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# An Investigation into Stakeholders' Perception of Smart Campus Criteria: The American University of Sharjah as a Case Study

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**Abstract:** In recent times, smart cities and sustainable development have drawn significant research attention. Among developed and developing countries, the United Arab Emirates (UAE) has been at the forefront in becoming an incubator for smart cities; in particular, it has placed some efforts in the education sector by transforming the traditional campus into a Smart Campus. As the term Smart Campus attracts professionals and academics from multiple disciplines, and the technology keeps intervening in every aspect of life, it becomes inevitable for the Smart Campus to take place and deploy the future vision of smart cities. As a first step to achieve this vision, it is very important to develop a clear understanding of what is a Smart Campus. To date, there is still no clear perception of what a Smart Campus would look like, or what are the main components that can form a Smart Campus. Therefore, the objective of this research is to use the set of comprehensive criteria to identify what it is perceived to be a Smart Campus and evaluate these criteria from the stakeholders' perception. The main criteria are defined from the literature review, and a case study is conducted on the American University of Sharjah campus stakeholders (faculty, students, management, and Information Technology (IT)) to assess the designated criteria. This exploratory research relies on both qualitative and quantitative methods to perform the analysis, taking into consideration the perceptions of students, faculty, and IT service providers. Finally, having defined and evaluated the criteria that underpin the Smart Campus framework, a set of recommendations are drawn to guide the utilization of a Smart Campus within higher education settings. This research opens the doors for future studies to gain a deeper insight into the type of decisions that need to be made to transform a traditional campus to a Smart Campus.

**Keywords:** smart campus; internet of things; cloud computing; facilities management; sustainable practices

## 1. Background

Smart cities and sustainable development have gained a massive amount of attention over the years. As a result, institutions, cities, and nations as a whole have been working towards improving the living standards of their people and ameliorating the quality of their lives in many aspects. Amongst other countries, such as the UK, US, Japan, and China, the United Arab Emirates (UAE) has recently become an incubator for Smart Cities' applications, aiming to put its capital city Dubai on the map as the first smart city in the world [1]. This is evidenced by the launch of the "Smart Dubai 2021" initiative, which provides a strategic roadmap to transform the city and its resources to their maximum efficiency based on four digital transformation goals, thus creating an efficient, seamless, safe, and personalized city. Since the launch of this initiative, several other public and private sectors also had to transform under the Dubai Data Initiative: blockchain strategy, the happiness agenda, the Dubai AI Roadmap, and the Paperless Strategy [2]. Whilst all these initiatives are extremely important for supporting the developments of smart cities, there is no doubt that one of the most significant sectors that play a role in the development of any society is its education sector [3]. This makes it pertinent to incorporate the recent technologies into existing educational institutions in order to transform them into Smart Campuses. In the UAE this is evidenced by one of the first attempts made to transform a traditional campus into a Smart Campus by establishing Hamdan Bin Mohammed Smart University (HBMSU), which compromises of a virtual campus that integrates various applications and advanced systems that are designed to meet the needs of learners, faculty, and administrative personnel [4]. However, despite these integrated systems, HBMSU only assembles partial aspects of a Smart Campus, i.e., smart online management systems, but it does not transform a traditional campus facility into a Smart Campus. It is therefore important to develop well-defined criteria that underpin the definition of a Smart Campus from different stakeholders' perceptions (i.e., faculty, students, management, and Information Technology (IT)).

The literature contains several studies that are directing their inquiries towards smart cities and sustainable development [5–7]. Following the same approach, Pagliaro et al., defined in [8] a Smart Campus as a small self-contained city with different dimensions and structures. The study argues that a smart city approach and technology can be adopted in a traditional campus to support its stakeholders efficiently.

Moreover, the Internet of Things (IoT) was integrated into a traditional campus to introduce the concept of a Smart Campus in [6]. The research proposes the concept of smart education, smart parking, and smart rooms using PGRI Yogyakarta University as the case study.

Additionally, Muhamad et al. (2017) presented in [9] a systematic literature review to define the existing condition of the Smart Campus concept, supported technologies, and their applications, such as iLearning [10,11], iSocial [10,12], iManagement [12,13], iGovernance [10,14], and iHealth and iGreen [13]. However, due to the dynamic nature of the topic and its related technologies, there still exists room for improvement in terms of the integration of different aspects of the technologies within educational institutes under a unified framework of a Smart Campus.

It is therefore within the intention of this study to develop an understanding of the Smart Campus concept and its infrastructure in order to define the underpinning criteria that make a traditional campus facility a Smart Campus. Additionally, this research provides a pathway for smart applications to be incorporated in future development plans for a Smart Campus by opening the door for smart services and applications to take place and present themselves as real features in future cities.

## 2. What is a Smart Campus?

To achieve the overall objective of this study, it is important to underpin a clear definition of a Smart Campus, describing its main components and structure in relation to the adaptation of the enabling technologies, and its utilization within educational establishments for digital transformation.

### *2.1. Smart Campus Definitions and Structure*

The literature reports on a number of definitions of a Smart Campus, which mainly underpin three distinct features as core characteristics, these being personalized services, information services, and environmental platforms. As such, a Smart Campus is an inevitable trend in the construction of a digital campus and requires the integration of all of these features. In support of this, Mishalani et al. defined in [15] a Smart Campus as an intelligent and smart environment of teaching, learning, and living, which is based on Internet technology and application services; hence, it consists of teaching, research, management, and campus life. This also aligns with Liang et al.'s [16] definition of a Smart Campus as consisting of the integration and combination of applications based on the Internet of Things, cloud computing, and GIS technology to support the campus information acquisition, sharing, and services, in order to promote the intelligence process of teaching, scientific research, and services. Based on these definitions, it can be concluded that Smart Campus applications require a sophisticated infrastructure to operate on. To top this, several studies suggest that the Internet of Things (IoT), being a unified framework, allows the actuator and sensors to share information over a common operating network, thus enabling innovative applications [17]; cloud computing, which is a shared pool of configurable computing resources, can be accessed conveniently, in real-time, and on-demand with minimal management effort or service provider interaction [18]; and Big data analytics [19] are a process that provides a richer and deeper insight and reveals hidden patterns and correlations among the massive and complex data, as the backbone of future Smart Campuses.

This is supported by Nie in [14], who proposed a system framework for a Smart Campus that is based on the integration of the Internet of Things (IoT). Nie's framework comprises three layers: an awareness layer, a network layer, and an application layer, as shown in Figure 1.

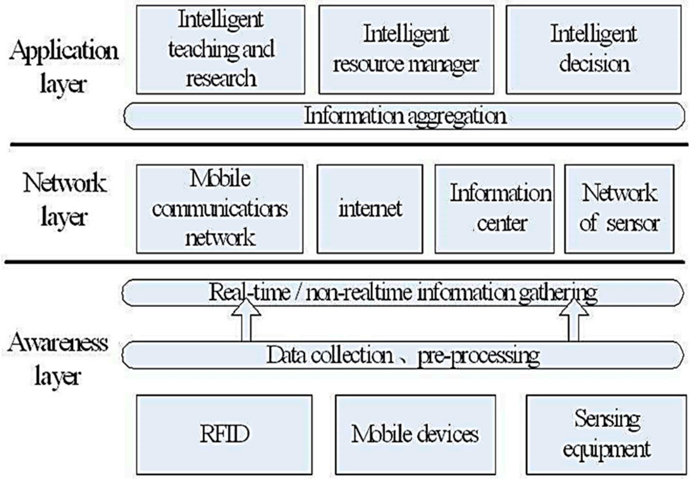


**Figure 1.** Three Internet of Things (IoT) system layers for the Smart Campus. Adapted from: [14].

The '**awareness'** layer is responsible for data collection and pre-processing, while the '**network'** layer is responsible for information aggregation; however, the '**application'** layer is the most important layer, which allows a platform for a smart application that processes and utilizes data to transform a traditional campus facility into a Smart Campus.

Similarly, the overall architecture of a Smart Campus is proposed in [20] and illustrated in Figure 2. The proposed architecture comprises three main platforms. The first platform is the **comprehensive perception network foundation platform**, which is based on the Internet of Things (IoT) and is supported by three layers, as described below:

- *The Network communication infrastructure layer*, which is responsible for providing the groundwork for strong continuous Internet connections, and is proposed to be supported by strong Wi-Fi, 3G/4G networks, and IPv4/IPv6, which are the latest versions of Internet protocols that can simultaneously handle and manage a large amount of Internet data transactions.
- *The Object perception system layer*, which is proposed to monitor and track any changes in the surrounding environment, record its data, and transfer the data to the next layer of the information collection and management system. The main tools used in the objective perception system are sensors, Radio-Frequency Identification RFID, QR codes, and video monitoring.
- *The information collection and management system layer*, which is the last layer in the platform and is responsible for the information collection and management system and acts as the management center of the Internet of Things (IoT).

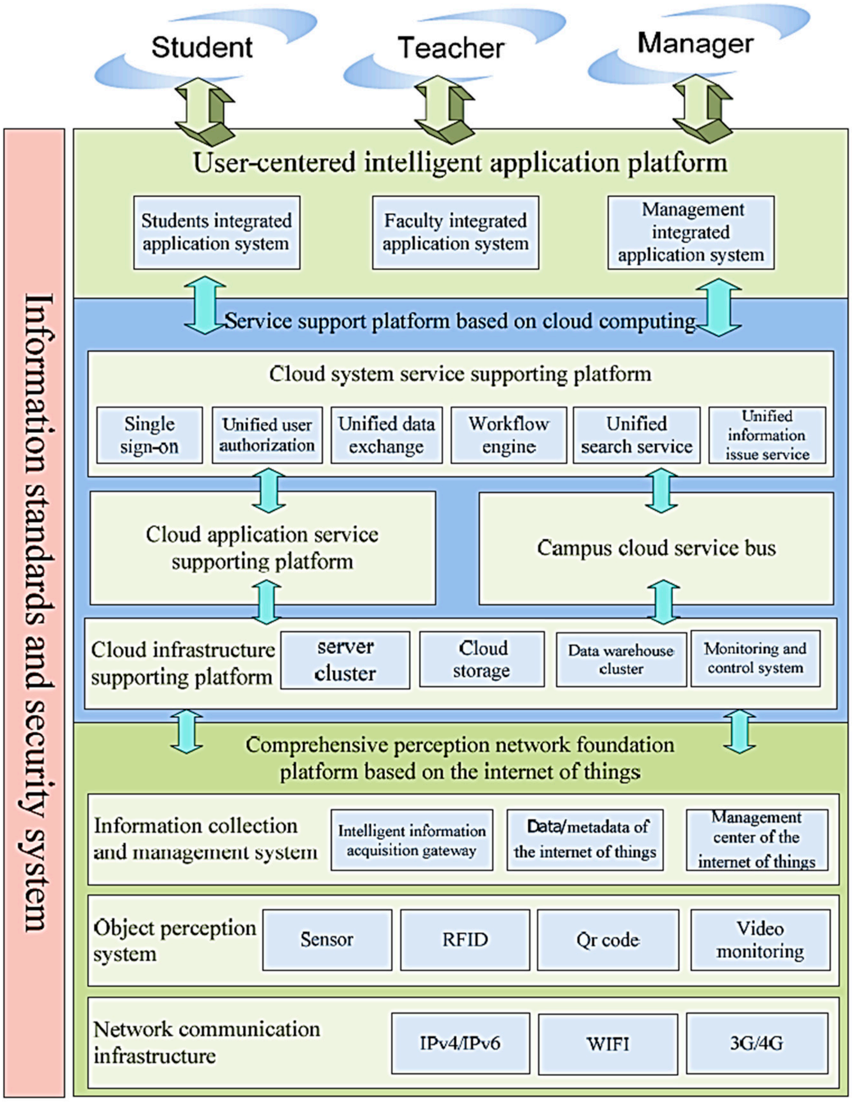


**Figure 2.** Three platforms that represent the architecture of a Smart Campus. Adapted from: [20].

The second platform is the service support platform, which is based on cloud computing and acts as a storage unit that filtrates data into clusters that can be further served to end-users based on their authorization level. It is therefore important to highlight that this platform was proposed to operate completely on cloud servers instead of traditional servers. Finally, the user-centered intelligent platform is the last platform, and it includes several applications that can be applied in the future to help and serve students, faculty, and management inside a Smart Campus.

Moreover, Huang, in [5], analyzed and compared the differences between networks in the traditional campus and a Smart Campus. The study proposed the building of a Smart Campus from the perspectives of cloud computing and the Internet of Things (IoT). It mentioned several advantages of the smart network compared to the traditional network in terms of resource integration, reduction of capital investment, reduction of energy consumption, improvement of information security, openness, and sharing. In addition, [5] proposed architectural layers that include an infrastructure layer, a platform layer, and the software layer, as shown in Table 1.

**Table 1.** Proposed architecture layers of a campus cloud. Source: Huang [5].

| Basic Layers of Campus Cloud | A Key Point of Layer Construction | Purposes of Layer Construction |
|---|---|---|
| Infrastructure layer | Infrastructure refer service layer | Providing a virtualized hardware resource pool |
| Platform layer | Platform refers service layer | Providing software support platform with unified standards |
| Software layer | Software refer service layer | Providing various applications services |

It can therefore be concluded from the literature that the Internet of Things (IoT) and cloud computing go hand in hand in providing a seamless infrastructure for a Smart Campus. However, with the advancement of technology and a massive amount of data generated due to the transformation of a traditional campus into a digital campus over a unified network, Big Data analytics are proposed by [21], as illustrated in Figure 3. The Figure demonstrates the data acquisition from the traditional university campus with the aid of sensors and actuators. These sensors and actuators translate an event into data and send the data to the information layer to be stored either in relational or non-relational Bandwidth and delay estimation based TCP (BDTCP) protocols. Once the data are transferred into the knowledge layer or big data platform, the knowledge extracted is used to improve services. The Hadoop allows storing the data and performing cluster assignment small analyses in order to process accurate information.

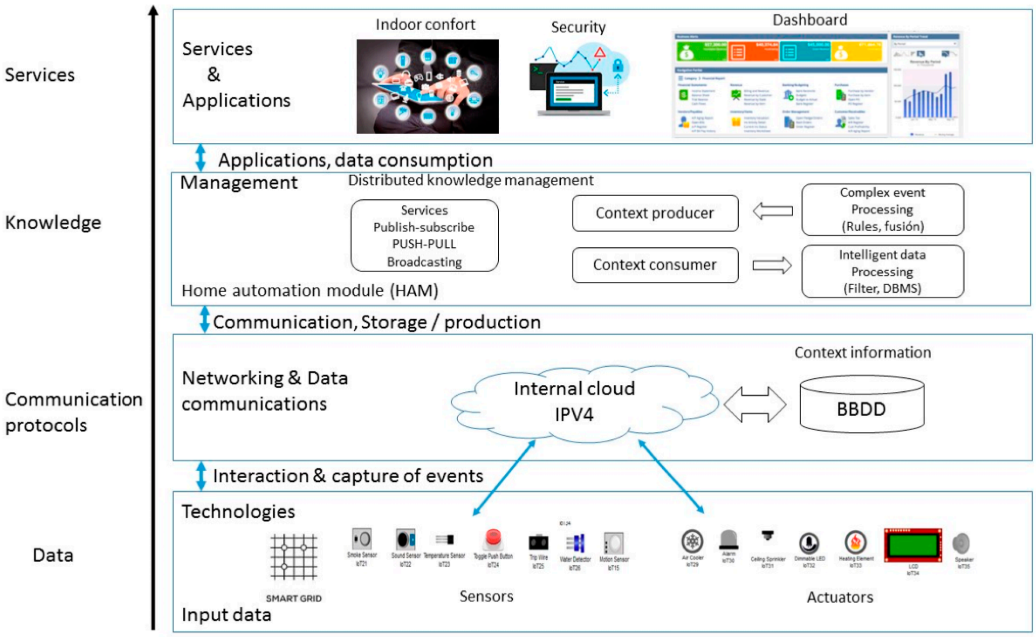


**Figure 3.** Internet of Things (IoT) architecture within a sustainable Smart Campus. Adapted from: [21].

Thus, it can be seen from Figure 3 that the purpose and role of each layer presented in Villegas et al.'s study were similar to those mentioned by [5,14,20], as illustrated in Table 1 and Figures 1 and 2 consecutively.

Accordingly, it can be concluded that there exists a consensus between academia and scholars that the Internet of Things (IoT), cloud computing, and Big Data Analytics are the main technologies and the backbone to building a Smart Campus infrastructure. Moreover, such infrastructure provides a platform for smart applications under the Smart Campus framework.

The following section will, therefore, review the applications of a Smart Campus within education establishments by way of examples of how a traditional campus facility can be digitally transformed into a Smart Campus.

### 2.2. Applications of Digital Connectivity of Traditional Educational Establishments

The underlying principle of a Smart Campus is related to connectivity. A "connected campus" is therefore described by its ability to perform a more informed decision-making process by integrating several IT devices and applications with the surrounding environment. Over the past few years, many proposals started to appear in the field of digitizing and connecting educational entities. For example, Cisco developed a framework that connects several buildings domains, such as lighting and automation, under a single Internet Protocol (IP) network [22]. This model (See Figure 4) was initially developed to support business industries as a part of the digital transformation of companies; however, in 2016, Cisco expanded this model to the educational sector. This model included a number of components, such as energy management, bring your device/mobile learning, intelligent digital signage, tele-presence in classrooms, campus lighting, campus Wi-Fi, building optimization analytics, smart parking, and a campus operations center. This framework recommends deploying IoT in all of these nine aspects, as it will result in improving the campus quality and efficiency [22].


**Figure 4.** Cisco connected campus proposal. Adapted from: [22].

Similarly, CenturyLink developed a model for digitally transforming campuses, which consisted of seven areas that IoT can contribute to, as shown in Figure 5. These areas are energy management, fleet management, security and safety, venue services, learning spaces, digital connections, and data analytics [23].


**Figure 5.** CenturyLink proposal for IoT services in future connected campus. Adapted from: [23].

In addition, the report in [24] highlighted several applications, such as smart lighting, video surveillance with analysis, parking, transportation management, facility access control, interactive signage and kiosks, asset protection, and wayfinding.

The main concern, however, lies in the IoT applications and the responsibility of the data collected from students, faculty, and visitors. Furthermore, the methods of data collection have to be transparent and work toward increasing awareness by highlighting the benefits of these applications to all campus users and stakeholders. Finally, the IoT service provider should follow and understand the campus data privacy regulations, along with protecting the students, faculty, workers, and visitors [25].

Furthermore, Nokia and National Chiao Tung University (NCTU) partnered under the ng Connect program to deploy an Internet of Things (IoT) system for 3 years in order to adopt the idea of a Smart Campus. As can be seen from Figure 6, the vision of a Smart Campus includes the following applications: environmental monitoring, drone and robot applications, fiber and WIFI networks, critical space management, smart dorms or residences, smart transportation, smart building, smart lamp poles, and smart parking. The program, therefore, results in a reduction in energy costs of the traditional facility by 11 percent [26].

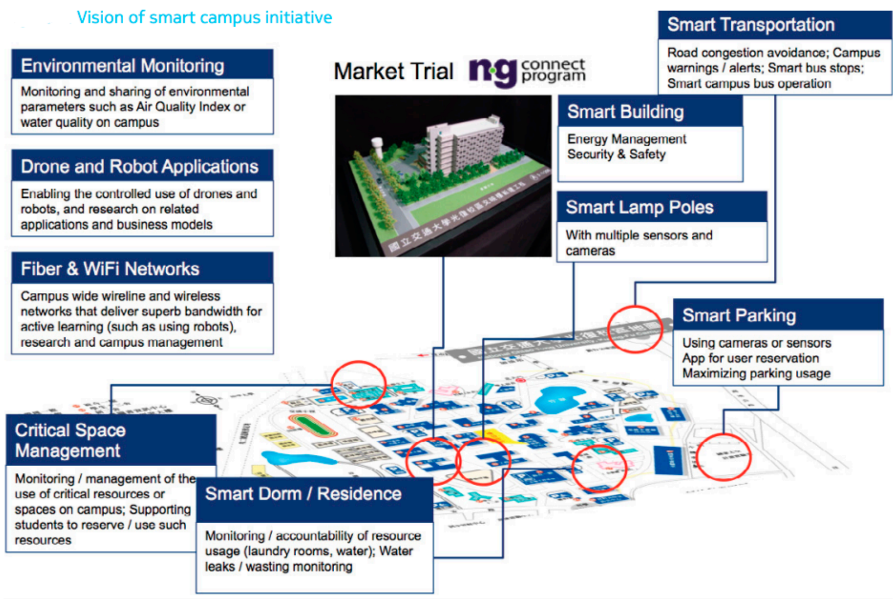


**Figure 6.** Vision of Smart Campus initiatives as per Nokia's ng Connect program. Adapted from: [26].

Therefore, it can be concluded that IoT, cloud computing and Big Data Analytics have proven their efficiency when it comes to integrating smart applications in a campus facility in order to transform it into a Smart Campus. Despite the existence of these technologies, little has been reported in the literature in order to define the comprehensive set of criteria that underpin the development of a Smart Campus. The next section will review these criteria and present them under a unified framework, including the different applications that are underpinned by these criteria.

### 2.3. Comprehensive Criteria for Smart Campus

The literature reports on a number of criteria that are considered to be the main enablers of a Smart Campus. These criteria comprise applications that provide seamless and connected environments that are supported by the Internet of Things (IoT), cloud computing, and Big Data Analytics under the Smart Campus framework. This section intends to review and present these criteria under one framework.

#### 2.3.1. Smart E-Card

A smart card can be perceived as a minicomputer that can store and process data with the aid of a microprocessor chip. The smart card enables secure, fast, flexible, and easy accessibility of facilities in a Smart Campus. The authors of [27] in their paper used King Fahd University of Petroleum and Minerals (KFUPM) as a case study to present the smart card in a campus facility that can be used to store a photo ID and an electronic wallet and enable library borrowing privileges, recreation, medical center services, e-learning, and controlled access to university facilities. Moreover, some of the other applications addressed in the literature are summed up in Table 2.

**Table 2.** Smart E-card applications.

| | | |
|---|---|---|
| **Smart E-Card** | - For attendance (classrooms, labs, access to facilities)<br>- Dorms (all residential activities and administration)<br>- Library usage (booking, borrowing, registration, printing)<br>- E-wallet (payments and verification with E-invoice for registrar, administration, cashier, restaurants, financial holds, fees)<br>- To record personal data (student information, admission, transcript, graduation information, student records and activities) | [16,27–30] |

Source: authors.

Therefore, it can be concluded that a smart card is an essential criterion for the Smart Campus framework, which allows quick identification of all transactions and a personal database that can be accessed through the cloud.

#### 2.3.2. Smart Classroom

A smart classroom can be considered as a technology bridging the gap between tele-education and traditional classroom scenarios by seamlessly integrating the two distinct educational practices. The concept of a smart classroom is based on modern technologies like 3G, 4G, and Internet of Things (IoT) platforms so as to produce a connected and coordinated environment by using voice recognition, computer vision, and other technologies [28]. Moreover, the literature reports on a number of applications for smart classroom criteria as summarized in Table 3.

**Table 3.** Smart classroom applications.

| | | |
|---|---|---|
| **Smart Classroom** | - Virtual reality (for labs, experiments, site visits, simulations)<br>- Remote digital learning (online lectures, visual interviews, cloud storage, online access to all course information and lectures)<br>- Interactive cloud sharing platform (between classmates and professors, between the market and the university, between government and university)<br>- Collaborative research (connectivity and communication with several universities, companies, governments for research) | [28,31–33] |

Source: authors.

Therefore, a smart classroom can be considered as a significant criterion in the Smart Campus framework, as it enhances the learning quality by making it more interactive, collaborative, time-efficient, user friendly, and sustainable.

#### 2.3.3. Energy Management

An energy management criterion is defined as a system that schedules and integrates power usages with local renewable energy sources and battery banks. The energy management system is integrated with storage and data exchanging infrastructures that can be used as a data center to predict energy consumption and production. The proposed system aims to enhance the power management for future Smart Campuses by using an optimizer for electric loads and maintaining the same level of comfort for users [34]. Table 4 summarizes the applications of the Energy Management System (EMS) system that can benefit the facility management of Smart Campuses.

**Table 4.** Energy management applications.

| | | |
|---|---|---|
| **Energy Management** | - Buildings energy management system (monitoring and automated: heat and air conditioning, lights, power devices)<br>- Sustainable energy (solar power, sustainable design buildings, carbon capture storage)<br>- Smart street lights<br>- House management system (for residential end-users' usage)<br>- Energy trading system (for electric vehicles' inside parking) | [30,34] |

Source: authors.

Energy management is a crucial concept for the facilities management, thus making it significant to be addressed when transforming from a traditional to a Smart Campus. The literature supports this notion of smart energy management for the improved utilization of resources, at a lesser cost in a more sustainable, monitored, and controlled way for better planning.

#### 2.3.4. Adaptive Learning

Adaptive learning or ubiquitous learning in a Smart Campus can be defined as an educational method based on a computerized algorithm that can aid in tailoring the educational strategy or learning environment according to an individual's needs. Furthermore, it helps locate learners in a Smart Campus environment and provide context-based personalized learning and feedback [35,36]. Similarly, [37] also emphasizes the need of introducing an Artifical Intelligence (AI) model to the infrastructure of the traditional campus in order to transform it into a Smart Campus. The literature reports on a number of applications of adaptive learning, as summarized in Table 5.

**Table 5.** Adaptive learning applications.

| | | |
|---|---|---|
| **Adaptive Learning** | - Adaptive learning (customized learning according to market needs and students' interests, customized learning for students' weak points)<br>- Optional supplementary courses in specialized fields (besides curriculum)<br>- Computerized Adaptive Testing (CAT) (tailored questions as per an exam taker's needs, questions depend on previous answers for more accurate results, deep assessment) | [36,38–40] |

Source: authors.

Therefore, with the advancement in technology and the transformation to a digitally augmented campus, the concept of adaptive learning becomes a significant criterion to be included in the framework of a Smart Campus as it enables customization, improving weak points for students, more visibility of class performance, accurate testing, supporting the students and giving recommendations, optional extra courses, and improving learning.

#### 2.3.5. Smart Transportation

Another significant criterion to define a Smart Campus is smart transportation. This criterion enables optimizing the logistics and providing an informative, quick notifications, and enables better mobility. Some of the applications mentioned in the literature are presented in Table 6.

**Table 6.** Smart transportation applications.

| | | |
|---|---|---|
| **Smart Transportation** | - Smart parking<br>- Fleet tracking of all campus transportation (for logistics, transportation, smart bus shelters)<br>- Intelligent signage (for navigation, broadcasting)<br>- In-campus navigation (smart kiosks, wayfinding for offices, room, facilities, events) | [22,23,25,30] |

Source: authors.

#### 2.3.6. Security and Safety

The Security and safety criteria assist in advance protection by relying on the concept of Root Cause Analysis (RCA), which is a systematic approach of identifying the "root cause" of a problem and preventing it from occurring in the future. Additionally, reference [41] proposes the adoption of named data networking disaster management in a Smart Campus for efficient IoT-based disaster management without any delays. Some of the applications highlighted in the literature are summarized in Table 7.

**Table 7.** Security and safety applications.

| | | |
|---|---|---|
| **Security and Safety** | - Smart safety and security systems (tracking, surveillance, evacuation, etc.)<br>- Disaster management | [23,25,26,30,42,43] |

Source: authors.

Security and safety are an integral component for any facility and its management. Therefore, it becomes significant to address this criterion in the Smart Campus framework.

#### 2.3.7. Optimization and Analytics Data Center

An optimization and analytics datacenter is a significant component of any facility, therefore making it a crucial criterion to be addressed in the Smart Campus framework. This criterion aids in up-to-date enhancements, data lakes, data openness, and classification. Table 8 highlights the applications of optimization and analytics data centers mentioned in literature.

**Table 8.** Optimization and analytics data center applications.

| | | |
|---|---|---|
| **Optimization and Analytics Data Center** | - Operations optimization<br>- Data storage<br>- Research center | [14,20,22,26,42] |

Source: authors.

#### 2.3.8. Smart Facilities Services

Smart facilities services provide stakeholders with an interactive campus life, responsive buildings, and quick access to sports fields, students' centers, libraries, and restaurants. The literature reports on a number of applications for smart facilities services, as summarized in Table 9.

**Table 9.** Smart facilities services applications.

| | | |
|---|---|---|
| **Smart Facilities Services** | - Facility management smart systems<br>- Campus social network (events, broadcasting, accessible information) | [30] |

Source: authors.

As smart facilities services are a critical component of facilities management, they are significant to be incorporated into the Smart Campus framework.

Furthermore, the section can be summarized in Figure 7, which highlights the underpinning criteria deduced from the literature.

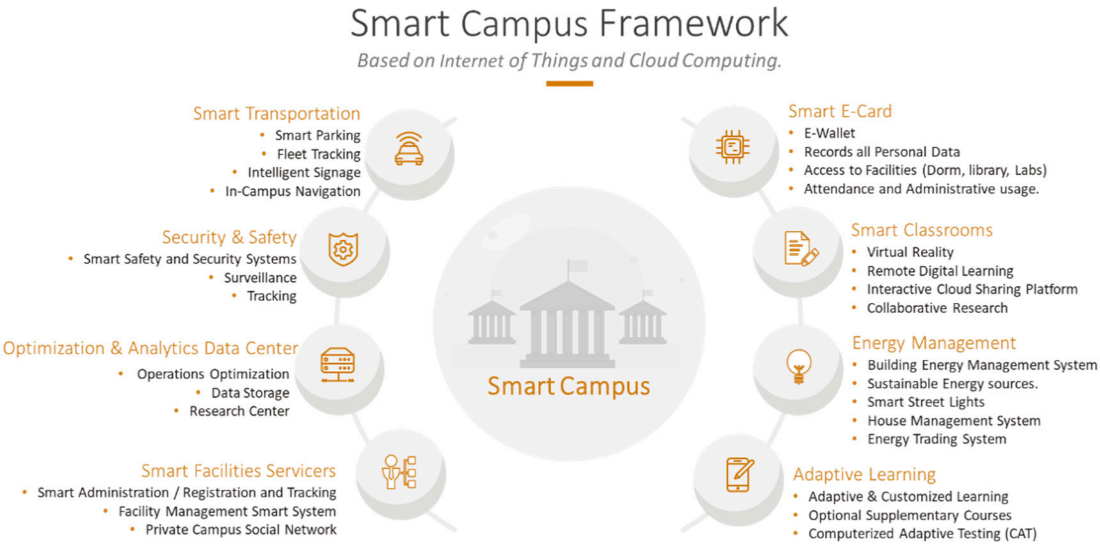


**Figure 7.** Proposed comprehensive smart campus framework. Source: authors.

As shown, Figure 7 presents a unified framework for a Smart Campus, comprising eight main criteria and 25 applications based on the Internet of Things (IoT) and a cloud computing platform. The intent of this study is to use the set of comprehensive criteria to identify what is perceived to be a Smart Campus and evaluate these criteria from the stakeholders' perception of implementing Smart Campus applications, by also highlighting the significant enablers and challenges facing the implementation of a Smart Campus using the American University of Sharjah as a case study.

## 3. Case Study

The research focuses on an embedded case study of the American University of Sharjah, which is an independent non-profit educational institute, based in Sharjah, United Arab Emirates (UAE). The American University of Sharjah is recognized for its distinctive teaching, learning, research, scholarships, educating, and mentoring of future leaders [44].

The American University of Sharjah is ranked first (#1) in the world in terms of diversity, with an 88% employability rate; it is ranked within world's top 50 universities under 50 years of age by QS world ranking; and is ranked among top 10 in the Arab world for the past 5 years, with 66% students awarded scholarships.

The institution comprises a wide range of Bachelors, Masters, and PhD programs for multiple colleges such as the College of Architecture, Art and Design, the College of Engineering, the School of Business, and the College of Arts and Sciences.

In Fall 2019 alone, the university welcomed 5125 students: 4578 undergraduate, 414 graduate, and 19 PhD students, of which 53% were female and 47% were male. Additionally, the institution comprises students and faculty from more than 90 countries around the world. The institution is also recognized for its accomplishments and success in the world of knowledge, and has received a "2 Pearl" designation for its new sustainable engineering and science building. The institute is a state-of-the-art university that believes in continuous growth and the adoption of new and smart technologies.

## 4. Methodological Approach

This section focuses on the methodological approach adopted to evaluate the criteria that underpin the development of a Smart Campus and the associated challenge, taking into consideration different stakeholders' perspectives, using the American University of Sharjah as a case study. To achieve this, both qualitative and quantitative methods of data collection were used, as described below.

*Stage I—Literature Review*

The first stage of this research entailed examining extensive literature to define the main criteria for the Smart Campus framework, as shown in Figure 7. The framework includes eight main criteria and 25 sub-applications that are based on the Internet of Things (IoT) and cloud computing. These designated criteria and their applications were further validated by using semi-structured interviews and surveys.

*Stage II—Semi-Structured Interviews*

Five semi-structured interviews were conducted targeting faculty members and the Information Technology (IT) personnel from the American University of Sharjah in order to gain an in-depth understanding of the experts' perceptions of criteria development of a Smart Campus and the most significant enablers and challenges that face its implementation.

*Stage III—Questionnaire Survey*

The third stage of the study was based on a questionnaire survey that was aimed at understating the stakeholders' perceptions of the significance of each of the Smart Campus applications underpinned by each defined criteria in Figure 7. The survey was targeted at students and alumni from the American University of Sharjah, which successfully returned a sample of 144 responses. The data generated were analyzed using the Relative Importance Index (RII), which is an approach used to determine the importance of each criterion as compared to the maximum importance it can achieve.

Based on the above methodological steps, the subsequent section will focus on the data collection and analysis.

## 5. Data Collection and Analysis

This section aims to present the analysis of the qualitative and quantitative methods used to gain the experts' and stakeholders' perception of implementing Smart Campus applications and the most significant enablers and challenges to its implementation.

### 5.1. Semi Structure Interviews

Table 10 below shows the profile of the interviews, four of which were professors that were selected based on their expertise and understanding of topics related to Smart Campus applications. These experts belonged to different departments (the civil engineering, computer science, and industrial engineering departments) as well as the director of Information Technology (IT) at the American University of Sharjah.

**Table 10.** Profile of interviewees.

| Interviewee | Profile |
|---|---|
| P1 | Professor in industrial engineering |
| P2 | Professor in computer engineering |
| P3 | Professor in civil engineering |
| P4 | Professor in industrial engineering |
| P5 | Director of information technology |

Source: authors.

Analysis

In order to validate the findings from the literature and gain an in-depth understanding of the experts' perceptions of the challenges and enablers of a Smart Campus, the interviewees were asked about:

- Their perceptions of the identified criteria and applications of a Smart Campus, and whether these are sufficient to transform a traditional campus to a Smart Campus;
- What other applications would they like to see applied in their campus, or what other criteria would they like to see added; and
- Their perceptions of the challenges and enablers for promoting a Smart Campus.

The analysis of the responses revealed that all the interviewed professors believed that the Smart Campus applications and criteria mentioned in this research are sufficient to transform a traditional campus into a Smart Campus. Both P1 and P2 stated that "*the mentioned criteria and applications are enough to denote a campus as a Smart Campus as an initial step but would require further additional applications to reach the extra mile*". Moreover, P3, P4, and P5 were in agreement that "*the studied criteria and applications were very much similar to those implemented worldwide and are in the right directions of a smart transformation*". As for the interviewees' perceptions of the other applications that they would see applied in their Campus, and what other criteria would they like to add to those that have already been identified by the study, the flowing responses were given:

- Interviewees P1, P2, P3, and P4 emphasized the need for smart buildings that are featured with sensored doors that open and close automatically, and classrooms that are equipped with remote-controlled devices, in addition to smart building facilities that help enhance both the teaching and learning experiences of the educators and learners by making them feel comfortable both inside and outside the classroom;
- Interviewees P1, P3, P4, and P5 stated the need for "smart communication facilities" that feature the use of video and similar communication devices that allow for synecious communications between the students and their instructors due to limited office hours, which could help overcome the hectic nature of communication between professors and students outside the classroom;
- Interviewee P1 stated that a Smart Campus should also include smart applications that allow students to know whether a professor is occupied or available in the office without having to knock on the door, and that applications of this kind help professors notify students of their availability and occupancy without hindering their working hours.

When asked about the challenges and enablers for promoting a Smart Campus, the following responses were deduced:

- Interviewees P2, P3, and P4 shared similar concerns and perceived the "initial costs" of integrating the Smart Campus applications to be the most significant challenge, but they also eluded to the long-term benefits that could help overcome these costs.
- All interviewees were in agreement that the Smart Campus criteria and applications that have been identified require "training" for all stakeholders, whether including students and instructors, although it may be challenging to get all stakeholders on board.
- Interviewees P1 and P4 perceived "cultural barriers" to be one of the barriers in a traditional setting, therefore introducing Smart Campus applications may withstand some initial frictions in the beginning.

On the other hand, P2, P3, P4, and P5 were in agreement that these challenges could be overcome by proper planning, execution, and monitoring of implementation. P1, P3, and P5 added that training students and professors and educating them about Smart Campus education goes a long way in reducing the gap of knowledge. Therefore, amongst these responses the main challenges were perceived to be:

- Resistance to changing the traditional modes of delivery;
- Costs of smart application and guaranteed returns of investments;
- Privacy and data protection protocols;
- Lack of leading examples;
- IT support and skilled end-users;
- Failover system to ensure redundancy and business continuity.

Whilst the main enablers of a Smart Campus were perceived to be:

- Change management, willpower, and a clear vision of smart transformation;
- Technology awareness and raising the awareness of Smart Campus capabilities;
- Incentivizing professors and students to implement Smart Campus applications;
- Sufficient training and motivation of all campus stakeholders;
- Close engagement and participation of industrial companies with the academic institutions to further improve their smart application and continuous support.

These challenges and enablers assist this study in understanding the educators' perceptions and understanding of the concept of a Smart Campus and how best to promote the existing criteria for the shared benefits of the stakeholders.

### *5.2. Questionnaire Survey*

The questionnaire survey aimed to determine the stakeholders' perceptions of implementing Smart Campus applications at the American University of Sharjah. The questionnaire was comprised of four sections and 22 questions that aimed to study the demographics of participants, their understanding of a Smart Campus, and their perception and rating of smart applications. Finally, the section uses a Relative Importance Index (RII) to identify the most significant criteria based on stakeholders' perceptions.

#### 5.2.1. Demographic Analysis

A sample size of 144 students and alumni of different demographics from the American University of Sharjah was randomly selected. The sample was made up of 50% Bachelor's students, 20% Masters, and 30% Alumni students with 43% male and 57% female participants. The sample was taken from different departments and majors, including 69% from the College of Engineering, 11% from the College of Arts and Science, 13% from the School of Business Administration, and 7% from the College of Architecture, Art and Design, as shown in Table 11.

**Table 11.** Demographic profile. Source: authors.

| Categories | | Frequency |
|---|---|---|
| Program | Bachelors | 50% |
| | Masters | 20% |
| | Alumni | 30% |
| Department | College of Engineering | 69% |
| | College of Arts and Science | 11% |
| | School of Business Administration | 13% |
| | College of Architecture, Art, and Design | 7% |
| Gender | Male | 43% |
| | Female | 57% |

As suggested by Raigor et al. [45], the minimum number of respondents required to achieve accurate results using the Relative Importance Index (RII) is 100, thus the sample size achieved seems sufficient to fulfill its purpose.

5.2.2. Analysis

To evaluate the participants' awareness of the concept of a Smart Campus, they were asked: *"How familiar are they with the term Smart Campus?"*. All of the respondents showed some understanding of the term Smart Campus, as illustrated in Figure 8.

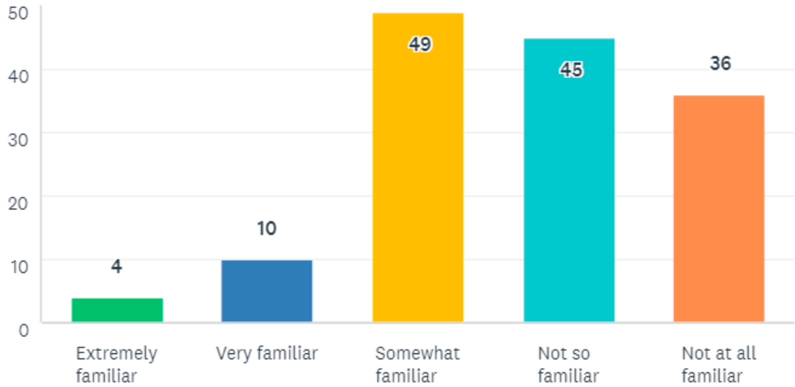


**Figure 8.** Interview graphical representation. Source: authors.

The results show that more than half of the surveyed population (56%) were not familiar with the concept of a Smart Campus, while (34%) were somewhat familiar with this concept, leaving a small minority claiming to be familiar with this concept. Yet, when asked about their initial thought of what a Smart Campus means to them, the majority of the respondents related this concept to connectivity, intelligent solutions, easier or faster interactions, using technologies to enhance the campus experience, going paperless, Artificial Intelligence (AI), machine learning, data collection, smart transportation, Internet of Things (IoT), automation, interactive maps, and remote classes, as illustrated in Figure 9. This indicated that the majority of the participants could relate to the term Smart Campus in a superficial way, but did not necessarily understand what it entails and how to define it.

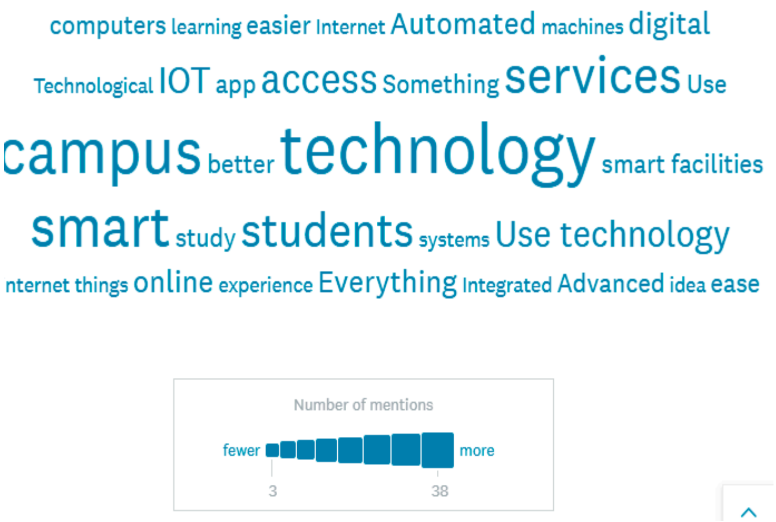


**Figure 9.** Interview word cloud. Source: authors.

The figure shows a word cloud that highlights the most frequently occurring words among respondents; hence, words in a large size represent the most occurring words in the responses, while the small-sized words are the least occurring.

The participants presented a good understanding of the concept of the Smart Campus. Thus, to address the aim of the study to evaluate the set of comprehensives criteria and applications of a Smart Campus from the stakeholders' perception, the participants were asked to rank these criteria based on their significance. The next section will, therefore, determine the importance of these criteria by using the Relative Importance Index (RII) analysis of the stakeholders' perception.

*5.3. Relative Importance Index (RII) Analysis*

The relative importance index is a powerful tool to understand how important a point is relative to the unit of study [45]. Therefore, the data generated from the ranking survey were analyzed using the Relative Importance Index (RII) in order to determine the importance of each criterion as compared to the maximum importance it can achieve, which can be calculated using the formula below as suggested by Raigor et al. [45]:

$$\textit{Relative Importance Index} = \frac{\Sigma w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (1)$$

where $w$ is the total weight given by the respondent from 1 to 5. In addition, $n_1$ is the number of respondents for "not important at all"; $n_2$ is the number of respondents for "slightly important"; $n_3$ is the number of respondents for "moderately important"; $n_4$ is the number of respondents for "very important"; and $n_5$ is the number of respondents for "extremely important". $A$ denotes the highest weight (5 in this case) and $N$ represents the number of respondents. To determine the significance of the 25 smart applications in the eight criteria of a Smart Campus framework, the participants of the questionnaire survey were asked to "Rate the importance of each of the following applications" with weights varying from 5 (extremely important) to 1 (not important at all). The Likert scale of 5 included: extremely important; very important; moderately important; slightly important; and not important at all. The results of each of the criteria are illustrated in the figures below.

Figure 10 shows the average score given to the E-card criterion and its importance within different facilities within the university campus, such as its importance for monitoring students' attendance in a classroom, students' residential activities, library activities, borrowing, as an E-wallet for processing payments, and for recoding students' data (e.g., student information, admission, transcript, graduation information, student records, and activities). The results showed that the use of E-cards to record personal data gained the highest scores amongst the respondents, followed by its use for library activities and payments.

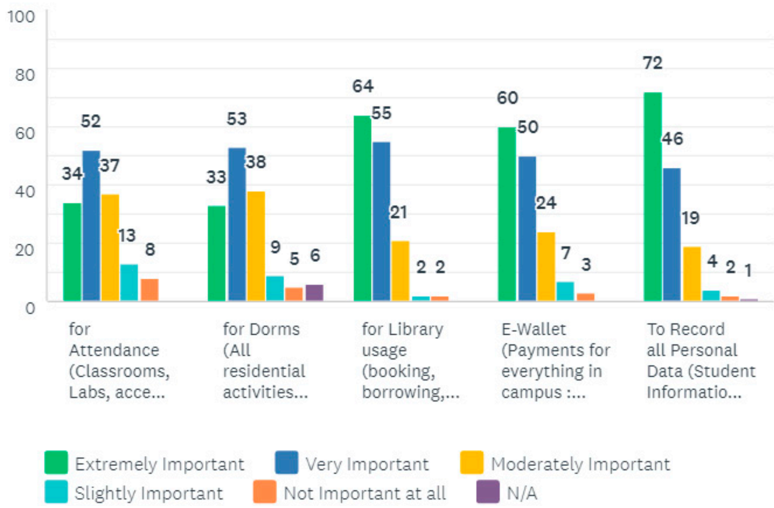


**Figure 10.** Smart E-card survey ranking. Source: authors.

These results, therefore, indicate that students are more interested in the use of E-cards to facilitate and speed up services and processes rather than physical mobility and accessibility.

Figure 11 shows the significance of smart classroom applications for a Smart Campus, such as virtual reality (for labs, experiments, site visits, simulations, etc.), remote digital learning (online lectures, visual interviews, cloud storage, online access to all course information and lectures, etc.), interactive cloud sharing platforms (between classmates and professors, between the market and the university, between government and university, etc.) and collaborative research (connectivity and communication with several universities, companies, and governments for research).

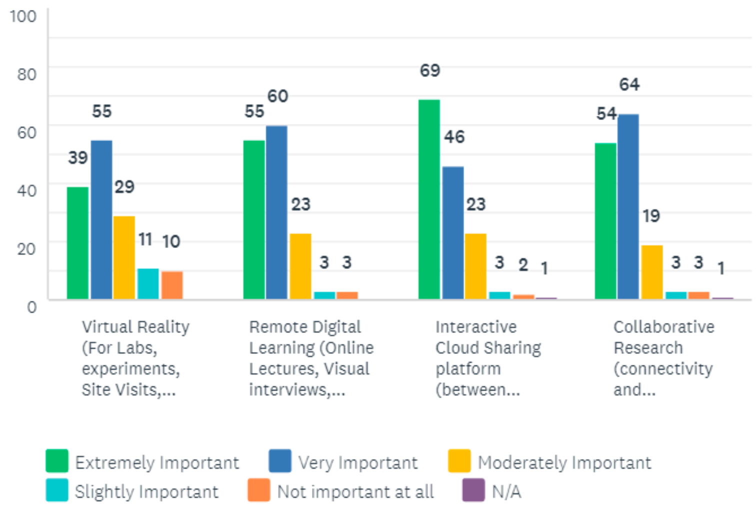


**Figure 11.** Smart classroom survey ranking. Source: authors.

The result concludes that the interactive cloud sharing platform is considered as the most important application in comparison to other applications based on the student's perceptions.

Figure 12 presents the students' perceptions of the importance of energy management applications for a Smart Campus. The applications include buildings energy management systems (monitoring and automated: heat and air conditioning, lights, and power devices), sustainable energy (solar power, sustainable design buildings, carbon capture storage), smart streetlights, house management systems (for residential end-users usage), and energy trading systems (for electric vehicles inside parking). The results reveal that the students considered sustainable energy (solar power, sustainable design buildings, carbon capture storage) as the most important application, followed by buildings energy management systems, smart streetlights, house management systems, and energy trading systems.

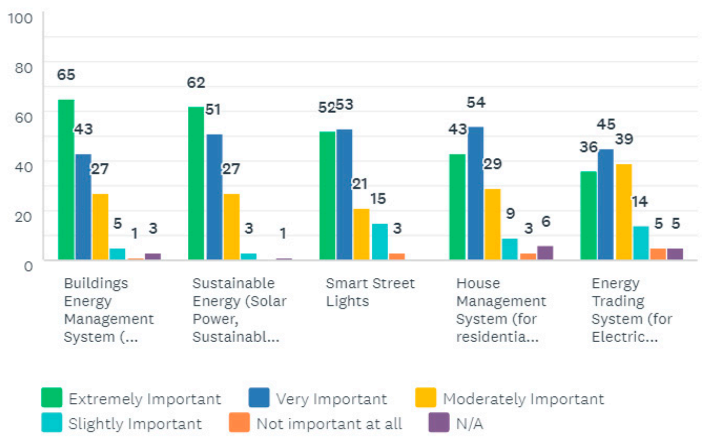


**Figure 12.** Energy management survey ranking. Source: authors.

These results, therefore, indicate that the students understand the importance of a sustainable environment and prefer it to the smart management of energy.

Figure 13 illustrates the students' perception of the three applications in terms of their importance for the Smart Campus. The application includes adaptive learning (customized learning according to market needs and students' interests, customized learning for students' weak points), optional supplementary courses in specialized fields (besides the curriculum) and Computerized Adaptive Testing (CAT) (tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, and deep assessment).

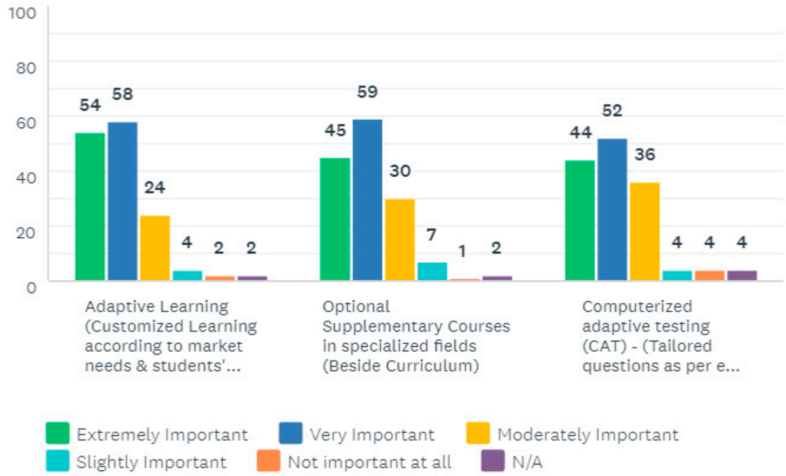


**Figure 13.** Adaptive learning survey ranking. Source: authors.

The results conclude that students considered adaptive learning (customized learning according to market needs and students' interests, customized learning for students' weak-points) as the most important applications followed by optional supplementary courses and Computerized Adaptive Testing (CAT).

Similarly, Figure 14 shows the average score given to the smart transportation criterion and its applications as per their importance within the university campus. The applications include smart parking, fleet tracking of all campus transportation (for logistics, transportation, smart bus shelters, etc.), intelligent signage (for navigation, broadcasting, etc.) and in-campus navigation (smart kiosks, way-finding for offices, room, mobile app, facilities, events, etc.).

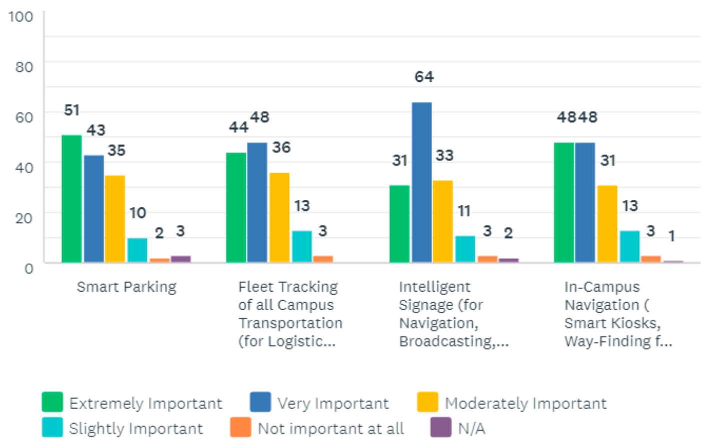


**Figure 14.** Smart transportation survey ranking. Source: authors.

The figure illustrates that 51 (35%) participants ranked smart parking as the most important application, followed by 48 (33%) participants that ranked in-campus navigation (smart kiosks, way-finding for offices, room, facilities, events, etc.) as important, 44 (30%) ranked fleet tracking of all campus transportation (for logistics, transportation, smart bus shelters, etc.) as important, and 31 (21%) considered intelligent signage (for navigation, broadcasting, etc.) as important applications. This indicates that, although the participants seemed in favor of all of these applications, they did not show a particular preference towards one application over the other, except for the use of intelligent signage.

Finally, Figure 15 illustrates the result of the students' perceptions when they were asked to evaluate applications from three different criteria including security and safety, optimization and analytics data center, and smart facilities services.

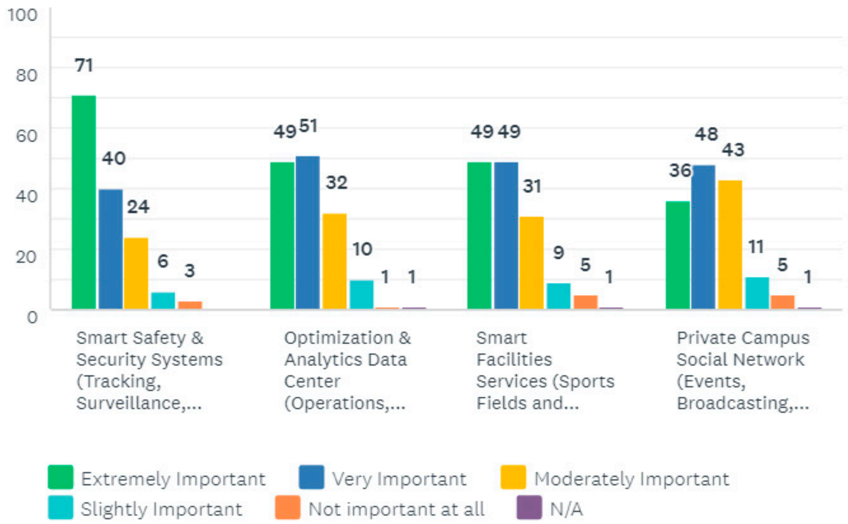


**Figure 15.** Smart (security, optimization, and facilities services) survey ranking. Source: authors.

The results reveal that the students considered smart safety and security systems (tracking, surveillance, evacuation, etc.) as the most important criteria and applications, followed by optimization and analytics data center (operations, data storage, research center, etc.), smart facilities services (sports fields and centers/libraries/restaurants/student center/activities), and private campus social networks.

Thus, to summaries the results obtained from the questionnaire survey, Table 12 combines the average scores gathered from the participants in order to produce the Relative Importance Index (RII) values of the eight identified criteria and the 25 associated applications of the Smart Campus. The smart list of the Smart Campus applications was sorted in a descending manner from the highest RII values to the lowest, while the five important levels were transformed from RII values as suggested by [45]: high (H) ($0.8 \leq$ RII $\leq 1$), high-medium (H-M) ($0.6 \leq$ RI $\leq 0.8$), medium (M) ($0.4 \leq$ RI $\leq 0.6$), medium-low (M-L) ($0.2 \leq$ RI $\leq 0.4$), and low (L) ($0 \leq$ RI $\leq 0.2$).

It can, therefore, be concluded that the highly important applications (RII score above 0.80) from the stakeholders' perspective include: smart card applications, smart classroom applications, energy management applications, adaptive learning application, and smart security and safety applications. Moreover, the rest of the applications were also above 0.72 RII value and inside the H-M range. This indicates and validates that all the designated criteria and applications are important features of a Smart Campus as previously illustrated in the literature review. In the beginning, it was not expected to have all applications above the high-medium level (above a 0.60 RII value), but the results were extremely aligned with the selected applications and criteria for Smart Campuses. All in all, campus stakeholders' perceptions are certainly important to validate the smart applications, since they are the targeted people who will deal directly with these features and changes in educational institutes. However, to comply and integrate the concept of a Smart Campus, it is important to initiate:

- Deeper, more technical research on each of the designated criteria inside the proposed framework;
- Implementation guidelines on each of the smart applications inside the Smart Campus framework;
- Cost–benefit analyses on each of the proposed Smart Campus criteria;
- The engagement of industry experts to help develop a full understanding of all challenges and limitations;
- Further research into decision support tools that aid with decisions regarding which smart application to invest in or not invest in, based on the budget, vision, and current preferences of campus stakeholders.

**Table 12.** Relative Important Index (RII) of Smart Campus applications.

| Criteria | Application | RII | Imp. Level |
|---|---|---|---|
| Smart Card | Record all personal data (student information, admission, transcript, graduation information, student records and activities, etc.) | 0.8545 | H |
| Smart Classroom | Interactive cloud sharing platform (between classmates and professors, between the market and the university, between government and university, etc.) | 0.8476 | H |
| Smart Card | For library usage (booking, borrowing, registration, printing, etc.) | 0.8458 | H |
| Smart Energy Management System | Sustainable energy (solar power, sustainable design buildings, carbon capture storage) | 0.8406 | H |
| Smart Safety and Security | Smart safety and security systems (tracking, surveillance, evacuation, etc.) | 0.8361 | H |
| Smart Energy Management System | Buildings energy management system (monitoring and automated: heat and air conditioning, lights, power devices) | 0.8355 | H |
| Smart Classroom | Collaborative research (connectivity and communication with several universities, companies, governments or research) | 0.8280 | H |
| Smart Classroom | Remote digital learning (online lectures, visual interviews, cloud storage, online access to all course information and lectures, etc.) | 0.8236 | H |
| Adaptive Learning | Adaptive learning (customized learning according to market needs and students' interests, customized learning for students' weak points) | 0.8225 | H |
| Smart Card | E-wallet (payments and verification with E-invoice for registrar, administration, cashier, restaurants, financial holds, fees, etc.) | 0.8181 | H |
| Adaptive Learning | Optional supplementary courses in specialized fields (besides curriculum) | 0.7972 | H-M |
| Optimization and Analytics Data Center | Optimization and analytics data center (operations, data storage, research center, etc.) | 0.7916 | H-M |
| Smart Energy Management System | Smart street lights | 0.7889 | H-M |
| Smart Transportation | Smart parking | 0.7858 | H-M |
| Adaptive Learning | Computerized Adaptive Testing (CAT) (tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, deep assessment). | 0.7829 | H-M |
| Smart Energy Management System | House management system (for residential end users usage) | 0.7812 | H-M |
| Smart Facilities Services | Smart facilities services (sports fields and centers/libraries/ restaurants/student center/activities) | 0.7790 | H-M |
| Smart Transportation | in-campus navigation (smart kiosks, way-finding for offices, room, facilities, events, etc.) | 0.7748 | H-M |
| Smart Transportation | Fleet tracking of all campus transportation (for logistics, transportation, smart bus shelters, etc.) | 0.7625 | H-M |
| Smart Transportation | Intelligent signage (for navigation, broadcasting, etc.) | 0.7535 | H-M |
| Smart Card | Dorms (all residential activities and administration) | 0.7449 | H-M |
| Smart Classroom | Virtual reality (for labs, experiments, site visits, simulations, etc.) | 0.7417 | H-M |
| Smart Facilities Services | Private campus social network (events, broadcasting, easy access to information, etc.) | 0.7385 | H-M |
| Smart Energy Management System | Energy trading system (for electric vehicles inside parking) | 0.7338 | H-M |
| Smart Card | For attendance (classrooms, labs, access to facilities, etc.) | 0.7264 | H-M |

Source: authors.

This study therefore contributes to the body of knowledge in a number of ways. First, by exploring the current state of the art in relation to the utilization and adaptation of Smart Campus applications within educational settings. This led the authors to believe that educational establishments have thus far only utilized limited aspects of the Smart Campus applications and have not utilized the Smart Campus applications to their full potential. Accordingly, and in the absence of a set of well-defined criteria that present a holistic model of a Smart Campus with its embedded applications, this study proposed a framework based on a set of criteria derived from the literature, which underpin the definition of Smart Campuses and their applications. This framework provides researchers and stakeholders with a holistic overview of the definition of a Smart Campus that is currently missing in the literature.

The second contribution that this study makes is through exploring the level of importance of the Smart Campus criteria from the Stakeholders' perception. These include educators, who would be likely to gain an ultimate benefit from Smart Campus facilities, and students, who would be the ultimate beneficiaries of such facilities. In doing so, the results of this study led the researchers to belief that students' priorities in relation to Smart Campus facilities are closely related to automated processes that enable the smart handling of data, such as the use of smart E-cards for their importance in monitoring students' attendance in a classroom, students' residential activities, library activities, and borrowing, as an E-wallet for processing payments or for recoding students' data (i.e., student information, admission, transcript, graduation information, student records, and activities, etc.). On the other hand, the educators' priorities are mainly focused on smart facilities, such as automated access to buildings and smart communication facilities and applications. Such a realization provides stakeholders with an interest in developing a Smart Campus within educational establishments, with an insight into the different end users' perspectives of Smart Campus applications and their reaped benefits. In doing so, this study therefore lays the path for future studies that will be concerned with stakeholders' interests in investing in the development of Smart Campuses, and to recognize the most important criteria that are of interest to certain beneficiaries, in addition to the added value that these criteria and their applications can bring in terms of cost versus value. It is therefore within the intended future research of this study to build on the current findings in order to develop decision support tools that will help decision-makers and investors to make sound investment decisions in relation to Smart Campus applications' value and related costs. This study, therefore, provides a pathway for the integration of smart applications into future Smart Campus development plans.

## 6. Summary and Conclusions

Smart cities and sustainable development have gained a massive amount of attention over the years. As a result, institutions, cities, and nations as a whole are working towards improving the living standards of its people and ameliorating the quality of their lives in many aspects. However, there still exists room for improvement in terms of the integration of educational institutions with the technology under a unified framework of a Smart Campus. Therefore, this study presents a unified framework for a Smart Campus, which comprises eight main criteria and 25 applications based on IoT and cloud computing platforms. The research used the set of comprehensive criteria to identify what is perceived to be a Smart Campus and evaluate these criteria from the stakeholders' perception by also highlighting the significant enablers and challenges facing the implementation of Smart Campuses, using the American University of Sharjah as a case study. A few of the challenges and enablers identified were resistance to change in the academic learning methods, investment costs, privacy agreements for data collection, a failover system to ensure redundancy, and business continuity. Whereas the main enablers included change management, willpower, a clear vision for smart transformation, technology awareness, incentivizing professors and students to implement Smart Campus applications, sufficient training, and motivation of all campus stakeholders. In addition, the conclusion drawn from this research is that all the designated criteria and applications are important features of a Smart Campus, as all applications ranked above the high-medium level (above a 0.60 RII value) using the RII analysis. These results were aligned with the proposed criteria and selected applications of Smart Campuses. The results of this study have set the foundation for further research to be conducted in order to develop a decision support tool that will enable stakeholders to prioritize their decisions in terms of investment costs and the added values of utilizing any of these identified Smart Campus criteria and their applications.

**Author Contributions:** Conceptualization, V.A.; methodology, K.A.A. and S.S.; validation, V.A., K.A.A. and S.S.; formal analysis, K.A.A.; investigation, V.A., K.A.A. and S.S.; resources, V.A., K.A.A. and S.S.; data curation, V.A. and K.A.A.; writing—original draft preparation, K.A.A. and S.S.; writing—review and editing, S.S., V.A. and K.A.A.; visualization, K.A.A.; supervision, V.A.; project administration, K.A.A. All authors have read and agreed to the published version of the manuscript.

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