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RESEARCH

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A determination of the smartness level of university campuses: the Smart Availability Scale (SAS)

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Abstract

Technological developments on university campuses are among the most recently investigated topics, but the whole notion of a smart campus has yet to be developed. A smart campus can only be comprehended as a whole, which is why it requires an extensive planning process. This article investigates the required smart campus services with a holistic approach. The smart campus concept has been defined by three major categories: smart building, the scope, and the technology, and then the aspects that affect these categories are defined. A fundamental calculation has been constructed based on the smart campus concept created with newly consolidated categories and a case study with post-occupancy evaluations. The Smart Availability Scale (SAS) calculation is based on superimposing two matrices: campus system output and weighted value matrix. For this calculation, the multi-criteria decision-making (MCDM) method was adopted using newly created index parameters and categories. The technologies selected for this research are based on the most recent developments. It extracted valuable conclusions and inferences from this smart campus conceptual framework, providing insights and directions toward the required calculation technique for the services offered by the smart campus. During the evaluation period of traditional to smart universities, this research draws an outline and guidance for the stakeholders of the affiliated campus.

Keywords: Smart campus, University campus, Building systems, Educational technologies

Introduction

This article's objective is to clarify the idea of a complex, multifaceted smart university campus and examine what it entails in terms of a smart building, the scope, and the technology, and finally provide a fundamental calculation technique. Instead of a small team of authors, many authors can offer more in-depth knowledge of current research and development in their professions and areas of specialization. Many universities have started smart campus-related projects in specific areas like smart classrooms or smart transportation, but the concept of a smart campus as a whole has yet to be developed

[33]. Therefore, this study presents a holistic approach and explores how to integrate these various fields and disciplines under one umbrella.

Technological advancements, and ultimately the Internet of Things (IoT), have enabled the development of a wide range of smart building solutions. Buildings' intricate structures and systems, as well as rapid developments in technology and construction, have prompted extensive research over the years. Some research has concentrated on assessing building services [30, 54, 59], but others have focused on other variables such as measuring adaptability or individual comfort factors [58]. LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment's Environmental Assessment Method), DGNB (German Sustainable Building Council), and SRI (Smart Readiness Indicator) are just a few of the rating systems and schemes available. As can be seen in Table 1, the most common system's targeted typology does not include campuses and instead focuses on different building typologies. Thus, one of the main deficiencies is that the building does not contain technologies that serve its purpose. Furthermore, because these rating systems and schemes exclusively evaluate buildings, outdoor spaces on campuses are not addressed. While there is ongoing research on what constitutes a 'smart campus', it is useful to define and combine new parameters that indicate the smartness level of campuses and finally to explain the fundamental calculation technique.

Finding effective project solutions involves more than just using the appropriate methodology in each subject; it also involves using a coordinated execution strategy. Planning strategies for smart campuses should always be integrated to prevent prioritizing one issue over another [13]. This is crucial in large-scale, intricate operations like the development of university campuses. As a result, information on what is now accessible in terms of smart campus development and a variety of themes will be presented with a motivational all-encompassing strategy to address numerous complicated challenges concurrently. Briefly, this study is devoted to determining the response to the following questions:

> *RQ1.* What are the smart campus parameters (services) to predict the prospective smartness of university campuses?
> *RQ2.* How can a method be developed?

Therefore, to determine the potential smartness of university campuses, a method—the Smart Availability Scale (SAS)—has been developed using newly created

Table 1 Targeted building typology of current rating systems and schemes [59]

	LEED	BREEAM	HKBEAM	BIQ	EPC-Labs21
Targeted building typology	Residential and non-residential buildings	Residential and non-residential buildings	Residential and non-residential buildings	Office buildings	Laboratory buildings
	SI	Level(s)	R2G	DGNB	SRI
Targeted building typology	The construction industry in the USA	Residential and non-residential buildings	Residential and non-residential buildings	Residential and non-residential buildings	Residential and non-residential buildings

parameters (smart building, scope, and technology) for the multi-criteria decision technique.

This study is structured as follows. In the literature review section, smart campuses and services are investigated, and related works are explained. The research method is then described in the fourth section. The study's fifth section is dedicated to the explanation of the conceptual model of a smart campus. The sixth section is dedicated to the calculation of the SAS score, determining the weighted values, and describing the parameters and value drivers. Then, in the discussion, the Smart Availability Scale is explained. Finally, the research is concluded with implications of findings, conclusions, and limitations of the study.

Literature review

Thousands of students, faculty members, and guests congregate on a university campus, which resembles a small city, to take advantage of the facilities offered by the institution. In other words, the smart campus is compared to a small, autonomous city in terms of its number of features, users, activities, and connections [40].

Greater sensors, cloud computing, and the Internet of Things (IoT) are the three main advancements that gave rise to the concept of a smart campus recently [31, 34, 37, 57]. Institutions and academia have developed and presented several ideas regarding the smart campus.

Based on high performance and cloud computing over the Internet, Nie [37] offered an isolated system for smart campuses with teaching management, school management, a financial system, a library system, and an office system. These systems are the fundamental ones that are accepted for smart campuses. Aion et al. define a concept called iCampus which is made up of six crucial features: iLearning, iGovernance, iGreen, iHealth, iSocial, and iManagement. These features are designed to enhance the student's experience during the teaching-learning process. The iLearning module focuses on the student's capacity for comprehending and accomplishments, with lecture delivery or evaluation, course material, access to materials and books, and other campus resources. The integrated technology of classroom and workspace management is demonstrated in iManagement. A method and process known as iGovernance facilitates institutional responsibility and improves the institution's reputation through actions such as public relations, policies, and procedures. Smart social networking tools including forums, blogs, webpages, Facebook, and Twitter are all incorporated into iSocial. In order to save energy, reduce waste, and protect the environment, iGreen covers the effective use of natural resources. Last, iHealth is a strategy for institutions in clinical healthcare services and student monitoring using wireless technology [2].

Aiming to provide greater quality services, the smart campus attempts to explain several services. These services broaden their scope by highlighting the campus' social, financial, and environmental facets in addition to the academic goal. The key is to create a cost-effective system, that effectively uses resources, and offers the campus high-quality services. Numerous advantages of a smart campus include "provide an interactive and creative environment for students and faculty, promote smart energy management, bring effective surveillance system and real-time incident warnings, automate maintenance and business processes, maintain efficient parking and access control management, and provide secure payments and transparent voting systems" [4]. The core concept of the smart campus is to combine a variety of advanced technologies in order to have high educational performance, provide users with comfort, and be environmentally friendly, according to the various definitions and features. It can be characterized as productive, versatile, and user-centered information technology services that integrate architectural systems and instructional technologies on university campuses and support automation and real-time reporting. A thorough investigation into smart campuses conducted by Muhamad et al. concluded that the fundamental concept of a smart campus is an endeavor to integrate a collection of advanced technologies by the university to enhance performance, the caliber of graduates, and the convenience of life. The availability of information technology services is useful, dynamic, and user-oriented to enable automation and reporting instantaneously, not just for learning activities but covering a wider aspect, including socialization, environment, and, most importantly, the student experience [34].

Omotayo et al.'s conceptual framework illustrating the infrastructure elements for smart campus study is very comprehensive and has consequences for selecting services for this research. The model concentrates on the components of the campus development infrastructure. Four major sections are formed from the fifteen cluster themes. Smart building construction or reuse, technology and IT networking, continuous improvement, and intelligent learning and teaching systems comprise the four divisions. The first step in enabling smart buildings is the opportunity to modify or retrofit existing campus buildings with IoT. The way a building manages its water use, IoT capabilities, smart meters, energy use, and sustainability all contribute to its smartness. Second, the development of the smart campus buildings includes a smart network grid, which consists of a microgrid on the campus. The inclusion of cloud computing is implied by the existence of a smart campus network grid. Intelligent campus communications, data processing, interfaces, human-computer interaction, and persuasive computing issues can all be addressed by cloud computing infrastructure. Third, the concept of continuous improvement in smart campus management is related to knowing how to improve systems and learning from data and applications already in use. Finally, the learning management system regulates the way students and other campus users engage with smart technologies, smart buildings, and energy use on campus during the teaching and learning process [38].

Another point that needs to be highlighted while discussing the concept of a smart campus is the definition of smart service, which has become a subject that has been addressed lately, thanks to the Internet of Things (IoT) and big data. A smart service can be regarded as an enhancement of the standard services that are prevalent on today's Internet. The conscious goal of a smart service is to automate and technologically aid daily human operations [7, 10]. A smart service seeks to remove human involvement by connecting other services and information fragments. This approach, in particular, offers smart service characteristics such as working with and integrating different data sources, personalized state-based service setup and customization, and proactive service delivery [28].

The six domains Muhamad et al. classify the smart services as "(1) technologies and systems for intelligent learning, (2) governance, (3) social networks, (4) campus management, (5) health, and (6) green aspects" [34], specifically for university campuses. The organization of the university's objectives as an academic institution serves as the foundation for this conceptual classification setting [26]. First and foremost, it seeks to improve teaching and learning. It also offers cost-efficient options for maintaining strong governance and management processes. Then, it is to create balanced and conscientious environmentally friendly solutions for the local and larger scale. Finally, it emphasizes the users' health. Anagnostopoulos et al.'s five research dimensions are outlined in a proposed taxonomy for IoT-enabled Smart Campus: (1) physical infrastructure; (2) enabling technologies; (3) software analytics; (4) system security; and (5) research methodology [5]. Briefly stated, this idea is shaped by incorporating research methodology in addition to hardware and software technologies.

The determination of smart service detection can be resolved by defining unique properties [27]. According to Rijsdijk and Hultink's concept of 'smartness', this entity has seven dimensions: "autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, humanlike interaction, and personality" [41]. Akhrif et al. contend that smart services have a variety of characteristics, including "being user-centric, ubiquitous, highly integrated, adaptive, context awareness, and open" [3]. Briefly, due to the numerous sensors, devices, and physical connectivity, smart service is essentially the merger of management and information systems to provide comfort, health, and well-being to users along with positive energy-related results. This study acknowledges that smartness as a notion can be acquired over time, and all universities are typically equipped with objects and services that represent the potential for gaining smartness. University campuses can be sufficiently equipped with innovative technology on several levels, from the design components to the more intricate architectural spaces.

Related work

Numerous research has provided definitions of the idea and systems of smart campuses from various angles [2, 4, 14, 24, 35, 37, 49, 52]. The range of services offered by smart campuses is fairly broad, and some services related to this subject can be listed as follows: heating, cooling, and ventilation; lighting; water; waste; occupant detection, wayfinding and mobility; safety and security; dynamic building components; renewable energy; and educational technology. A conventional university campus can be open to advancement in every one of these areas.

In the European Union (EU), the residential and commercial building sector accounts for about 40% of overall energy consumption [16]. A large increase in greenhouse gas (GHG) emissions from 19% in 2010 to 39% as a result of this high share of energy use [17]. Concerns about rising energy needs, their detrimental consequences on the environment, and climate change are prevalent today [19]. Multiple recent studies have revealed that the HVAC system consumes approximately half of the energy used in buildings [29]. The new HVAC technology responds well to a variety of factors, including weather, time, occupancy rate, comfort scale, and energy [19, 45]. As a result, the value of these factors can be maintained at an optimal level without requiring direct control of the HVAC systems. Another advancement has been observed in lighting systems, which can improve academic productivity by offering comfort to campus occupants

[47]. Lighting systems have evolved in response to changes in building type, space, season, time of day, and occupancy [46].

Smart water systems improve efficiency, longevity, and reliability through real-time monitoring and automation. These systems are designed to provide effective and efficient power distribution, wastewater distribution, treatment and recovery, water flow, quality, and saturation, and energy conservation [39, 44]. Production and consumption are rising as a result of the rise of densely populated cities. Systems for waste collection and separation have arisen in response to the rise in consumption. Solutions were provided by three key advancements in waste technology: smart solid waste management, hardware (sensors), and software [18].

Wayfinding in university buildings or on campus might be challenging for campus occupants. Due to advanced sensor systems, obtaining support with location technologies is now more advanced. Numerous proximity and navigation technologies, such as optical codes, smart cards, Radio Frequency Identification (RFID), and Near Field Communication (NFC), are being developed [11, 15]. These sensor technologies have an impact on practically every system on campus, but one of the most essential applications is safe and secure campuses with access control [9]. The incorporation of sensors and actuators for effective smart campus surveillance is made possible by IoT technology. Students are discreetly watched in this setting to protect their privacy and human rights [5]. Briefly, these technologies made it possible to track campus visitors and safely and efficiently manage the equipment. Additionally, it addressed the issue of wayfinding and proposed solutions for visitors with disabilities. In addition, advanced technology enables hazardous source monitoring and early fire warning, fire safety equipment management, and on-site situational assessment [12]. For network security, developments have been observed on the following topics: "access control, virus and antivirus software, application security, network analytics, types of network-related security (endpoint, web, wireless), firewalls, VPN encryption, and more" [36]. However, as the number of networked devices is constantly increasing, security solutions and regulations to address the risk of data privacy violations on user data also need to increase.

Elevator and plug load management concerns in active building components have an effect on the campus' overall energy consumption. The modern elevator trend is shaped by increased security, energy efficiency, and effective crowd management [23]. Although university campuses include a diversity of building typologies, the end-user behavior pattern is consistent. This provides an opportunity to define the academic community's energy consumption pattern [21].

The major purpose of making traditional university campuses smart is to improve teaching and learning experiences. The adoption of IoT has undoubtedly built a true foundation for a simple and connected educational environment [32]. With the advent of digital learning, access to education has been reimagined and expanded. High-quality resources are now accessible to a global audience, and peer-to-peer feedback is made possible. In the last thirty years or more, traditional campuses have transitioned from paper-based to digital to smart campuses, depending on the location of the campus and available resources [33]. The most recent innovations assist educational settings by adjusting learning environments and empowering students to govern and self-evaluate their learning process using a holistic and ubiquitous approach. A university can get closer to being referred to as a smart university when it implements instructional technologies on campuses along with the smart building solutions mentioned above.

Methods

The methodology is principally based on a literature review, a case study with post-occupancy evaluations (POEs), and finally the development of calculations. First, a literature study of current information has been done in order to engage in a conceptual framework for smart campuses. POEs were then implemented and this is because it is widely agreed that the technique provides a method of gathering information that is valuable to all stakeholders in the lifecycle of a building, and that particular components of this information benefit different stakeholders in different ways [20]. In addition, despite the fact that the transition to smart campus development is still occurring, there is little proof that the opinions of the users are taken into consideration by the decision-making processes [1, 8]. Thus, POEs allowed the collection of information to indicate the value of various parameters from an end-user perspective [43]. Therefore, the data collected from the literature review and POEs were merged to develop the Smart Availability Scale (SAS). The SAS is a calculation method that uses the multi-criteria decision technique to determine the potential smartness of university campuses.

Multi-criteria decision-making (MCDM) is a discipline that allows the simultaneous evaluation of various conflicting criteria in the decision-making process. In most cases, sorting or classification is combined with multi-criteria evaluation problems. Hence, many issues are systematically included in the calculation. In multi-criteria design problems, the variables may be unknown or infinite [50, 53]. This technique is often encountered in building performance calculations [25, 48, 56]. Furthermore, several energy, sustainability, and performance-related rating systems and schemes, such as LEED, BREEAM, and SRI, use the multi-criteria decision-making technique [53, 55].

Smart campus model

The development of a smart campus can be said to have two key components, according to Xiong's definition of a smart campus: systems integration and diverse data applications [57]. Considering this, the definition of a smart campus and the subsequent calculation (SAS Score) are greatly influenced by the accurate determination of the systems within the campus. Consequently, when selecting the services of the campuses with a rather broad range of applications, it is advisable to use classification and categorization methods [50, 53]. Three main categories have been identified as defining the smart campus concept and these are smart building, scope, and technology. The conceptual framework for the smart campus model is shown in Fig. 1.

First, it has been accepted that smart building features are the key to transforming university campuses into smart. Three categories become prominent under the topic of smart building: perceptual factor, comfort factor, and environmental factor (Table 2). The Perceptual factor covers those that an occupant feels with his senses. Several architectural elements directly or indirectly affect the senses of the occupants, such as heating, cooling, and air conditioning (HVAC) systems and lighting systems.

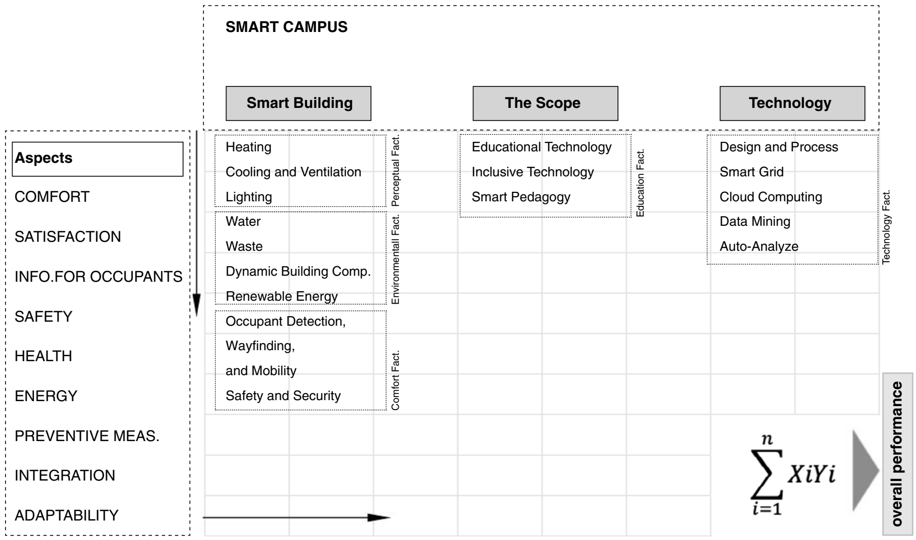

Fig. 1 The smart campus model

Table 2 List of campus services and categories

	Campus services	Categories
X_1 and Y_1	Heating	Perceptual factor
X_2 and Y_2	Cooling and ventilation	Perceptual factor
X_3 and Y_3	Lighting	Perceptual factor
X_4 and Y_4	Water	Environmental factor
X_5 and Y_5	Waste	Environmental factor
X_6 and Y_6	Occupant detection, wayfinding, and mobility	Comfort factor
X_7 and Y_7	Safety and security	Comfort factor
X_8 and Y_8	Dynamic building components	Environmental factor
X_9 and Y_9	Renewable energy	Environmental factor
X_{10} and Y_{10}	Educational technology	The scope
X_{11} and Y_{11}	Inclusive technology	The scope
X_{12} and Y_{12}	Smart pedagogy	The scope
X_{13} and Y_{13}	Design and process	Technology
X_{14} and Y_{14}	Smart grid	Technology
X_{15} and Y_{15}	Cloud computing	Technology
X_{16} and Y_{16}	Data mining and auto-analyze	Technology

The comfort factor covers technological solutions that play a role in the potential for a comfortable and easier life for the occupants. This factor includes occupant detection, wayfinding, and mobility technologies that contribute to campus guidance systems and access control. Because of their impact on psychology, safety and security technologies are also recognized as comfort elements. In addition to focusing on energy management and advantageous energy-efficient technology, smart campuses also aim to boost efficiency. Water, waste, dynamic building components, and renewable energy are the technologies that are evaluated under the subject of environmental factors.

Second, the scope category investigates the subjects that will advance the goal of smart campuses, namely teaching and learning. These are, in essence, smart pedagogy, inclusive technology, and educational technology. A smart campus infrastructure's division for learning and teaching systems depends on on-campus information portals with the addition of digital content and e-learning, smart classrooms, learning analytics, smart pedagogy, and more [22].

The third category is explained as technology. Design and process come first in this category. It describes the design and delivery tools such as Computer-aided design (CAD) Building Information Modeling (BIM), Geographic Information Systems (GIS), and then simulation, visualization, and decision-making tools such as material flow analysis and life-cycle analysis [13]. IoT is at the foundation of a smart campus, and the development of the smart campus includes a smart network grid on campus [33]. Cloud computing will be a part of every smart campus network grid that exists. Finally, data mining and auto-analysis aim to achieve more useful results by replacing human intervention in the decision-making process. Although these three basic categories describe the systems of smart campuses, they are found in different aspects that affect the level of smartness of the systems.

As important as the determination of smart campus services, aspects that determine the level of smartness and in which areas the developments will be recorded should be defined. Thus, nine 'value drivers' were defined; comfort, satisfaction, information for occupants, safety, health, energy, preventive measures, integration, and adaptability [3, 6, 27, 34, 41]. As a result, the theoretical idea of a smart campus has been defined, and SAS calculations utilize this notion.

Results

The SAS score is an indicator that measures the current level of technology-enhanced university campuses. The targeted typology of the SAS score is specifically university campuses because they operate differently than a unique building.

There are reasons to distinguish this calculation from other performance-related rating systems and schemes. First, this calculation covers all areas of the campus, not just buildings. In other words, all systems required for open areas should be taken into account, for example, transportation on campus, wayfinding, and movement, and security technologies in open areas. In addition, the necessary hardware systems must be suitable for the outdoor environment and applied correctly.

Second, the calculation includes educational technology, for which solutions can overlap with many different systems. For example, RFID sensors are frequently used for security purposes in smart buildings [26]. However, an RFID sensor can also be used for attendance [51] and should be listed in educational technologies. Another example is that a closed-circuit camera system (CCTV) installed for security purposes [42] conflicts with camera systems used for course recording [51]. Since the two serve different purposes, they should be evaluated differently.

Due to the broad scope of the SAS calculation, context-sorting has helped to determine weighted values. Five categories become prominent: perceptual factor, comfort factor, environmental factor, scope factor, and technology factor. Therefore, the first proposal for weighted values is equal-weighted. Each category is assigned a fixed equal weighted value of 20%.

In Table 2, 16 subcategories (campus services) are listed: heating; cooling and ventilation; lighting; water; waste; occupant detection, wayfinding, and mobility; safety and security; dynamic building components; renewable energy; educational technology; inclusive technology; smart pedagogy; design and process; smart grid; cloud computing; data mining and auto-analyze. 'Heating' and 'cooling and ventilation' have been studied as two different campus services. This is because the number of index parameters is vast and must possess a higher weighted value. These sixteen campus services have several index parameters. Although these index parameters belong to a diverse number of campus services, there are a relatively similar number of index parameters in each service.

The defined SAS categories and subcategories can affect the campus in various ways. Therefore, 9 significant value drivers have been listed: comfort; satisfaction; information for occupants; safety; health; energy; preventive measures; integration, and adaptability. Each driver possesses seven levels of performance indicators: − 3, − 2, − 1, 0, + 1, + 2, + 3. The reason behind the adaptation of seven categories is to create a measurement scale similar to that of the European Union Energy Labels. Since many technological products use this labeling system, it will easily facilitate the perception of value. Furthermore, the energy classification of products can be used in a straightforward way to evaluate the energy value driver.

Index parameters represent a list of hardware and software from the latest advanced building and educational technologies that have been categorized through context sorting. Each index parameter has been assigned a code number for convenience in the scoring process. Table 2 demonstrates an example of a rubric for campus system output.

The SAS calculation

The SAS score is calculated as follows:

$$\sum_{i=1}^{n=16} XiYi$$

SAS score $= X_1Y_1 + X_2Y_2 + X_3Y_3 + X_4Y_4 + X_5Y_5 + X_6Y_6 + X_7Y_7 + ... + X_{15}Y_{15} + X_{16}Y_{16}$

where,

$Xn =$ score of 16 subcategories (%)

$Yn =$ weighted value of 16 subcategories (%)

Equal weighted value drivers (Y_i)

The following scores are suggested by the authors for equal-weighted value drivers. The calculation gives the numerical values of the campus services that occur when 20% are evenly distributed over the five factors. When categories are assigned equal weighted, subcategory weighted values are:

SAS score $= X_1 x\ 6.66\% + X_2 x\ 6.66\% + X_3 x\ 6.66\% + X_4 x\ 5\% + X_5 x\ 5\% + X_6 x\ 10\% + X_7 x\ 10\% + X_8 x\ 5\% + X_9 x\ 5\% + X_{10} x\ 6.66\% + X_{11} x\ 6.66\% + X_{12} x\ 6.66\% + X_{13} x\ 5\% + X_{14} x\ 5\% + X_{15} x\ 5\% + X_{16} x\ 5\%$

Divergent weighted value drivers (Y_i)

Divergent weighted values enable us to obtain more accurate results in the calculation.

Calculation of any Y_i value:

$$Yi = \sum_{j=1}^{9} Zij$$

where Z_{ij} : (i) represents the number of rows where the data are located in the (j) column.

For instance,

$Y_1 =$ the subcategory of the heating weighted value

$Y_1 = Z_{11} + Z_{12} + Z_{13} + Z_{14} + Z_{15} + Z_{16} + Z_{17} + Z_{18} + Z_{19} = 6.66\%$

In the table, Z_{16} and Z_{17} can be accepted for any value, such as 60%, and Z_{11}, Z_{12}, Z_{13}, Z_{14}, Z_{15}, Z_{18}, and Z_{19} will be 40% of the value Y_1.

It is required to proceed with the same calculation for all divergent value subcategories (Y_i).

Subcategory scores (X_i)

Determining the nine value drivers for each subcategory should be done by taking the average score of 7 levels of performance indicators. The factor to be considered here is converting the data to a percentage before calculating the SAS score.

$$Xn = \text{Score of 16 subcategories } (\%)$$

Since the scores will be divergent, the calculation of any X_i value:

$$Xi = \sum_{j=1}^{9} Wij$$

For instance;

$X_1 =$ The subcategory of the heating score

$X_1 = W_{11} + W_{12} + W_{13} + W_{14} + W_{15} + W_{16} + W_{17} + W_{18} + W_{19}$

It is required to proceed using the same calculation for sixteen subcategories (X_i).

Boundary conditions

In some unique cases, certain subcategories or index parameters can be excluded from the calculation of the SAS score.

Therefore, the SAS score is calculated as follows:

$$\sum_{i=1}^{n-q} XiYi$$

where,

The number of removed category or categories $= q$

SAS score $= X_1Y_1 + X_2Y_2 + X_3Y_3 + X_4Y_4 + \ldots + X_{n\text{-}q}Y_{n\text{-}q}$

Discussion

The first step was to review a number of studies on smart buildings. Then, as a separate topic, university technologies, which are prevalent in this area, were studied and their integration into campuses was reviewed. The concept of smartness was also investigated specifically from the technology point of view. One of the most important and comprehensive research studies on the concept of a smart campus was done by Omotayo et al. [38]. The classification used in this study—systems, subsystems, even hardware, and software—is the key point of distinction. Because this research uses an approximation computation method to draw its conclusions, the interaction between technologies on campuses, such as hardware and software, or which system should generate more value, is taken into consideration.

Broad smart building solutions have been proven feasible through technological developments. The complex systems and structures of buildings, along with the rapid advancements in technology and construction methods, have led to a lot of research over the years. Some have focused on criteria including measuring adaptability or personal comfort factors. Some studies have focused on evaluating building services. Campuses are not included in the most prevalent system's or scheme's intended typology, which instead concentrates on various building typologies. As a result, one of these systems' fundamental flaws is that they lack technology that is appropriate for space. Furthermore, because most rating systems and schemes only evaluate buildings, they neglect outdoor spaces on campuses. Even if research on what constitutes a 'smart campus' is still ongoing, it is helpful to define and combine new characteristics that indicate the smartness level of campuses and, in the end, to describe the basic calculation method.

Systems integration and a wide range of data applications are two essential elements in the development of a smart campus. Given this, the precise identification of the systems on the campus has a significant impact on the definition of a smart campus and the consequent calculation (SAS Score). Therefore, a strategy that incorporates the data from several of the publications under examination has been adopted. The smart campus concept has been broken down into three primary categories: smart buildings, scope, and technology. The first step was to review a number of papers on smart buildings. Then, university technologies that are prevalent in this area were studied and their integration into campuses was reviewed. The concept of smartness was also investigated, specifically the technology and integration category which is a point of difference to other building systems. Since this research uses an approximate calculation method to reach its conclusions, it is important to specify which system should be given more weight or how campus technologies, like hardware and software, relate to one another.

The SAS represents a heuristic scale that focuses on finding class intervals. There are two fundamental reasons for this development. First, the SAS application focuses mainly on understanding the level of smartness of university campuses as a single organism rather than identifying their flaws. Therefore, a heuristic scale facilitates accessibility and communication for this issue. Second, some data for the calculation can be based on personal interpretations. This may evoke certain deviations in the score, and, as a result, this may create an error margin. Therefore, minor deviations in the calculations are tolerated. On this heuristic scale, there are six interval classes (Table 3).

Table 3 The Smart Availability Scale

SAS Class	SAS Score	
A	80-100	The campus meets all expectations. It is a net-zero energy campus or close to being a zero-energy campus which means that the campus produces enough energy to meet the needs of the campus through renewables. Occupants have the highest comfort and satisfaction when placed in a healthy teaching-learning environment. It is a smart campus with responsive occupancy behaviors.
B	60-80	The campus meets many requirements for all 9 value drivers. Accurate decisions have been made on energy and maintenance. Many components have been successfully implemented with consideration for the occupants. However, some issues have to be resolved.
C	50-60	The campus is scored at a standard level that meets current industry standards. The campus is not working to its optimal smartness.
C	40-50	The campus is close to meeting current technology standards. However, several issues will contribute to the development and increase of smartness.
D	20-40	The campus does not meet many of the driving values of smartness required. The performance of the campus on energy, occupancy, health, comfort, and satisfaction is remarkably low. A development plan must be prepared.
E	0-20	The campus is built using traditional methods. The occupant specifications do not meet the expectations of comfort and satisfaction. There is not any, or maybe a limited contribution to energy efficiency, and environmentally friendly decisions. All subcategories of the campus should be reviewed and a development plan should be prepared.

Table 4 Assessment methods

	Assessment 1	Assessment 2
Method	Checklist approach	Data collection
Duration	1 week	1 year
Expertise Level	Occupants or whoever is interested in the subject	Expert
Location	-	Campus
Result	Self-assessment	Reporting

Before conducting the SAS assessment, a number of requirements must be completed. The following is an overview of these conditions:

- The intended audience must consent to this assessment being made.
- Time and money concerns need to be balanced.
- Current parameters for the index are required.
- The setting for an assessment must be appropriate.

Certain conditions should be considered in the data collection and calculation processes as well. The precision of the SAS score can vary depending on the time and level of expertise. In order to produce more structural results, two different assessment techniques are described. Especially, when it is intended to make a comparison between two universities, the same assessment method must be used (Table 4).

The first assessment method provides a more rapid result with a higher error margin compared to assessment 2. It is an efficient method if there is a limited amount of time. In assessment 1, the checklist approach might be employed. This assessment can be done by anyone interested in the subject. The data collection period is approximately 1 week. Since SAS is a heuristic scale, it can be utilized in this rating type. Thus, the range of the campus' level of smartness is determined.

The second strategy necessitates an extended data collection period on campus. It produces a more thorough and accurate result. Since the evaluation takes longer and the accuracy is higher, the SAS score can be specified along with the scale intervals. There is a data collection period of one year. This assessment can be reported on, indicating the outcome of a more methodical examination. The report can include information concerning reliability.

Another crucial factor that affects the accuracy of the SAS score is the boundary issues that experts can define and manage with a more efficient approach. For example, considering climatic factors, the heating category may not be required for campuses in hot regions. Identifying such cases directly affects the accuracy of the SAS score and it should be clarified which categories or subcategories will be removed before starting the data collection process.

Furthermore, the matrix of divergent weighted value drivers (Yi) provides a more accurate value for nine subcategories. For example, heating, cooling and ventilation, lighting, and renewable energy systems significantly affect energy and preventive measures (value drivers). In this case, their weighted value might be higher than other value drivers. Therefore, by superimposing the two matrices, Yi and Xi, the SAS method is performed in the most efficient way.

In summary, the steps below can be followed while completing the assessment.

1. Before evaluating the campus, it must be determined whether the prerequisite conditions have been met.
2. The purpose of the SAS evaluation should be determined for the campus.
3. It should be determined which assessment method will be used.
4. Data collection should be done in accordance with the assessment type once it has been decided.
5. Depending on the assessment method, an equal or divergent weighted matrix should be defined and the SAS calculation should be completed.
6. Reporting and self-assessment should be performed.

Implications of the findings

In order to clarify the methodological contribution of the SAS, a few factors must be highlighted. Over the years, many schemes examining the level of quality, performance, and sustainability of buildings have been offered in academia and industry. Two factors distinguish this approach from the other calculation methods. To begin, this strategy applies to the entire university campus, not just buildings. In this regard, It differs from others, in that it includes the campus' outdoor areas. This has an impact on various issues, including wayfinding and movement, campus transportation (within and outside of campus), some security systems, hardware suitability in an outdoor setting, and sensor installations.

The second key difficulty is that this method concentrates primarily on universities, which provide an important purpose, education. As a result, all advancements aimed at improving the teaching and learning experience are included. This is accomplished by incorporating educational technologies within the calculation. These technologies have an impact on the building, either directly or indirectly, and are seen as campus components.

More than just employing the proper technique in each area is required to find effective project solutions; a coordinated execution plan is also necessary. It is important to always integrate planning strategies for smart campuses to avoid making one issue more important than another. This is essential for complex, large-scale projects like building university campuses. In order to solve several complex difficulties concurrently, information on what is now available in terms of smart campus development and a variety of subjects is presented. Briefly, this study offers guidance for researchers who will investigate this topic and those in charge of setting policies for smart campuses.

Conclusions

This study originally proposed a conceptual model based on definitions of smart campus and services and it examines five separate criteria to analyze sixteen campus services. Aspects that define the level of smartness and the areas in which developments will be documented are equally crucial to the decision on smart campus services. Consequently, value drivers for smart campus services are also identified. Using this model, a method, the Smart Availability Scale (SAS), is explained for determining the level of smartness of university campuses. The SAS uses the multi-criteria decision-making (MCDM) technique by superimposing the values of these technologies on campus (campus system output) and a matrix system from equal or divergent weighted values based on the significance of these values (weighted value matrix). The technologies chosen for this study are those that have recently been developed. This study contributes to the current state of knowledge in both theoretical and methodological terms. As a theoretical contribution, campus services are reorganized/redefined to present a conceptual model. Methodologically, its contribution focuses on the correlation between the values of various services using a straightforward computational method. Therefore, this research provides an outline and direction for the affiliated campus stakeholders during the transition from a traditional to a smart university.

Limitations and future works

The limitations of this study were determined by fixing more precise weight values, and the implication of SAS in a case study. The following are potential areas for future research:

- Contextual flexibility (building-specific features, season, location)
- The application of the calculation
- Development of policy objectives
- Determination of fixed weight values

The relative frequency and significance of HVAC or hot water energy consumption can be affected by variations in climate, as indicated by different climatic zones.

Climate also affects the value of the dynamic building envelope in terms of solar shading and the amount of energy generated by solar panels or wind turbines per unit m^2. Therefore, contextual flexibility directly affects the correct calculation of the SAS score. Making a choice about a service that is not included in a framework but can be significant is essential. The criteria to be applied to determine relevance in terms of public policy are not always apparent and go beyond simple technical judgments. As a result, if an entire building is missing a space, all of its smart services will be ignored, and the SAS will be renormalized following their exclusion.

One of the aims of this research is to develop a benchmark standard for smart campuses. A standard can be established without leaving much room for individual interpretation. As a result, research on weighted values is open to further development.

Abbreviations

BIM	Building Information Modeling
BIQ	Building Intelligence Quotient
BREEAM	Building Research Establishment's Environmental Assessment Method
CAD	Computer-Aided Design
CCTV	Closed-Circuit Television Systems
DGNB	German Sustainable Building Council
EPC-Labs21	Environmental Performance Criteria
GIS	Geographic Information Systems
HKBEAM	Hong Kong Building Environmental Assessment Method
HVAC	Heating, Ventilation, and Air Conditioning
IoT	Internet of Things
LEED	Leadership in Energy and Environmental Design
MCDM	Multi-Criteria Decision-Making
POEs	Post-Occupancy Evaluations
R2G	Rust2Green
RFID	Radio Frequency Identification
SAS	Smart Availability Scale
SRI	Smart Readiness Indicator
VPN	Virtual Private Network

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Authors' contributions
NS has analyzed and designed the work and created a new method presented in the work. SN has substantively revised it. All authors read and approved the final manuscript.

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Availability of data and materials
1. All data analyzed before this study are included in this published article:

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2. The dataset (listed index parameters) generated during the current study is available from the corresponding author upon reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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