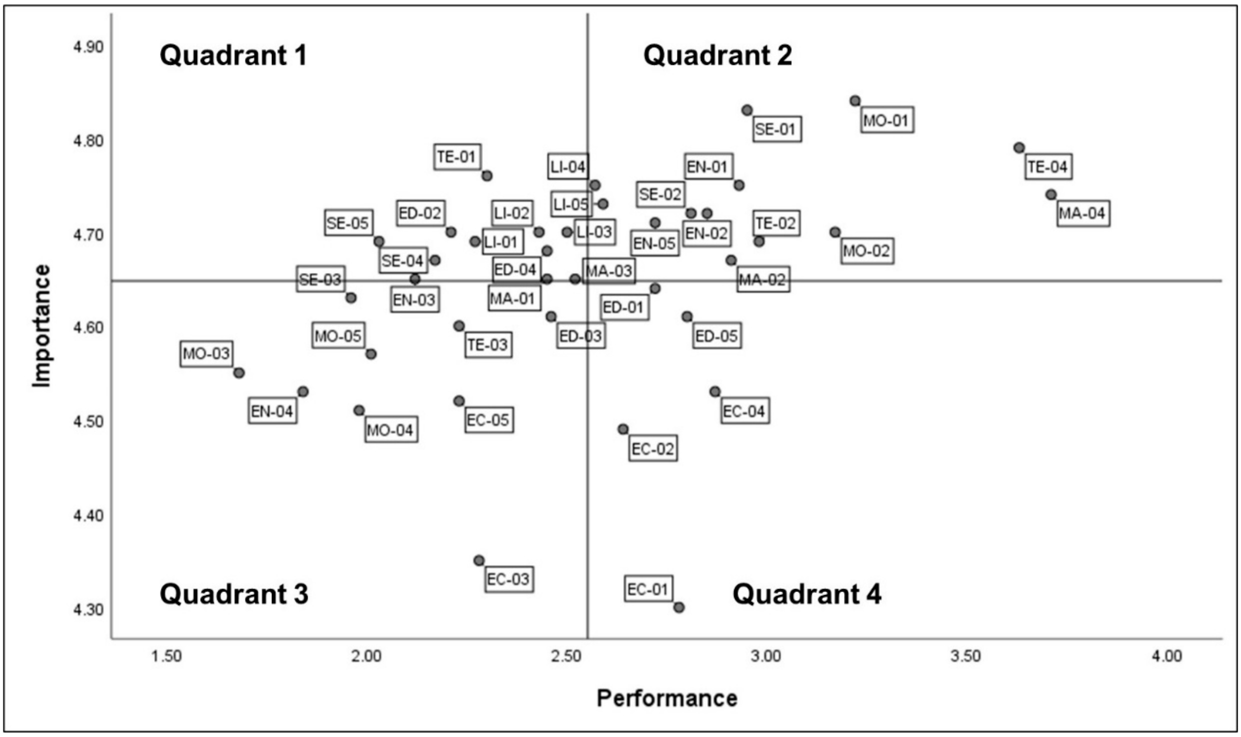


Figure 5. IPA matrix results.

Quadrant 2 collected the most attributes (13), representing 34.2% of variables, indicating that decision makers should maintain good work. Thus, variables in this dimension have high importance for respondents and good performance in UFCG. The best item of the general ranking is here (accessibility), which is also third in best performance and fifth in satisfaction. This quadrant comprises variables of six dimensions, namely environment (EN-01, EN-02, EN-05), living (LI-04, LI-05), management (MA-02, MA-04), mobility (MO-01, MO-02), security (SE-01, SE-02), and technology (TE-02, TE-04).

The third quadrant consists of 23.7% of the attributes (9) corresponding to low-scoring items for both importance and performance. Thus, managers should keep those at low priority. Smart technologies (SE-03) is the most highlighted attribute in this quadrant; however, it is 26 in the general ranking, and even lower at performance and satisfaction (36). Quadrant 3 also aggregates variables of six dimensions: economy (EC-03, EC-05), education (ED-03), environment (EN-04), mobility (MO-03, MO-04, MO-05), security (SE-03), and technology (TE-03).

At last, Quadrant 4 clustered 13.2% of variables (5) that have high performance but are not very important for students, representing a possible overkill of resources. Smart technologies (ED-01) is the most underlined attribute, but it ranks 25 in the general ranking with both performance and satisfaction levels at 15. This quadrant included variables from two dimensions: economy (EC-01, EC-02, EC-04) and education (ED-01, ED-05).

According to Figure 5, we may establish a priority list for the university to improve, based on Quadrant 1. IPA results showed decision makers should prioritize actions toward internet access (ED-02), satisfaction (ED-04), eco-friendly resources (EN-03), quality of life (LI-01), health (LI-02), social inclusion (LI-03), sustainable management (MA-01), participation (MA-03), cybersecurity (SE-04), disaster prevention (SE-05), and internet technologies (TE-01).

Quadrant 1 gathers almost all dimensions, emphasizing smart living with three variables related to students' quality of life, health, and social inclusion. As foreseen in the previous analysis, UFCG needs to implement actions toward students' needs and sustainability to improve its smartization process.

These findings align with the statement that being smart should not confound with being digital. This is because the smart campus comprises a learning ecosystem of digital and social services to meet the present and emerging needs of both modern society and the labor market in a sustainable, social, and technological manner [11,23,46,74–76].

5. Discussions

This research aimed to identify the essential elements and the most significant deficiencies in the smart campus dimensions and its variables from the user's viewpoint to offer a list of priorities for decision makers. Based on an integrative framework, we used a perspective from Latin-American experts to consider the social and economic context influence.

Our research offered three-fold results: theoretical, methodological, and empirical. At first, we reinforced the use of an integrative perspective to analyze or implement a smart campus. A smartization process cannot focus only on technology attributes, but universities should use technologies to build a comprehensive and sustainable living environment [12,50,77]. Thus, these research results tested eight smart dimensions: economy, education, environment, living, management, mobility, security, and technology.

Methodologically, we developed a set of indicators adapted to an IPA matrix, offering a management tool for decision makers in the academic context. Empirically, our research has specific findings to UFCG, which is the priority list. The results indicated a route for academic managers toward a smart campus, including a priority list.

The research used a quantitative approach based on the IPA technique. We synthesized our findings in two groups: (1) the test of the integrative model of smart campus and its indicators; (2) the position of UFCG as a smart campus and its priorities for improvement in each smart dimension.

Our framework qualitative validation, previously performed with Latin American experts, was now quantitatively validated by users, i.e., the students. Performed in a statistically significant sample with a 95% confidence level and 5% error, we gathered sufficient and reliable data. The alpha test results higher than 0.7 in all dimensions confirmed an adequate internal consistency of the dataset for an IPA analysis [65]. Consequently, we validated our smart campus integrative concept with the complete framework composed of eight smart dimensions connected to the SDGs. Universities worldwide may apply this framework, although it is more applicable to Latin American institutions, since its validation was in this context.

The participants validated all items as suitable for a smart campus evaluation, since they attributed high importance (>4) to all variables. On the other hand, the performance rating reflected the smartization level for this university. The low performance average score (2.55) and the high discrepancy between importance and performance (2.10) presented the dissatisfaction of users and the distance of UFCG to becoming a smart campus.

Despite technology-related items being ranked as high importance, Quadrant 1 (Figure 5) exposed issues related to life on campus as having priority. It confirms that recent smart campus perspectives promote new educational paradigms and improvements in different dimensions to better meet the needs of stakeholders in a sustainable, social, and technological manner [11,12,71].

Overall, the most important dimensions for a smart campus are living (4.713), technology (4.71), and security (4.7). This connects with the literature presenting smart campuses composed of technology, sustainability, and social actions improving the quality of life and needs of stakeholders [11,23]. The best performing dimensions by UFCG in students' opinion are management (2.9), technology (2.78), and economy (2.56). It demonstrates that UFCG should keep replacing old manual services with smart ones to optimize processes through information sharing mechanisms [42,43], using IoT and ICT to enhance the informatization level [6,31–37]. Through low and medium values of UFCG performance, students present dissatisfaction with the development of smart dimensions, while the high importance in all dimensions relates to end users (students) wanting a paradigm change in their university.

6. Conclusions

According to the results, the UFCG smart campus performance achieved only medium values; no indicator had excellent performance. Among these, some presented a mild performance and indicated that UFCG is building an integrative, transparent, and open workplace to manage the campus with active stakeholder participation in the smart management, which attends to SGDs 7, 9, 11, 16, and 17. On the other hand, the university needs to improve smart security, the worst performing dimension. By doing this, UFCG will better protect people in both physical and virtual contexts, which fulfills SGD 11 and 16.

Universities can apply the framework to evaluate themselves and provide a priority list for improvement. Using a wide range of stakeholders, such as professors and students, decision makers would gather an integrative result. Then, managers should create an open and transparent committee to plan specific goals and actions for each dimension. By calling for participation and monitoring the progress, universities can become smarter and more sustainable. This study was limited by students' unilateral opinion, rather than a multi-stakeholder perspective. We did not consider a multigroup analysis, such as a clusterization, based on courses or age, which generalized our results to all students of UFCG. Despite a wide possibility of applications, we only conducted the framework validation in a public Brazilian university.

Thus, we suggest further research comprising the assessment of managers, employees, professors, and other stakeholders. Also, new applications of this framework in other institutions, with a stratified sampling of different stakeholders. Merging qualitative and quantitative methods can result in specific analyses for each dimension, such as multigroup analysis, to understand smart living in age ranges and how the user sociodemographics influence their perception of smart dimensions. Another perspective relates to a wider analysis, such as the linkage between university and smart city management and planning.

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