A STRATEGIC FRAMEWORK FOR SMART CAMPUS: AMERICAN UNIVERSITY OF SHARJAH CASE STUDY

by

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Dedication

To my loving family…

Abstract

As the term smart campus attracts the 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 contribute in 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 how would a smart campus look like, or what are the main components that can form a smart campus. In this study, an intensive research is conducted to explore and compile the recent accomplishments in the fields of: smart cities, internet of things and smart campus; to utilize these recent studies into a coherent entity called 'The Smart Campus'. The objective of this research is to propose a conceptual framework for the Smart Campus that underpins the most important criteria from the campus end users' perception. The main criteria are defined from literature review, and a case study is conducted on the American University of Sharjah campus end users 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, faculties, and IT service providers. The results of the case study shows that 10 smart application scored High Importance level (H) ($0.8 \leq RII \leq 1$) based on the Relative Importance Index, and 15 other application are in the High-Medium importance level (H–M) ($0.6 \leq RI \leq 0.8$) based on the same index. Moreover, the case study shows that students prefer to deploy respectively the application of Smart Cards, Smart Classrooms, Smart Energy Management, and Smart Transportation in their campus life, and 60% of them believe that their university is capable to do the smart transformation. Nevertheless, professors and IT professionals confirmed the proposed smart criteria, and highlighted the main obstacles in: implementation cost, buildings' reliability, and resistance to change. Finally, having defined and evaluated the criteria that underpins 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 in order to transform a traditional campus to a smart campus.

Keywords: ***Internet of things; smart city; relative importance index.***

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Chapter 1 . Introduction

1.1. Overview

With the current emerging technologies, cities are moving toward improving the living standards of individuals and ameliorating the quality of their lives in many aspects. As a matter of fact, a good education is one of the most important factors to develop societies, as it plays a vital role in building future generations and cultivating the way they think. Therefore, there appears a current need to merge the current education institutes with the new technologies available in hands, or with what might be developed in the near future. Moreover, the world currently relies on many unsustainable sources of power and energy, and there is a current trend to move toward other sustainable sources. Therefore, there is not only a need to merge educational institutes with new technologies, but also to replace its current resources with a more sustainable and environmentally friendly solutions.-As a matter of fact, all these factors together can act as the catalyst to reshape the current educational institutes in a way that is aligned with the recent vision of smart cities, to propose what can be called a smart campus. In the IBM journal of research and development [1], they defined smart cities as *"urban areas that exploit operational data, such as that arising from traffic congestion, power consumption statistics, and public safety events, to optimize the operation of city services".* Nevertheless, it stated that it is built on three foundation concepts: *Instrumented, Interconnected, and Intelligent*. It further explains each of the terms as per the following: 'Instrumented' indicates the ability of recording and connecting real world with data extracted using sensors, personal devices, etc.... 'Interconnected' means processing these data and integrate it into a computing processors that can connect various city services to all these data. 'Intelligent' refers to the "inclusion of complex analytics, modeling, optimization, and visualization in the operational business processes to make better operational decisions" [1]. Nevertheless, research by [2] shows a list of definitions for smart cities from several sources. In addition to smart campus, many researches have linked the word smart with sustainability. Thus, the sustainable development can be described as "A dynamic process which enables people to realize their potential and improve their quality of life in ways which simultaneously protect and enhance the earth's life support systems" [3]. Many universities and research institutes are directing their studies towards smart cities and sustainable development, because of the promising expected outcomes of applying those concepts in real life. American University of Sharjah (AUS), which ranks 376 worldwide and 7th in the Arab region [4], provides a Doctoral program in Engineering Systems Management that have several research areas including ‘Smart Cities Management’[5]. In addition, UAE in general and Dubai in specific, have recently became an incubator for smart cities’ applications that aim to put Dubai or UAE on the map as the first smart city in the world [6]. Nevertheless, Dubai have recently launched an initiative with the name ‘Smart Dubai 2021’ through a website to describe their objectives and expected impacts [7]. Therefore, and as a part of the recent global focus on smart cities; it became inevitable to facilitate those cities with smart educational facilities, called “The Smart Campus”. Finally, as a prominent name in the field of education and research in the UAE, it becomes inevitable for AUS to follow UAE vision and develop a smart campus that represents the smart vision of the country

1.2. Thesis Objective

Driven by the evolving attention to smart cities’ applications around the world, and the opportunities that smart cities can create in terms of raising the living standards for both individuals and nations; this research will investigate and focus on the most recent practices that promote the concept of Smart Campus. It is just a matter of time for smart campuses to take place as a part of smart cities development, and therefore, our research will be focused on smart campuses applications and the main components that can form such entity. The ultimate aim of this research is to explore the underpinning criteria for developing a smart campus, and propose a strategic framework for promoting a smart campus using AUS as a case study. Nevertheless, this aim can be achieved via the following objectives:

- Identify the recent achievements in the fields of smart cities and smart campuses around the globe.
- Develop an understanding of smart cities and smart campus, in order to define the main criteria for a smart campus.
- Evaluate the criteria of smart campuses, and identify the challenges through a case study on AUS using qualitative and quantitative analysis.
    - Draw a set of recommendations that empower the idea of smart campus.

If the major components and structures of the smart campus are clearly defined, then it becomes a requirement to analyze these criteria and applications from the perspective of end users and campus stakeholders.

1.3. Research Contribution

Although UAE is a leader in taking the smart and sustainable agenda seriously, and it thrives to be one of the leading countries in those fields; there is still not a great deal happening in the UAE regarding smart campuses. This research will contribute to upgrade the educational institutes to the next level by proposing a comprehensive framework for a smart campus, based on literature review, and AUS as a case study. As a result, this will return with positive impacts on the quality of education, socio-environmental preservation, and create pathway for future applications to take place in many other campuses and future cities.

The contribution of this research can be briefly demonstrated as follows:

- Propose several practical solutions to develop existing traditional universities' campuses and turn it into smart campuses. This can be achieved by exploring the smart campus criteria and selecting the applicable practices based on the current structure of the university and surrounding environment.
- Provide a pathway for smart applications to take place in future smart campuses' development plans. The smart cities might not stick to the current practices demonstrated in this research, however; this research opens the doors for smart services and applications to take place and present itself as real feature in future cities in UAE, and around the world.
- Present suitable sustainable practices that can enhance the sustainability rating of university campuses on the sociological, environmental, and economical aspects. This can further expand to positively affect the sustainability awareness inside cities and improve the living standards for individuals.

1.4. Research Question

By the end of this study, the research shall be able to define the clear model of a smart campus as a cohesive holistic entity. As a result, when the smart campus definition and components are defined, the research shall be able to answer the following questions:

- What are the underpinning criteria of a smart campus?
- What is the end users' perception of implementing smart campus applications in the American University of Sharjah?
- What are the most important enablers and challenges facing the implementation of smart campus in the American University of Sharjah?

1.5. Methodological Steps

In order to achieve the research objective, several procedures have to be followed in terms of literature review and data collection. Firstly, an intensive literature review will be conducted on smart cities in general, and smart campuses in specific. Thereafter, the selection phase will start, where it will shortlist the applications and features to the ones that perfectly fit the smart campus and have a significant impact on it. Nevertheless, these features will be categorized to form the main components of a smart campus based on a qualitative analysis. In this stage, the framework of the smart campus will be ready based on the qualitative analysis of the literature review. In terms of data collection, the research will rely on both qualitative and quantitative methods to validate its findings. These methods will include semi-structured interviews with professors inside AUS, and a distributed survey among students, alumni, and professors inside the AUS campus. As for the semi-structure interviews, it will allow academics to give their opinion about the selected criteria and suggest the limitations and enablers of smart campus applications. On the other hand, the survey will allow campus stakeholders to rate each of the smart applications and highlight the most important features to develop in the near future.

Chapter 2 . Background and Literature Review: Smart Campus Features and Underpinning Criteria

This section presents the previous works, ideas, publications, and recent accomplishments in the fields of smart cities, smart campuses, sustainable campuses, intelligent buildings, sustainable homes, and zero-carbon cities/buildings. In addition, it will also elaborate more on the benchmarks of these works, limitations, and how it can consult or utilize promoting a smart campus in UAE. Finally, the expected outcome of this chapter is to define the underpinning criteria that can constitute the idea of Smart Campus, through gathering multiple researches and achievements, then combine them to generate the underpinning criteria of a Smart Campus. These criteria will be further tested and validated in the Discussion and Analysis Chapter 4, by conducting a case study inside the AUS campus, to investigate the preferences and importance level of these criteria for the campus' end users.

2.1. Architecture of Smart Campus based on the Internet of Things and Cloud Computing

As mentioned in Chapter 1, a smart city means *Instrumental, Interconnected, and Intelligent*. Therefore, the smart campus shall have at least the same features of smart cities in order to convoy with its applications and advanced technologies. From this point, and since many smart cities' applications require a sophisticated infrastructure to operate on; there urges a need to study and define the infrastructure that smart campus will operate on. Hence, defining the software architecture in which the smart campus will operate on is a vital step before proceeding with the various smart applications and services that will be provided by the smart campus. Several studies propose Internet of Things (IOT) and Cloud Computing to be the main fundamentals of future smart campuses. Cloud Computing is simply using the network server on the internet instead of the local server or computer to store and manage data [8]. Moreover, IOT is simply the interconnection via the internet of several computing devices in order to process and perform daily activities by sending and receiving data on the internet. From bottom to top, Liu at al. [9] proposed the overall architecture of smart campus where it was divided into three platforms: comprehensive perception network foundation platform based on the internet of things, service support platform based on cloud computing, and intelligent application platform centred on users. Liu at al. [9] also discussed the concepts of each of platforms, how to manage the cloud network infrastructure and supporting services, and what elements should comprise these platforms. Thus, these proposals can be considered as a part of the framework for the architecture of smart campus. From bottom to top, it all starts with the first platform: comprehensive perception network foundation platform based on the internet of things, which shall be supported by three layers as shown in Figure 1: Network communication infrastructure, Object perception system, and Information collection and management system. Firstly, the network communication infrastructure is responsible for providing the groundwork for strong continuous internet connections, and it is proposed to be supported by strong Wi-Fi, 3G/4G network, and IPv4/IPv6 which are the latest versions of internet protocols that can handle and manage a lot of internet data transactions at the same moment. Secondly, object perception system is supposed to monitor and track any changes in the surrounding environment in order to record its data and transfer it to the next layer which will be the information collection and management system. The main tools used in the objective perception system are sensors, RFID, Qr code, and video monitoring. Finally, the last layer in this platform is the information collection and management system which is considered as the management centre of the internet of things. The second platform which is the service support platform based on cloud computing, will play as storage that filtrates data into clusters that can be then served to end users based on their authorization level. It is important to highlight that this platform was proposed to operate completely on cloud servers instead of traditional servers. Finally, the user-centred intelligent platform is the last platform in this proposal. This platform includes the several applications that can be applied in future to help and serve students, faculty, and management inside a smart campus. A detailed illustration for this proposal is shown in Figure 1. Moreover, Chao Huang in his study [10] analyzed and compared differences between network in traditional campus and that in smart campus and made proposals on how to build smart campus from the perspectives of cloud computing and internet of things. He showed 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, and openness and sharing. Furthermore, as per Table 1, he suggested the Architecture Layers of Campus Cloud and discusses briefly each of them.

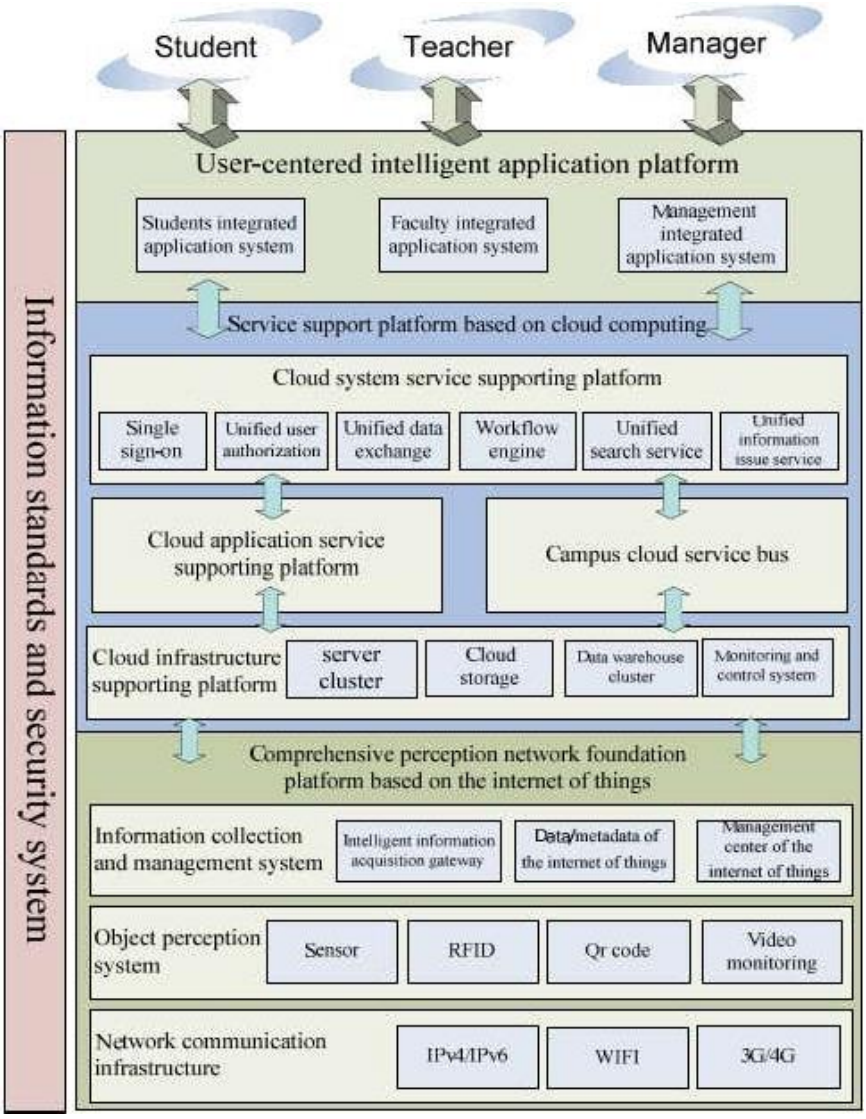


Figure 1: Three platforms that represents the architecture of Smart Campus [9].

Table 1: Proposed architecture layers of campus cloud [10].

Basic layers of campus cloud	Key points of layer construction	Purposes of layer construction
Infrastructure layer	Infrastructure refers service layer	Providing a virtualized hardware resource pool
Platform layer	Platform refers service layer	Providing software support platform with unified standards
Software layer	Software refers service layer	Providing various application services

Finally, Xiao Ni in another paper [11] proposes a system framework based on the IOT and it consists of three layers: Awareness layer, Network layer, and Application layer. The Awareness layer is responsible for data collection and pre-processing, while the Network layer is responsible for information aggregation, and the application layer will do the processing and utilization of data.

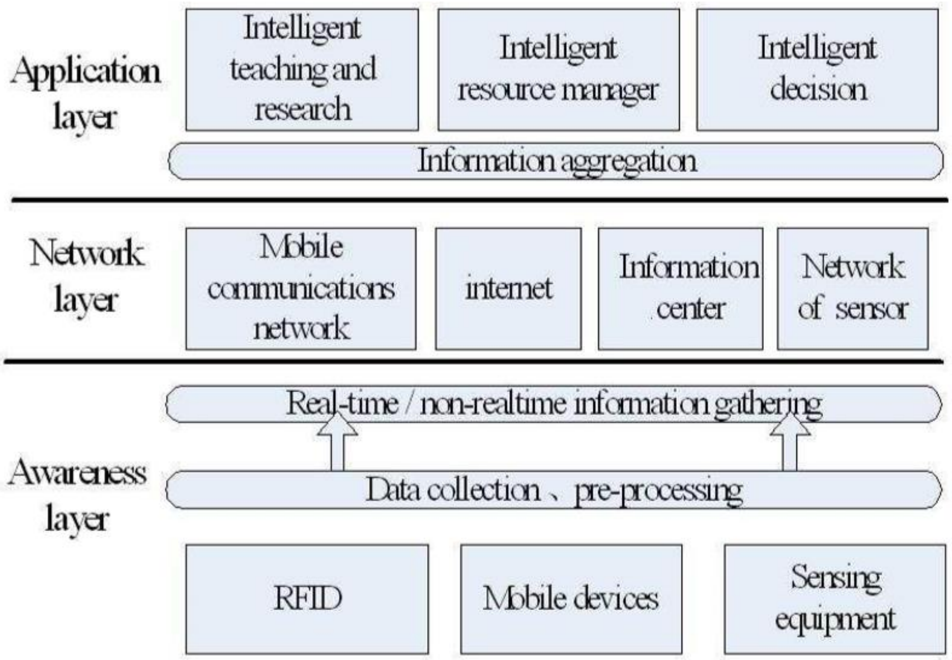


Figure 2 : Three IOT system layers for a smart campus [11].

Moreover, to distinguish between the Digital Campus and the Smart campus, Xiao Ni [11] compares the technical environment, application, and management systems for both digital campus and smart as per Table 2.

Table 2: Comparison between Digital Campus and Smart Campus [11]

	Digital campus	**Smart campus**
Technical environment	Local area network Internet	IOT Cloud computing wireless network mobile terminal RFID
Application	Digital teaching resources Distance education Digital library Administrator of networks	The smart system of sensory ability, interoperability, control capabilities
Management systems	Isolated system	System sharing Intelligent Push

To sum up this section, there is still no full-smart campus architecture been developed in real life examples, however; all these previous publications can work as guideline to create the architecture of smart campuses. Adjacently, all the previously mentioned proposals suggested using IoT, Cloud Computing, and RFID sensors as the main technology or tools to build the smart campus infrastructure. Similarly, this sophisticated smart architecture will definitely consist of several strong internet networks, different layers of objects monitoring, data collection tools, layers of organized information, and several applications for end users. All in all, the smart infrastructure will open the door for several application to take place, and this research will discuss a pleasant amount of application in the following sections.

2.2. Utilizing IoT in Smart Campus Application

Sari defines IOT in ~~his paper~~ [12] as a structure in which objects and people are provided with exclusive identity that gives them the ability to relocate data over a network without requiring two-way handshaking between human-to-human or human-to-computer interaction. Moreover, he mentioned that it is costly to build the infrastructures of a smart campus. However, when it is implemented, all the campus activities will be effective and efficient [12]. In addition, to achieve the large network, entity connection and intelligence; IOT will use several sensing devices such as, Global Positioning System (GPS), Radio-frequency Identification (RFID), Just in Time (JIT), Geographic Information System (GIS), and Electronic Data Interchange (EDI). The paper expects smart campuses to have Smart education, smart parking, and smart rooms. For the smart education, it assumes e-Learning system where all students can join the classrooms from anywhere. Moreover, students and teachers can face each other at anytime from anywhere as long as they have internet connections. In addition, for practicum learning and experiments, the smart campus will provide virtual simulation as a part of the virtual class in order to help students in learning. On the other hand, the smart parking will have sensors to show any vacant parking lot, and the total numbers or parker cars will be revealed on board. Finally, the smart room will have a camera, RFID sensor and Proportional-integral-derivative (PID) controller in order to provide the analysis for classrooms, show whether the room is vacant or not, and will show the number of students attending. All students' names, identifications, and activities will be saved in the database. Moreover, an auto-lighting system will control the on-off lighting switch according to human presence or absence. All these application and more, are just a simple introduction for what can be implemented based on IoT, and how it can grow to be the next revolution in data utilization. The research will continue to present more features and application in the upcoming sections.

2.2.1. IOT in Education. What mostly distinct IOT from former technologies is that it is considered ubiquitous, and autonomous [13]. Additionally, by the coming year 2020, it is expected to have 25 billion devices connected to the Internet, and that will create a plethora of data [14]. IOT will be a strategic tool to make use of all these data and it is considered as one of the top 10 strategic technology trends [14]. Moreover, IOT can connect the already built networks with each other [15]. In Figure 3, education is presented as one of the potential networks to implement IOT in future [15].

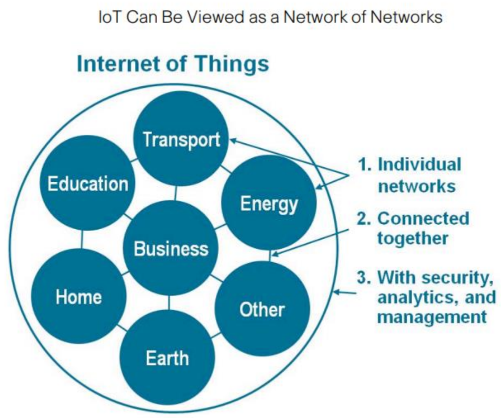


Figure 3 : Internet of Things Network [15]

Nevertheless, Cisco insists on modern organizations' needs for a digital strategy to achieve its desired outcomes [16]. Digital Strategy enlightens how to utilize the newest digital technologies to empower operations and business processes, in addition to improve the stakeholder experience [16]. Besides, Cisco categorizes IoT applications in digital campus into five main categories as shown in Figure 4 [16]: Building Control and Management, Security and Access Control, Video and Information System, Location and Attendance Systems, and finally Energy Monitoring and Control. Moreover, Cisco and Deakin University have collaborated to deploy Cisco Mobile Experiences (CMX) to provide cloud learning and location analytics information [16]. This way it can enrich the learning experience of both faculty and students and provide library usage data to the university [16], [17]. Figure 5 shows the Virtual Learning Environment (VLE) and educational content that can be provided for digital campuses [16]. In addition, the digital stakeholders' community can be illustrated as per Figure 6. The figure shows the external stakeholders and key partnerships for a typical digital campus [16].

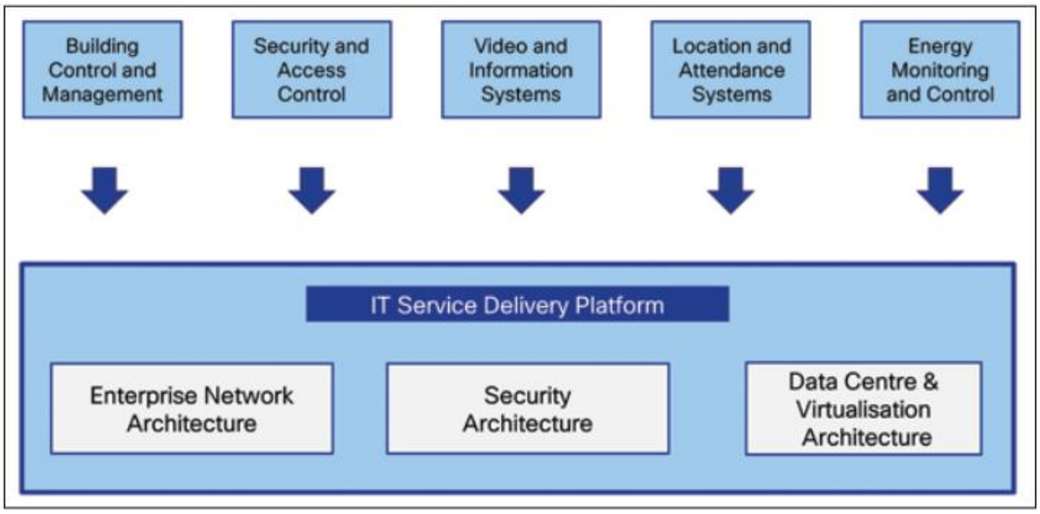


Figure 4: IOT Applications in Digital Campus [16].

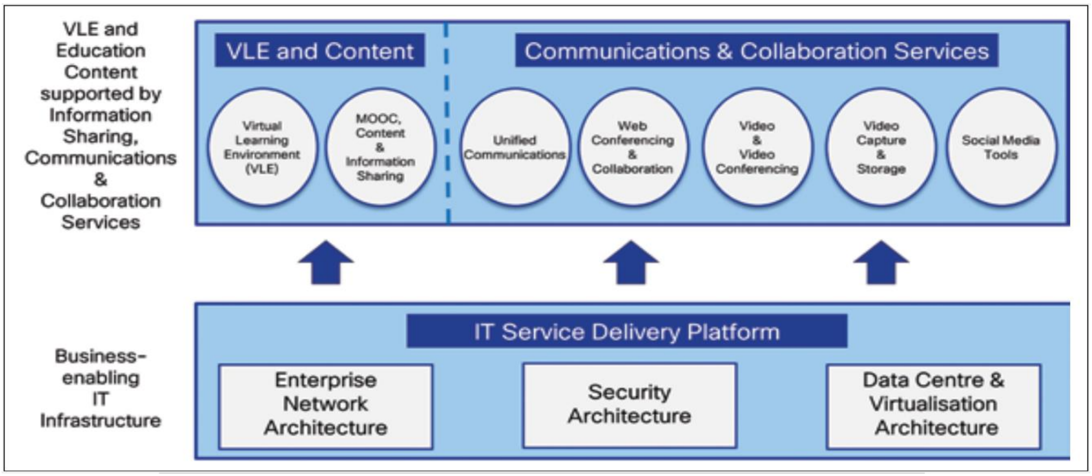


Figure 5 : Communications and Collaboration Services for Digital Teaching, Learning and Research [16].

Figure 6: Digital Stakeholders Communities [16].

Similarly, some examples of digital transformation in several educational institutes are mentioned in [18], these examples focuses mainly on learning and security. In addition, Cisco [19] briefly presents some of its applications in education inside and outside the classroom. Several tools such as Cisco WebEx, SpeakerTrack, Cisco TelePresence, and Cisco Spark can be used for remote digital learning [19]. These all are visual solutions that immerse the learning experience through meeting and interacting with the active speaker. Moreover, Cisco Spark allows instructors and students to cooperate in group projects by video chatting, sending messages and sharing files in one place [19]. Adjacently, some examples of partially digitized existing campuses can be seen in the following report [20]. Finally, it is clearly shown that the education sector have a great potential to digitize its processes and learning experience, and many leading universities are now welcoming the technology intrusion in their education, and of course, IoT is one of the most promising technologies in that field.

2.2.2. Technology for Classrooms and Identification. Face recognition technology in universities can be perceived as terrifying or useful depending on the way implemented. Based on trials, the face recognition technology can save up to 2.5 hours a week of teaching time, if it replaces the traditional methods of students' roll call [21]. Moreover, it was also estimated that we spends almost three working weeks of the year just to authenticate ourselves to several services whether they are provided by computers or humans. All this consumed time in proving your identity, resetting passwords and accounts, signing documents, and waiting in queues can be saved [21]. One comparable application was developed recently in Dubai Airprots DXB, and it is called the Smart Gates. Smart Gates has speeded up the passport control process and squeezed it to a few seconds process where UAE nationals and residents just scan their ID's and go without prior registration [22]. All in all, face recognition technology can really facilitate the campus life and smooth all administrative processes.

2.3. IOT Services for Smart/Connected Campus:

There are many fields for IOT services to take place in the smart/connected campus. Throughout the research, many fields and services were discussed separately inside the campus, and others were proposed for a bunch of applications to take place together inside the campus. In this section, the main features and criteria of smart campus will be presented from literature review for the potential applications of IOT inside the smart campus as a whole, not only limited to education field only.

2.3.1. Cisco's Digital Ceiling Technology. This framework was developed by Cisco to "connect several buildings domains such as lighting and automation under one single IP network" [23]. It was firstly developed to support business industries as a part of the digital transformation of companies. But in 2016, Cisco expanded this model to the educational sector as it seemed to be one of the potential future markets in adopting IOT and digital transformation. The model can be briefly illustrated in Figure 5:

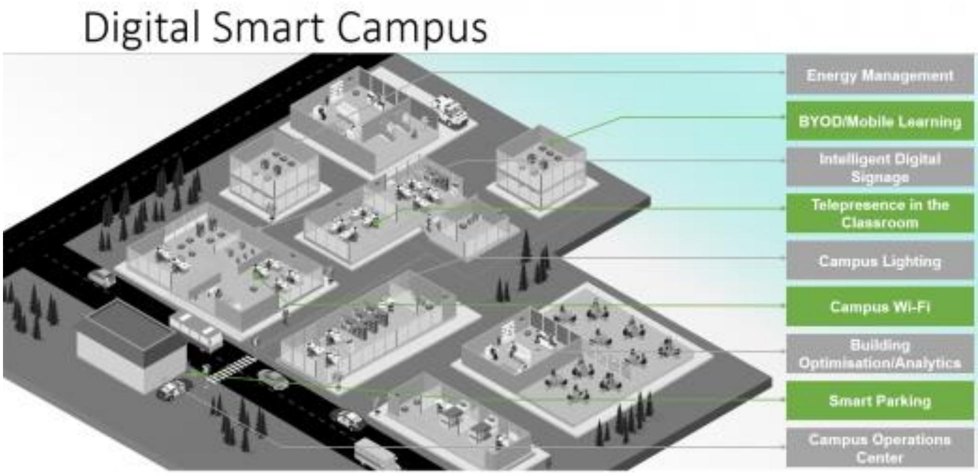


Figure 7: Digital Smart Campus Components [23].

This framework proposes nine main aspects that can be covered under the IoT applications of smart campus. It includes: Energy Management, Bring Your Own Device/ Mobile Learning, Intelligent Digital Signage, Tele-presence in classrooms, Campus Lighting, Campus Wi-Fi, Building Optimization analytics, Smart Parking, and Campus Operations Centre [23]. The framework recommends deploying IoT in all these nine aspects as it will result in many enhancements for the campus quality and efficiency. All these mentioned features can support this research to build and identify the main underpinning criteria of a smart campus.

2.3.2. CenturyLink Model of a Smart Campus. CenturyLink have also discussed the IOT services that make a typical campus a smart campus. Their model consists of 7 areas that IOT can contribute to change the campus nature from traditional to smart. These areas are: Energy Management, Fleet Management, Security & Safety, Venue Services, Learning Spaces, Digital Connections, and Data Analytics [24].

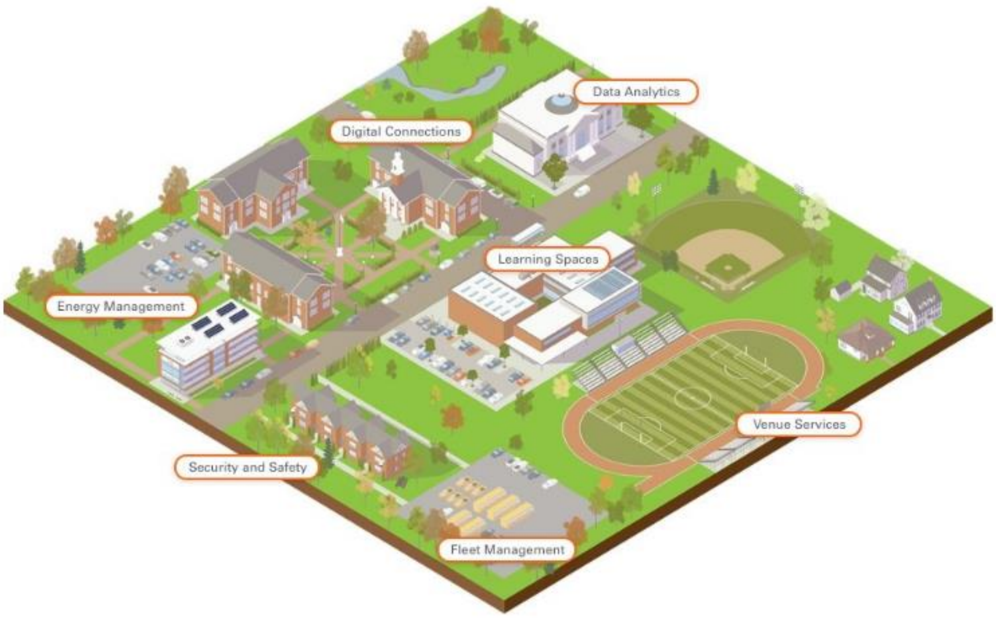


Figure 8: What makes a Campus Smart? [24]

The Center for Digital Education also produced another report for CenturyLink where it defined the connected campus and explained briefly each of the 7 areas potential applications. The term “connected campus” describes the ability to perform a more informed decision-making process by integrating several IT devices and applications with the surrounding environment [25]. Both reports [25] and [26] spot the light on several application such as smart lighting, video surveillance with analysis, parking and transportation management, facility access control, interactive signage and kiosks, asset protection, and way finding. The main concern in IOT applications is the responsibility of the data collected from students, faculty and visitors [25]. The methods of data collection have to be transparent and works toward increasing the 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]. The report includes a survey results also that was conducted on students and professors from several universities in the U.S. The survey respondents showed an agreement on connected campus positive impact on both students and faculty. These results showed expectations of 48% cost savings, 43% higher student retention and 38% improved student learning outcomes to be the main drivers for implementing technologies in smart campus [25]. Nevertheless, respondents also highlighted the importance of campus safety as the main area to invest over the coming years. To conclude, all the mentioned areas showed a real potential to implement smart technologies and solutions inside the campus, with a notable direct effect on all stakeholders. Along with other proposals, the mentioned mini model will assist this research to build a holistic framework for the Smart Campus.

2.3.3. Nokia Smart Technologies. Nokia and National Chiao Tung University (NCTU) partnered under the ng Connect Program to deploy an Internet of Things (IoT) system in order to adopt the idea of smart campus. The collaboration shall continue throughout the years under 3 main phases. Case Study [27] showed the results after deploying an energy management system inside the buildings, which represents only phase 1 of the plan. The results of such a deployment was a reduction in energy costs inside buildings by 11 percent [27]. The cost saving percentage is expected to reduce more after implementing phases 2 and 3. Figure 7 shows the vision of NCTU and Nokia after implanting the total 3 phases of the project.

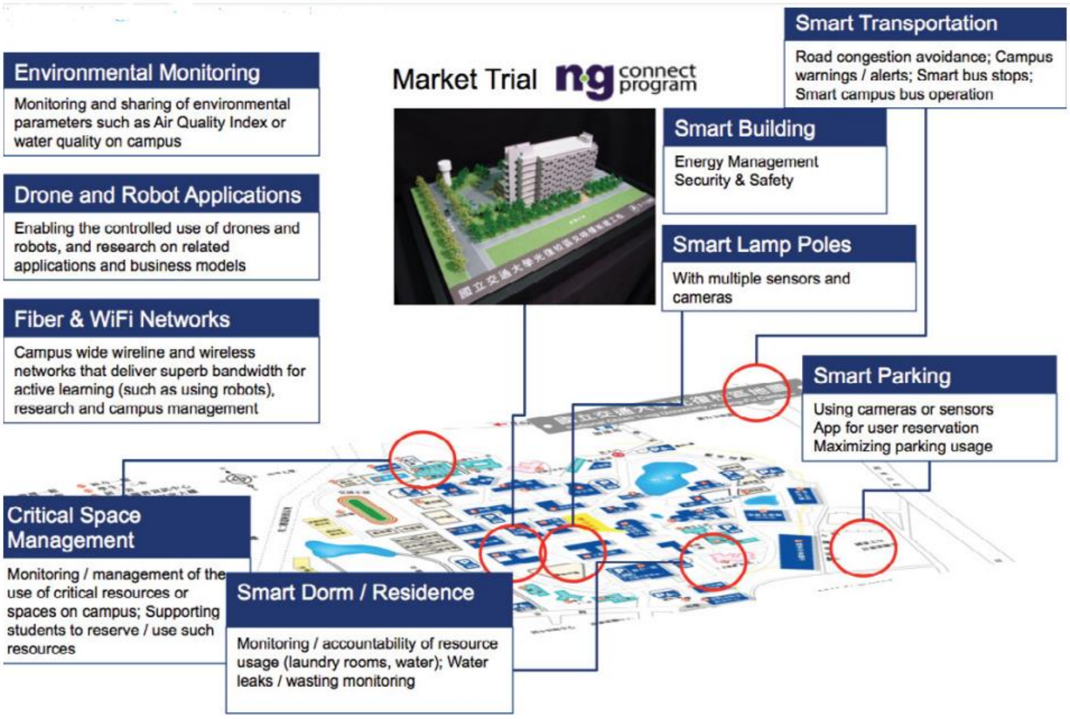


Figure 9: Vision of Smart Campus initiatives as per ng Connect program Nokia [27].

Moreover, the website shows the IOT opportunities for smart cities applications. Figure 8 illustrate the main fields for IOT applications that can take place in cities and campuses [28]. To sum up, the actual implementation of IoT in energy management inside campuses have resulted in 11% savings for the costs of energy.

Figure 10: IoT Applications' opportunities [28].

Altogether, the Nokia and NCTU case study leads to another significant reason for why to involve and utilize IoT as a main pillar for optimizing energy management inside campuses. Therefore, IoT has proved its efficiency when it comes to integrating energy management systems inside campus buildings.

2.4. Adaptive Learning

Adaptive learning is a method of education which leverages certain computer algorithms to tailor the educational strategy as per each student's need. Furthermore, it retargets students with customized educational resources and activities which fit each of their unique needs. Matthew states that the educational material presented to each student adapts and reshapes to fit the students' learning needs as implied by their exam answers, assignments, and classroom experience [29]. While traditional learning continuously faces the limitation of systemized learning experiences, which does not consider differences in learning experiences between students, adaptive learning recategorizes students from passive receptors to active collaborators in the educational system.

In addition, computerized adaptive testing (CAT) follows the same intuition of adaptive learning and applies it to exam taking. Instead of traditional standard exams for all students, CAT aims at tailoring questions as per the exam taker's needs. Magis and Barrada clarify that after each answered question, CAT identifies the student's level understanding of the question, and depending on it the next question is presented to maximize the precision of testing the student [30]. For example, if the student performs well on a question of minimal difficulty, the criteria is updated and a tougher question will be presented, and vice versa. As such, CAT provides more accurate results for both medium-level score students, and extreme level ones.

2.4.1. Flexibility of Adaptive Learning. Adaptive learning started gaining momentum in the 1970s, when the scholar system offered adaptive learning for the topic of geography in South America [31]. Since then, the topic has evolved and took different shapes, and it was adopted in various institutes to deliver unprecedented results. Adaptive learning frameworks provide four main services: management of the education process; adaptive learning content and resources; electronic evaluation and testing; and e-services to support traditional score measurement [32]. However, some frameworks provide different services than others, and they vary in complexity. Basic adaptive learning tools usually focus on deciding the student's course path depending on simple criteria, such as answers to multiple choice questions [33].

On the other hand, some adaptive systems revolve around assessment and exams rather than on content. For example, SIETTE (that stands for the Spanish translation of Intelligent Evaluation System using Tests for TeleEducation) emulates oral tests and deduces student learning through adaptive exams; presenting questions to the student adjusted to his/her learning level [34]. HELP is an adaptive English learning system which gives adaptive feedback and instructions according to student confidence scores; the confidence scores are in turn assessed by the system for each upcoming answer given by the student to determine the next question [35]. On the other hand, PEL-IRT (stands for Personalized E-Learning system using item response theory) utilizes two questions to determine students' feedback: "do you understand the content of the recommended course material?" and "what do you think about its difficulty?" (Each answered by yes/no) [36]. Based on the answer, the system utilizes the response to determine the comprehension degree and suggest appropriate course materials. Finally, TANGOW (Task-based Adaptive learNer Guidance On the Web) adopts a flexible framework for devising courses with varying adaptive features. For example, it adapts the magnitude of contents to be studied and adjusts the level of the test to be taken by the student [37]. The availability of various adaptive learning frameworks allows for flexibility of implementation in educational systems, depending of the desired degree of integration in the traditional system.

2.4.2. Advantages & Limitations of Adaptive Learning.

Adaptive learning has exhibited notable results in the education arena. In his paper, Walkington compared the performance of two categories of secondary-level students in math [37]. The first category went through a traditional learning experience, while the second category was taught using adaptive learning strategies. Walkington observed that the second category "continued to write symbolic equations for normal story problems with increasingly complex structures more accurately and with greater efficiency" [38]. Moreover, in a study conducted over 4 years on 8,500 students at West Virginia University (WVU) by Michelle et al., it was found that adaptive systems "increase the probability of higher final letter grade for average, below average, and failing students" [39]. The advantages of adaptive learning are promising and are constantly evolving and being adopted worldwide. Arnaudova et al. explain that adaptive learning systems are being integrated in learning systems worldwide in institutes, universities, schools, and corporations [40]. Therefore, it seems essential for adaptive learning to take place or to be considered at least as a supportive tool for learning inside future smart campuses; as it opens the doors for new methods of learning, more accurate assessments, and a more customized learning that supports the students to come over their learning difficulties and enhance the level of learning.

2.5. Energy Trading – Electrical Trading Vehicles

In [41], Ahmed and Kim suggest an energy trading system between electric vehicles inside a parking lot. The model proposes a parking lot control center (PLCC) that monitors and controls the energy trading between electric vehicles. It is responsible for optimizing and maximizing profits through selling and buying electrical energy for cars inside the parking lot. It will mainly check the demands and offers of cars inside the parking lots, and hence provide energy to the cars with lack of energy by simply buying from cars with excess of energy. The process involves 4 layers: the parking energy layer, data acquisition layer, communication network layer, and market layer.

2.6. Enhancing Mobility in Smart Campus

An indoor positioning system has been developed to support way finding inside Universitat Jaume I (UJI). The paper [42] focuses on enhancing the positioning system inside a supposed to be smart campus in future. Two mobile applications were developed for the study, and both were tested by students, university staff and visitors who later on reported the usefulness of both applications in locating the campus facilities and improving the spatial orientation. The first application *SmartUJI APP* allows users to use the campus map in order to obtain information and navigate several locations of university's facilities. Moreover, the second application *SmartUJI AR* provides an interacting augmented reality map where users can experience navigating the routes of their desired locations, facilities or any other point in campus. Screenshots for each application are shown in Figure 11 and Figure 12.

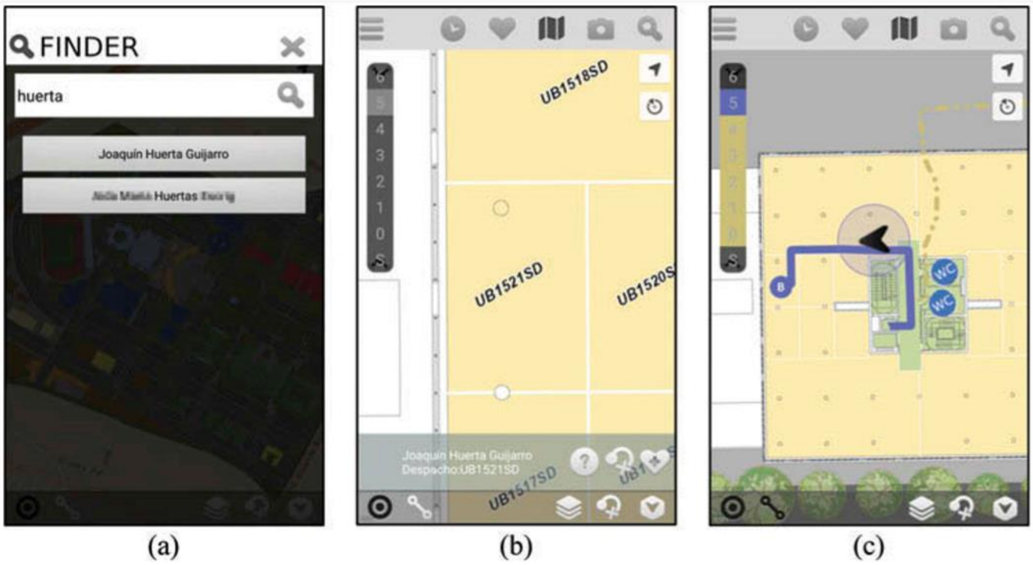


Figure 11: Screenshots of SmartUJI APP [42].

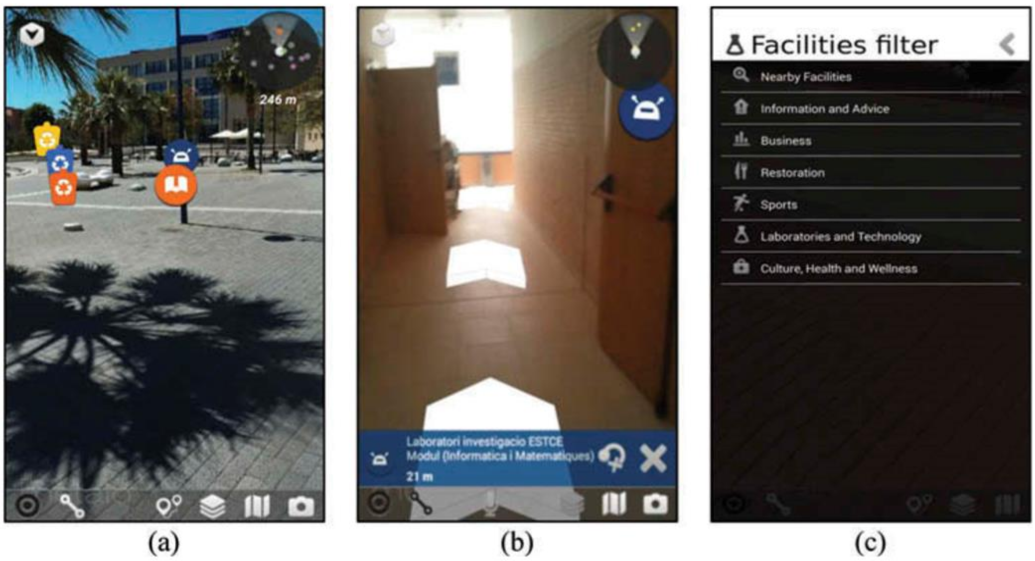


Figure 12: Screenshots of SmartUJI AR [42].

2.7. Energy Management

2.7.1. Energy Optimization and Management of Power Demand. Paper [43] describes an energy management framework where power usages are scheduled and integrated with local renewable energy sources and battery banks by an Energy Management System. The energy management system is integrated with a storage and data exchanging infrastructures, that can be used as a data center to predict energy consumption/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. This EMS system can be beneficial for future applications in smart campuses in terms of energy management.

2.7.2. Energy Management of End Users. Paper [44] proposes an energy management system for end users in residential homes, by developing a House Management System (HMS) that can effectively reduce the energy consumption in homes and rectify the consuming behavior of end users. The HMS will show to users the influence on power consumption of each of the home appliances (lights, washing machines, refrigerator, televisions, etc...). Moreover, the case study allows a power limit of 1500W only, so the end users have to manage their home appliances in a way that doesn't exceed 1500W load at any moment.

To support the end users, an optimization model called the dynamic load priority (DLP) is used to frequently change the load priorities based on the users' needs and the power limit. This case study is useful for future application on residential units by increasing the power limit based on the type of home and its' needs. However, a similar improved model can be developed to include residential, commercial, and educational unit as in our case for the smart campus.

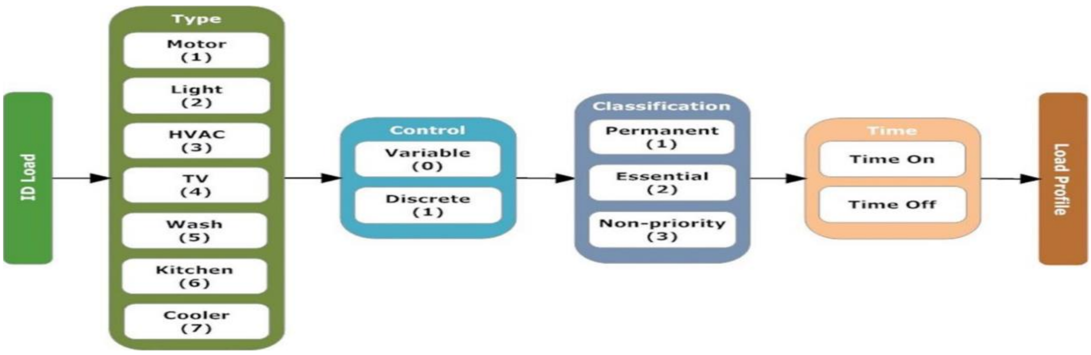


Figure 13: Diagram for the characteristics of the load in a management event [43].

2.7.3. Test of building smart sensors on campus building. This study was conducted in the University of California, San Diego where research scientist Yuvraj Agarwal and his team used real-time occupancy sensors and computer algorithms to create smart heating, ventilation and air-conditioning (HVAC) systems. Based on early test results, their developed system (software and sensor-based solution) resulted in electrical energy savings between 9.54 and 15.73 percent. Their test was conducted on only one floor out of a five floors campus building [45]. Mr. Yuvraj Agarwal also stated that it could save up to 40-50% of the current used energy if the systems is implemented on the entirety of CSE building [45].

2.8. Low Carbon and Sustainable Environment

2.8.1. Energy Management of End Users. Masdar city is 2006 initiative of the Government of Abu Dhabi, in the United Arab Emirates to build the first zero-net carbon, zero waste city based on renewable energies and sustainable environment [46]. One of the approaches to achieve this goal is by lowering the consumption of resources by preparing an intelligent design for buildings and streets that will reduce the need of energies during operations by 70%, compared with the conventional city of Abu Dhabi [46]. This can happen by specifying high standards of facade design for buildings, and shading them from the daily high temperature of Abu Dhabi throughout the year; so in this way the energy needed for coiling and power will be reduced. Moreover, all buildings will be facilitated with monitoring and control systems, which will help in being efficient while using the possible resources. Finally, in terms of renewable energies, Masdar City’s power infrastructure features a range of renewable energy technologies; including a range of photovoltaic plants (PV), a concentrating solar thermal power plant (CSP), evacuated thermal tube collectors, and a waste-to-energy plant [46].

2.8.2. Carbon Capture Storage (CCS). Masdar aims to build the world’s largest Carbon Capture and Storage (CCS) project. This come as a result of the initiative to reduce the emissions of Greenhouse Gases (GHG). CCS targets now only large-scale projects. It mainly captures the CO2 from power plants and industrial facilities and inject it in oil reservoirs. The CO2 is to be piped to offshore oil fields where, in a process known as enhanced oil recovery (EOR), it will be injected to maintain underground pressures and increase oil recovery [46].

As a result, Al Reyadah Carbon Capture Company, an Abu Dhabi National Oil Company (ADNOC) and Masdar joint venture has been established and Al Reyadah plant was constructed [47]. All these new technologies can be studied and possibly scaled-down to a size of campus, to check the processes of capturing and compressing the CO2 to make it beneficial to use in other applications rather than harming the environment.

2.9. Challenges and Barriers to IOT

Several barriers were spotted to apply the ubiquitous concept of IOT, and it can be highlighted as per the following:

2.9.1. Sensor Energy. All these IoT devices are connected to sensors, and all these sensors need energy. Thus, these sensors have to be self-sustaining, in order to ensure the continuous autonomous features of IoT [15]. It is not possible to change batteries or recharge billions of devices deployed around the globe and even in the space. It is required for sensors in this case to produce electricity from several sustainable sources such as; vibrations, light, and airflow [48]. As a matter of fact, the American Chemical Society publicized a significant breakthrough for a practical Nano-generator where it utilizes the body movements such as the pinch of a finger to generate electricity at the 241st National Meeting and Exposition of the American Chemical Society in March 2011 [49].

2.9.2. Agreement on Standards. Although a lot of improvement has been made in terms of standards agreements, much more is needed to integrate all these networks together; especially for security, privacy, and architecture. IoT promises a lot of benefits in future, and as a result; people will try to overcome these challenges as soon as possible, since none of these challenges are impossible to solve [15].

2.10. Literature Summary and Outcome

After reviewing multiple publications, researches, white papers, journals, and websites in the fields related to Smart Campuses, a set of applications and criteria for smart campuses can be developed. This section is the final section in literature review where main findings in literature are summarized and presented in Table 3. The framework includes: 8 main criteria and 25 sub-applications that are based on IoT and cloud computing. The designated criteria and their applications will be further studied and assessed by campus stakeholders in Chapter 4: Results and Analysis.

Table 3: Designated Criteria and Applciations in Smart Campus

Criteria	Applications	Reason	Citation
- Internet of Things (IoT) and Cloud Computing Infrastructure	- Provides the infrastructure that supports all other applications and connectivity.	- A trustworthy strong connectivity with data transparency and accessibility from everywhere.	- [1], [2], [3], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [23], [25], [26], [27], [28].
Smart E-Card	- For Attendance (Classrooms, Labs, access to facilities, etc...) - Dorms (All residential activities and administration) - For Library usage (booking, borrowing, registration, printing, etc...0) - E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...) - To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...)	- Quick identification for all transactions, and a personal database. Accessible through cloud.	- [11], [12], [16], [21], [22], [28].
Smart Classrooms	- 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 platform (between classmates & professors, between the Market and the University, between Government and University, etc...) - Collaborative Research (connectivity and communication with several universities, companies, governments for research)	- Enhance the learning quality, more interactive, more collaborative, time efficient, user friendly, sustainable.	- [11], [12], [15], [16], [17], [18], [19], [21], [23], [24], [27], [28].
Energy Management	- Buildings Energy Management System (Monitoring and Automated :Heat & Air Conditioning, Lights, Power Devices) - Sustainable Energy (Solar Power, Sustainable design Buildings, CCS) - Smart Street Lights - House Management System (for residential end users usage) - Energy Trading System (for Electric Vehicles inside parking)	- Better utilization of resources, less cost, more sustainable, monitored and controlled, more data to analyze, better planning.	- [15], [16], [23], [24], [25], [26], [27], [28]. [41], [43], [44], [45], [46], [47], [48], [49].
Adaptive Learning	- Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points)	- Customized, improve weakness points for students, more visibility to class	- [15], [29], [30], [31], [32], [33], [34], [35],

Table 3: Designated Criteria and Applications in Smart Campus,

Criteria	Applications	Reason	Citation
	- Optional Supplementary Courses in specialized fields (Beside Curriculum) - Computerized adaptive testing (CAT) - (Tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, Deep assessment).	performance, accurate testing, supports the students and gives recommendations, optional extra courses, and more data to analyze and improve learning.	[36], [37], [38], [39], [40].
Smart Transportation	- Smart Parking - Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc...) - Intelligent Signage (for Navigation, Broadcasting, etc...) - In-Campus Navigation (Smart Kiosks, Way-Finding for Offices, Room, Facilities, Events, etc...)	- Optimized logistics, Informative, quick notifications, better mobility.	- [12], [23], [24], [25], [26], [27], [28], [41], [42].
Security & Safety	- Smart Safety & Security Systems (Tracking, Surveillance, Evacuation, etc...)	- Protective in advance, root cause analysis, more data.	- [16], [18], [24], [25], [26], [27], [28].
Optimization & Analytics Data Center	- Operations Optimization - Data Storage - Research Center	- Up to date enhancements, Data lakes, Data openness and classification.	- [11], [16], [23], [24], [25], [26], [28].
Smart Facilities Services	- Sports Fields and Centers/Libraries/Restaurants/Student Center/Activities). - Facility Management Smart System. - Private Campus Social Network (Events, Broadcasting, Easy Access to information, etc...)	- Interactive campus life, responsive buildings, quick.	- [11], [17], [23], [24], [25], [26], [27], [28].

Chapter 3 . Methodology

3.1. Introduction

The adopted methodology utilizes a mixed approach which will serve as the benchmark of reliability and validity of this research. This section deliberates over the research design and approach, strategies, and methods used in order to address the research questions and achieving the targeted results. Moreover, data collection and analysis approaches are explained and discussed. The methodology aims at defining the systematic procedure which the research will follow in order to generate new data, and explains the way this data will be analyzed to answer the questions of this research.

3.2. Research Design

This research aims to explore the concept of a smart campus and the underpinning criteria required to achieve it, in addition to assessing the applications of smart campus and their importance from the perception of end users. Moreover, the research discusses the enablers and challenges for promoting smart campus. As per the problem’s underlying nature, an exploratory approach is used. According to Allwright [50], exploratory research is the type of research which aims at better defining a problem which has not been studied thoroughly. The exploratory approach is chosen because this research does not aim at delving into a specific aspect of smart campus, nor is it expanding on previous research in the topic. However, this research aims at identifying smart campus criteria and exploring the feasibility of implementing smart campus applications in the American University of Sharjah. Within the exploratory approach, the vital success aspects will be assessed in addition to the challenges facing the implementation of smart campus applications. Furthermore, the noted aspects and factors will be cross-referenced with the findings in the literature review to assess the enablers and challenges facing the implementation of smart campus in the American University of Sharjah. The exploratory approach aims to answer the following questions:

- What are the underpinning criteria of a smart campus?
- What is the end user’s perception on implementing smart campus applications in the American University of Sharjah?

- What are the most important enablers and challenges facing the implementation of smart campus in the American University of Sharjah?

The research approach adopts a mixed approach, adopting both deductive and inductive methods. Seliger [51] states that deductive research is concerned with forming a hypothesis based on available research, while inductive research is concerned with devising new findings based on newly generated data. As such, the main underpinning criteria for a smart campus will be determined from the literature review using the deductive method. On the other hand, the surveys and interviews will generate new data from which the reality of implementing smart campus applications in the American University of Sharjah, its enablers, and its challenges will be assessed using the inductive method.

3.3. Research Strategy

After assessing the nature of the questions to be answered, the case study strategy was chosen to grasp a real sense of the need of a smart campus in the American University of Sharjah in addition to understanding the current theories and underpinning criteria of a smart campus. The case study is designed to assess susceptibility and acceptance of smart campus real life implementation, while maintaining the international standard of developed criteria found in the literature. Taking all details into consideration, it was assessed that a single case study is sufficient for the research design, as it will allow for the observation of demand and need by stakeholders, determine the enablers and challenges, and pave the way for further future research to be done by experts. The case study shall provide data to establish new connections in the subject matter, as well as determine which practical steps should be taken to achieve the goal of this research.

The American University of Sharjah, an independent non-profit educational institute, which is based in Sharjah, UAE was chosen for this case study in order to conduct intensive study regarding the application of smart campus criteria. This specific institute was chosen because it is considered top-tier in the UAE, and its students, faculty, and staff are mostly knowledgeable about the subject and can provide real feedback related to this research. Moreover, the type of case study which will be considered is an embedded case study. According to Yin [52], an embedded case study is a type of case studies which considers more than one sub-unit inside an organization, and it takes an empirical form best for descriptive and qualitative research. In the case study of the American University of Sharjah, various sub-units will be targeted, such as faculty including professors of different departments, students of different departments, alumni from different backgrounds, and administrative personnel. Focusing on several sub-units in this case study will allow for more breadth and depth in the data which will be acquired, which shall provide more valuable and reliable information for implementation and future research.

3.4. Data Collection Methods

Given the research questions and type of results expected to arrive at, a mixed data collection method was chosen to generate the required data. Data collection is an important aspect of this research, as it mainly focuses on devising new theories based on newly generated data; as such, great importance was given to determining which data collection method is to be utilized. The mixed data collection method includes both qualitative and quantitative methods, which are going to be conducted in parallel. Johnson and Lisa explain that mixed data collection allows for integration of results generated by various data collection methods, which aims at extracting more accurate and holistic results than simpler strategies [53]. The qualitative data collection approach will focus on review of the literature and semi-structured interviews with faculty members. Adjacently, the quantitative data collection approach will focus on questionnaire surveys targeting students and alumni.

3.4.1. Qualitative Data Collection Methods. The research will utilize the available literature about the topic to distinguish points of interest and information related to the research problem. Furthermore, the information derived from the literature will be cross-referenced with the generated data to devise conclusions and results. The literature will also be reviewed to support the interviews and survey by determining the information most relevant to the UAE, which in turn shall allow for better suited questions and inquiries. Finally, the reviewed literature shall pave the way for a better understand of the enablers and challenges of implementing smart campus applications, and the acquired information shall highlight possible risks which shall be given more weight in data collection.

The information collected from the literature review will support the research as well as help understand the data generated for the study. Cooper states that not only does the literature review help understand the topic and identify research niches, but it also serves as a strong tool to understand the data collected in a study [54]. By combining the reviews with the other qualitative methods, the questions will be ameliorated and the quality of data which will be generated will improve significantly. Moreover, reviewing the literature will serve as an additional qualitative method of data collection, which will support the collected data and ensure that data is generated from more than a single source, which in its turn ensures credibility and reliability of the research. Finally, cross-referencing the generated data with the available literature will reduce bias and ensure that findings are consistent with the literature, and if not, it will present information about the reasons of inconsistency.

Semi-structured interviews will be utilized as a qualitative data collection method, which serves to answer pre-determined questions important for the research as well as open-ended questions which may arise after delving into the subject. In the case study, the semi-structured interviews will be held with faculty members in the American University of Sharjah across different departments, and the aim of the interviews will be gaining insights and better understanding on the following questions:

- Do you see the designated criteria and applications are enough to transform a traditional campus to a Smart Campus?
- What other applications would you love to see applied in this Campus? Or what other criteria can be added to the designated criteria?
- What are the most important enablers and challenges facing the implementation of smart campus in the American University of Sharjah?

The main goal of the interviews is to expand the perspective of the research, generate more information about the topic, and improve the existing knowledge and details derived from the literature. In addition, a special interview will be conducted with the IT director in AUS to further validate the criteria, results, smart framework, and to hear his recommendations regarding the topic. As elaborated by Alshenqeeti, interviews generate expert data which serves to improve research quality and build on the existing knowledge of the research [55]. Semi-structured interviews were specifically chosen due to its flexibility and ability to enhance and better define research questions, ability to integrate new information into research, and confirm information derived from the literature review. Semi-structured interviews are preferred over structured and open-ended interviews because they allow for systematic data collection, while maintaining a degree of flexibility to expand on the topic. Furthermore, the interviews were made with faculty members of the American University of Sharjah; hence, their insights are of great value to determine realistic enablers and challenges in the way of implementing smart campus applications. The details of interview questions are included in Appendix A.

3.4.2. Quantitative Data Collection Methods. The research will use the data generated from a questionnaire conducted in the American University of Sharjah as a quantitative data collection method. Although information was already collected from the literature review, the reviewed studies were conducted under different conditions and encompassed a different scope; hence, additional information and data is required to adjust their impact as per the scope of this research. Qualitative data collection will be used to accumulate data on the research topic and couple it with the qualitative data to derive conclusions. The scope of the questionnaire is to:

- Determine the awareness of American University of Sharjah stakeholders about smart campus applications.
- Evaluate smart campus applications from the point of view of American University of Sharjah stakeholders.

The design of the questionnaire considered three main concepts: demographic details, which includes student's academic level, department of study, gender, and place of stay; awareness about smart campus applications, in which stakeholders' familiarity with and understanding of smart campus application is assessed; and smart campus application's evaluation, in which subjects express their personal evaluation of smart campus applications in the American University of Sharjah. For accuracy of data collection, the questionnaires will be handed out only in electronic form. Consequently, after collecting the data, all responses will be quantitatively analyzed using Relative Importance Index (RII), which will determine the relative importance of each smart campus criteria pre-defined in the literature review. The details of the handed-out questionnaire includes: demographic questions, smart campus awareness, and evaluation of smart campus applications by respondents.

3.4.2.1. *Demographic Details.* The aim of this section is to gather personal information about the unit taking the questionnaire. By doing so, the generated data will be more categorized and defined, which will reduce any bias in that area.

The questionnaire shall include details about student's academic level, department of study, gender, and place of stay; awareness about smart campus applications; as such, this information will allow drawing correlations related to smart campus applications as related to specific demographic factors (i.e. student is staying in American University of Sharjah dorms or not.).

3.4.2.2. ***Awareness about Smart Campus Applications.*** The aim of this section is to gather information about the units' awareness about smart campus application, and how such awareness might reflect on their evaluation of such applications. This information is of great importance, as trends will be noticed regarding the relationship between awareness and evaluation. For example, one of the challenges for the implementation of smart campus application might arise from lack of awareness, where if more awareness is raised, more units would rate with a higher value, and vice versa.

3.4.2.3. ***Smart Campus Applications Evaluation by Students.*** The aim of this section is to understand how important each criterion of a smart campus is to the units in the American University of Sharjah. This section's importance lies in the question: if not all smart campus applications can be implemented, then which of them shall be? Each unit will evaluate each criterion in order to properly evaluate the relative importance of each. By doing so, a clear action map can be devised to achieve the intended result of a smart campus.

3.4.3. Units of the Study. The targeted units for the case study are the students and faculty of the American University of Sharjah. The American University of Sharjah is an independent non-profit educational institution of higher education located in Sharjah, UAE. The institute was founded in 1997 by His Highness Sheikh Dr. Sultan bin Muhammad Al-Qasimi, Supreme Council Member and Ruler of Sharjah [56]. Since its founding, it has spiraled into being one of the leading educational institutes in the Middle East, with more than 5,000 students from 94 different nationalities at the time of this research [56]. Given the prestigious position of the American University of Sharjah, it was chosen to be the center of this research, and naturally the case study is conducted on its stakeholders.

Given the nature of this research, and since it is a single case study within and for the American University of Sharjah, the sampling strategy revolved around gathering units across different departments and from different academic levels. The only factor the research had control over was the demographic factor; hence, the units were randomized to achieve a consistent sample to eradicate any bias caused by demographics.

The sample size for the interviews is four, as four interviews were conducted with American University of Sharjah professors, which are experts in departments related to smart campus applications. The three main departments which were targeted are:

- Civil engineering department professor
- Computer science department professor
- Two Industrial engineering department professors
- The departments were chosen due to the tied links between their expertise and that of smart campus applications, since they are the main expertise required to achieve a holistic vision of a smart campus.

The main aim of the interviews is to answer the question: What are the most important enablers and challenges facing the implementation of smart campus in the American University of Sharjah?

Participants of different demographics will be randomly selected to answer questions about their awareness of smart campus applications and how much they value them. The minimum number of respondents required to achieve accurate results using RII is 100, so the sample size must exceed 100 to deem sufficient. The questionnaire aims to answer the research question: What is the end users' perception of implementing smart campus applications in the American University of Sharjah?

3.5 Data Analysis

The data generated from the case study will be analyzed using Relative Importance Index (RII), which is a framework used to determine the importance of each criterion as compared to the maximum importance it can achieve.

$$\textbf{Relative Importance Index} = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Figure 14: Relative Importance Index Equation

Accoring to Raigor et al. [57], the relative importance index is a powerful tool to understand how important a point is relative to your units of study. Figure 14 shows the RII equation, where *w* is the weight given to a specific factor by a unit, which can be from 1 to 5. Moreover, consider *n1*: number of units which valued the factor as not important, *n2*: number of units which valued the factor as slightly important, *n3*: number of units which valued the factor as moderately important, *n4*: number of units which valued the factor as very important, *n5*: number of units which valued the factor as extremely important. In the equation, A is utmost value of importance that can be given to a factor (in this study it is 5) and N is the number of units who responded to the questionnaire. In this case, the number of units in each category of importance is multiplied by the respective value (1 to 5) assigned to the level of impotance. Finally, the sum is divided by the maximum importance that can be given to a factor (total number of respondents multiplied by 5) to arrive a value between 0 and 1, 0 meaning not important al all, and 1 meaning extremely important.

By assigning an RII to each criterion, the level of importance of each criterion will be determined, and they can be categorized as per their importance. Such findings shall facilitate any future research or practical measures related to smart campus applications in the American Univesity of Sharjah.

Chapter 4 . Data Analysis and Results

4.1. Introduction

In this section, we will analyze and present the results obtained from surveys and interviews to the main stakeholders inside the AUS campus. The research data was obtained through conducting two surveys that consists of 22 questions for each, and 5 interviews with professors from college of engineering and the IT Director in the AUS campus. As for the two surveys, one was dedicated to current students and alumni, while the other one was targeting professors and faculties in the same campus. The aim was to gather 100 responses from students and alumni, however; 144 responses were collected from the first survey. On the other hand, for the professors and faculties' survey only 5 responses were collected. Finally, the interview's main concentration was to further explore the challenges and enablers for promoting smart campus inside AUS specifically by interviewing several professors who are familiar with the smart cities topic.

4.2. Smart Campus Student Survey – AUS

The sample size for the questionnaires is 144. Participants of different demographics were randomly selected to answer questions about their awareness of smart campus applications and how much they value them. Students and alumni from AUS were requested to take the survey as a part of this research. The questionnaire consists of 22 questions that aim to study the demographics of participants, their understanding of smart campus, and their perception and rating of smart applications.

4.2.1. Demographic analysis. As for the demographic analysis, 4 questions were dedicated to study the respondents' demographics. These questions are:

1) Which Study Program are you enrolled in? (Bachelor, Masters, PhD, or Alumni)
2) In Which School/College are you studying (or studied)?
3) Do you Live in Campus or used to Live in Campus?
4) What gender do you identify as?

4.2.1.1. ***Question 1: Which Study Program are you enrolled in?*** For the first question, 49.65% of the respondents were from the Bachelor program with total of 71 respondents, 19.58% were from the Master's program with total of 28 respondents, zero responses from PhD students, and 44 respondents were AUS Alumni contributing to 30.77% of the responses as shown in Figure 15.

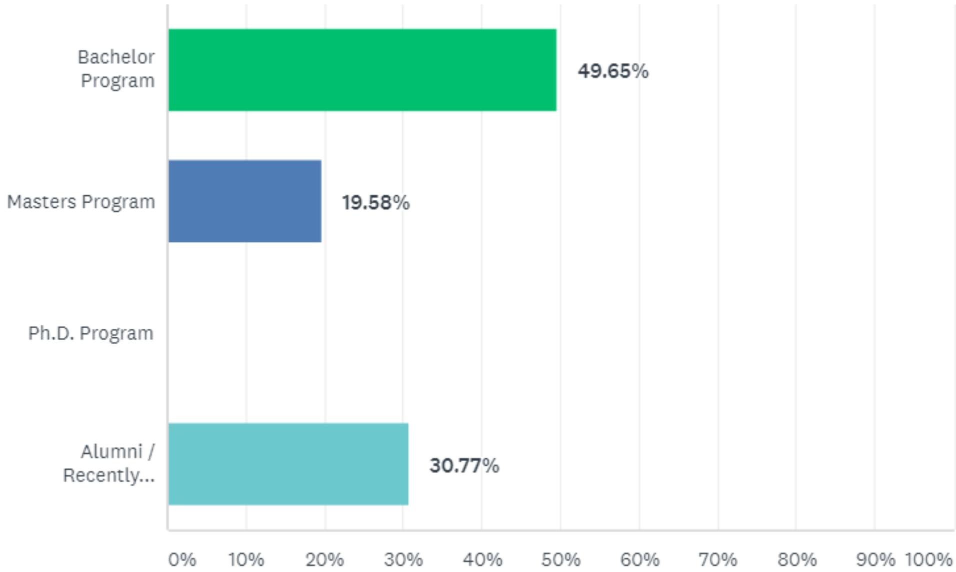


Figure 15: : Respondents educational background

4.2.1.2. *Question 2: In Which School/College are you studying (or studied)?*

Secondly, the 2nd question targets the respondent's' specific studying majors to give more depth of the analysis. 98 respondents were from the College of Engineering, 15 respondents were from College of Arts and Sciences, 19 respondents from School of Business Administration, and 10 respondents from college of Architecture, Art, and Design. The results can be illustrated in Figure 16 below.

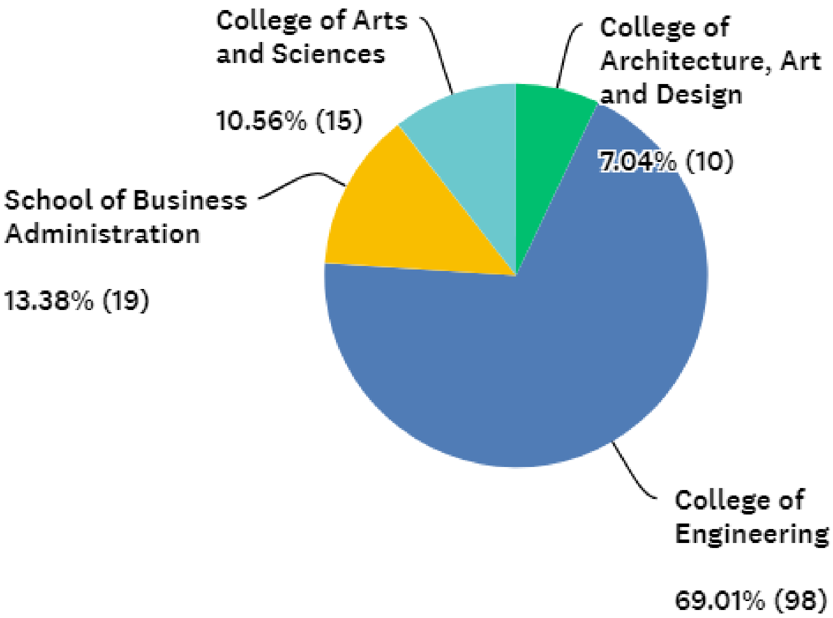


Figure 16: Respondants Studying majors

4.2.1.3. *Question 3: Do you live in Campus or Used to Live in Campus?*

Thirdly, a balanced results were obtained in terms of campus residency where 71 respondents stated that they live in campus, while 73 respondents said they don't or didn't live in campus as per Figure 17.

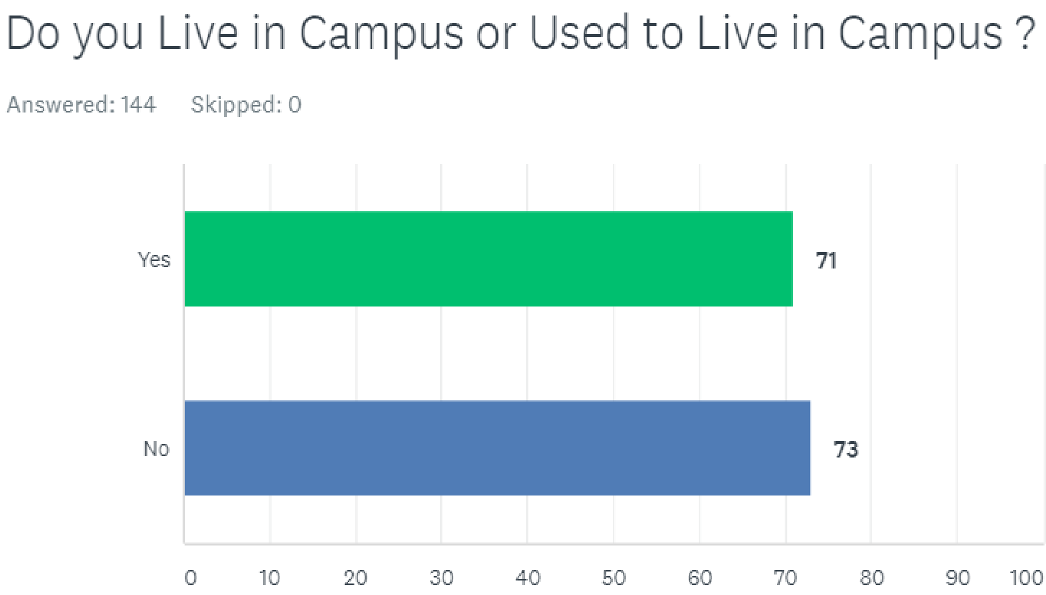


Figure 17: Respondents' Campus Residency

4.2.1.4. ***Question 4: What Gender do you identify as?*** Finally, the 4th question displays genders' identities for the 144 respondents where 82 were females and 62 were males as per Figure 18.

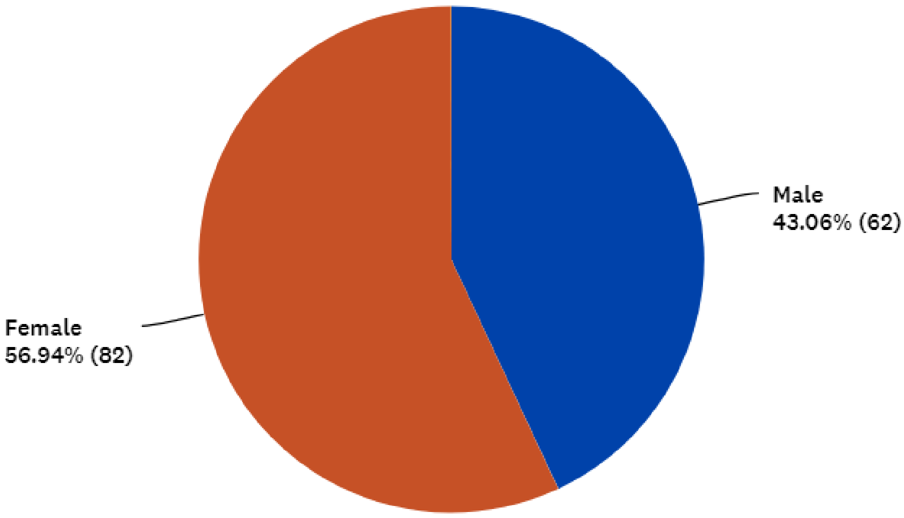


Figure 18: Respondents Gender Identities

4.2.2. Background analysis. This section will show the respondents awareness about smart campus, with three questions, one multiple choice question, one rating question, and one option to write the first thing they think about when hearing the word ‘Smart Campus’. The three questions are as the following:

- How familiar are you with the term “Smart Campus”? (Multiple choice)
- What do you think of when you hear the word “Smart Campus”? (Write)
- In your opinion, how Smart is AUS Campus? (Rating 0 to 100)

These three questions will help to get an understanding of the respondents’ awareness regarding smart campus and their opinion in AUS current campus.

4.2.2.1. ***Question 5: How familiar are you with the term “Smart Campus”?***

As for the first question, How Familiar are you with the term “Smart Campus”? The respondents clearly shows their lack of deep understanding to the term Smart Campus. Only 4 and 10 respondents said that they are extremely familiar or very familiar with the term smart campus respectively. On the other hand, 49 respondents stated that they are somewhat familiar, another 45 said they are not so familiar, and 36 respondents clearly said they are not familiar at all with the term. Table 4 and Figure 19 illustrates the responses on this question.

Table 4: Respondent’s Familiarity with the term Smart Campus

ANSWER CHOICES	RESPONSES	
Extremely familiar	2.78%	4
Very familiar	6.94%	10
Somewhat familiar	34.03%	49
Not so familiar	31.25%	45
Not at all familiar	25.00%	36
TOTAL		144

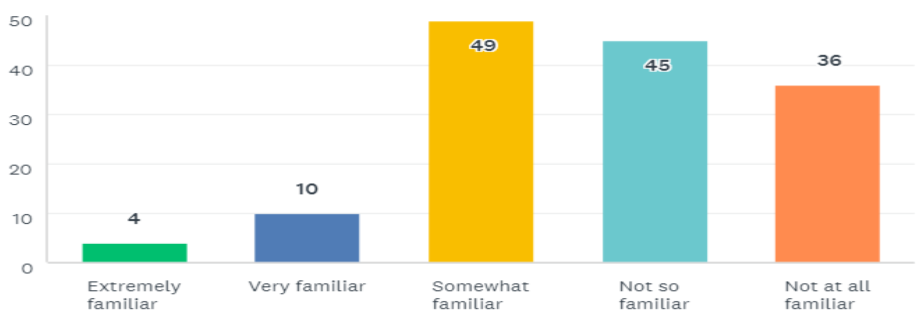


Figure 19: Respondent’s Familiarity with the term Smart Campus

4.2.2.2. ***Question 6: What do you think of when you hear the word "Smart Campus"?*** In this questions, the respondents were asked to write the first thing they have in mind when they hear the word 'Smart Campus'. Their answers were recorded before them getting exposed to the survey content or any of the smart applications or smart criteria mentioned in the survey. This question collected 138 responses, and the answers were mostly around E-learning, advanced technology and connectivity, E-gates, and a holistic mobile application.

Many of these responses show a respectful amount of understanding of smart campus since their responses included the words: connectivity, intelligent solutions, easier/faster interactions, using technologies to enhance the campus experience, paperless, AI, machine learning, data collection, smart transportation, IoT, automation, interactive maps, remote classes, artificial intelligence, etc… However, the words with most occurrences among respondents will be reviewed here to show the tendency of most responses to this question. The words in large size represents the most occurring words in the responses, while the small sized words are the least occurring as per Figure 20.

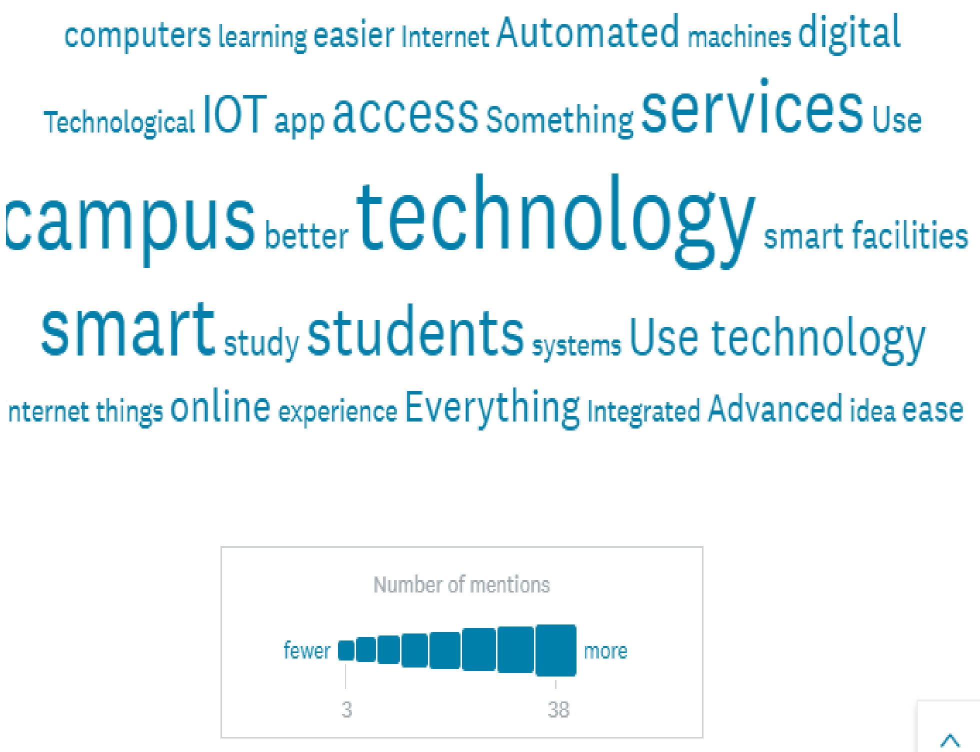


Figure 20: Respondents thoughts on Smart Campus

4.2.2.3. *Question 7: In your opinion, How Smart is AUS Campus?*

In this question, students were requested to use an online slider that ranges between 0 and 100 to give a rating to the current AUS campus in terms of smart features. The results shows an average of 34.62% for the respondents' ratings. In addition, the highest rating value was 93% and the lowest recorded was 0%. The 93% value can be considered as an outlier since no other rating was recorded within that range from other respondents. Additionally, some basic statistics regarding the respondents' answers are shown inside Table 5.

Table 5: Basic Statistics on Question 7 answers.

BASIC STATISTICS

MINIMUM	MAXIMUM	MEDIAN	MEAN	STANDARD DEVIATION
0.00	93.00	35.00	34.62	21.38

4.2.3. Relative Importance Index (RII) analysis.

There were 9 designated criteria for a smart campus as mentioned in section 2.10 Literature Outcome in chapter 2. Each of the designated criteria has its own applications. Therefore, this section will perform the Relative Importance Index (RII) analysis for the 25 designated applications from the perspective of AUS campus end users. To conduct this analysis, the 25 applications were demonstrated inside the survey through six main questions. Questions 8 to 13 are the six questions that allow respondents to give ratings for each of the designated applications, with weights varying from 5 for (Extremely Important) and 1 to (Not Important at All). The 5 ratings options were as per the following (Extremely Important, Very Important, Moderately Important, Slightly Important, and Not Important at All). The responses for each question will be collected and analyzed separately, then all in all, the six questions responses will be added jointly in a group table to show the rankings for the 25 applications in terms of RII for campus end users.

4.2.3.1. *Question 8: Rate the importance of each of the following application (for Smart Card) in a smart campus.*

The respondents had to rate the following applications with the 5 points weight rating method (Extremely Important to Not Important at All) as described previously. Where each application will be given a weight based on the respondent's opinion and preferences to the application. The applications were as follows:

- For Attendance (Classrooms, Labs, access to facilities, etc...)

- For Dorms (All residential activities and administration).
- For Library usage (booking, borrowing, registration, printing, etc...)
- E-Wallet (Payments for everything in campus: Registrar, administration, cashier, restaurants, financial holds, fees, etc...)
- To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...).

The answers and results of this questions are illustrated in Figure 21.

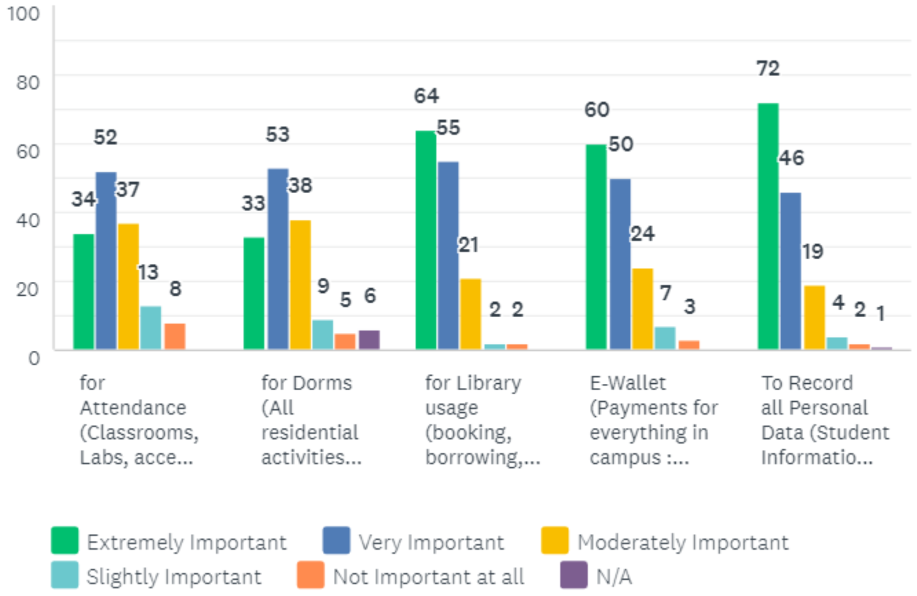


Figure 21: Question 8 Responses -Rate the importance of each of the following applications (for Smart Card) in a smart campus.

Subsequently, the results were extracted to Microsoft Excel in order to calculate the RII for each application and present it in Tables 6, 7 and Figure 22.

Table 6: RII Calculations for Question 8

		Number of Responses / Ranking					
Criteria	Values or Weight for each response -->	5	4	3	2	1	
	Application	Extremely Important	Very Important	Moderately Important	Slightly Important	Not Important at all	RII
Smart Card	For Attendance (Classrooms, Labs, access to facilities, etc...)	34	52	37	13	8	0.72639
	Dorms (All residential activities and administration)	33	53	38	9	5	0.74493
	For Library usage (booking, borrowing, registration, printing, etc...0)	64	55	21	2	2	0.84583
	E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...)	60	50	24	7	3	0.81806
	To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...)	72	46	19	4	2	0.85455

Thereafter, the RII results were organized from highest to lowest and presented in Table 7. Additional representation with bar charts is illustrated in Figure 22.

Table 7: RII Results organized for Question 8

Application	RII
To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...)	0.8545455
For Library usage (booking, borrowing, registration, printing, etc...)	0.8458333
E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...)	0.8180556
Dorms (All residential activities and administration)	0.7449275
For Attendance (Classrooms, Labs, access to facilities, etc...)	0.7263889

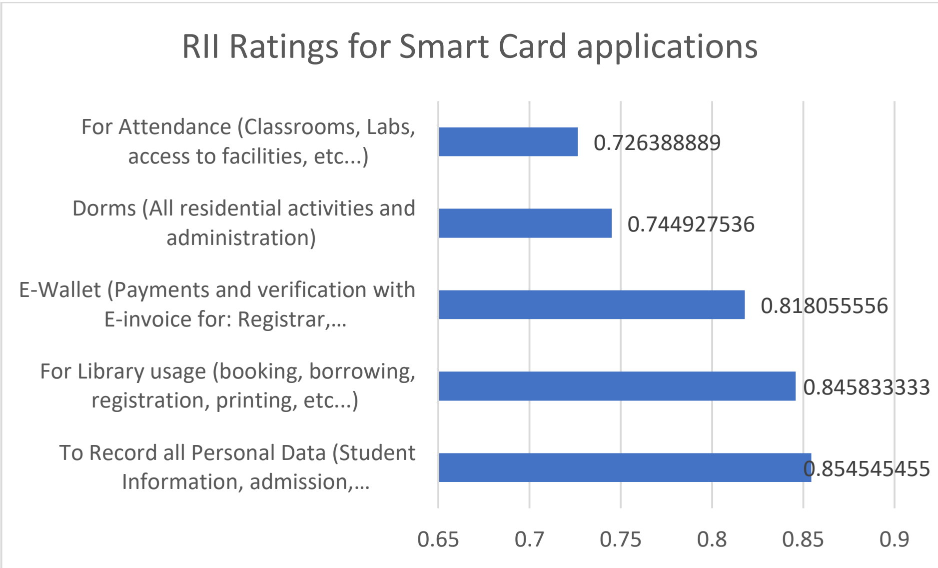


Figure 22: RII Values for Question 8

To condlude question 8 results, the highest RII value for Smart Card applications was for Recording all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...) with a value of 0.854546. Then, the respondants' answers gave the second place for Library usage (booking, borrowing, registration, printing, etc...) with an RII value of 0.84583. Thirdly, E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...) had an RII value of 0.818056. Finally, In the 4th places and 5th place were given to Dorms (All residential activities and administration), and For Attendance (Classrooms, Labs, access to facilities, etc...) respectively, with values of 0.7449278 and 0.726389 as well.

4.2.3.2. ***Question 9: Rate the importance of each of the following applications (for Smart Classroom) in a smart campus.*** Similar to Question 8, this question targets another 4 applications that can be applied in classrooms. The 4 applications that respondents were asked to rate are as follows:

- 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 platform (between classmates & professors, between the Market and the University, between Government and University, etc...).
- Collaborative Research (connectivity and communication with several universities, companies, governments for research)

The answers and results of this questions are illustrated in Figure 23. Afterwards, the results were extracted to Microsoft Excel in order to calculate the RII for each application as shown in Table 8. The data extracted from Figure 23 is used to calculate the RII values of these applications as shown in Table 8.

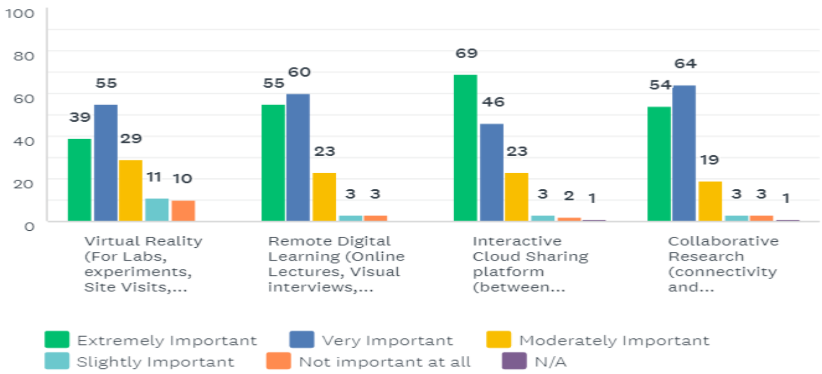


Figure 23: Question 9 Responses -Rate the importance of each of Smart Classroom applciations

Table 8: RII Calculations for Question 9

Criteria	Values or Weight for each response -->	5	4	3	2	1	RII
		Number of Responses / Ranking					
	Application	Extremely Important	Very Important	Moderately Important	Slightly Important	Not Important at all	
Smart Classrooms	Virtual Reality (For Labs, experiments, Site Visits, Simulations, etc..)	39	55	29	11	10	0.74167
	Remote Digital Learning (Online Lectures, Visual interviews,Cloud Storage, online access to all course information and lectures, etc..)	55	60	23	3	3	0.82361
	Interactive Cloud Sharing platform (between classmates & professors, between the Market and the University, between Government and University, etc..)	69	46	23	3	2	0.84755
	Collaborative Research (connectivity and communication with several universities, companies, governments for research)	54	64	19	3	3	0.82797

After that, the RII results were organized from highest to lowest and presented in Table 9. Additional representation with bar charts is demonstrated in figure 24.

Table 9: RII Results organized for Question 9

Application	RII
Interactive Cloud Sharing platform (between classmates & professors, the Market & the University, between Government & University, etc...)	0.847552
Collaborative Research (connectivity and communication with several universities, companies, governments for research)	0.82797
Remote Digital Learning (Online Lectures, Visual interviews, Cloud Storage, online access to all course information and lectures, etc..)	0.823611
Virtual Reality (For Labs, experiments, Site Visits, Simulations, etc...)	0.741666

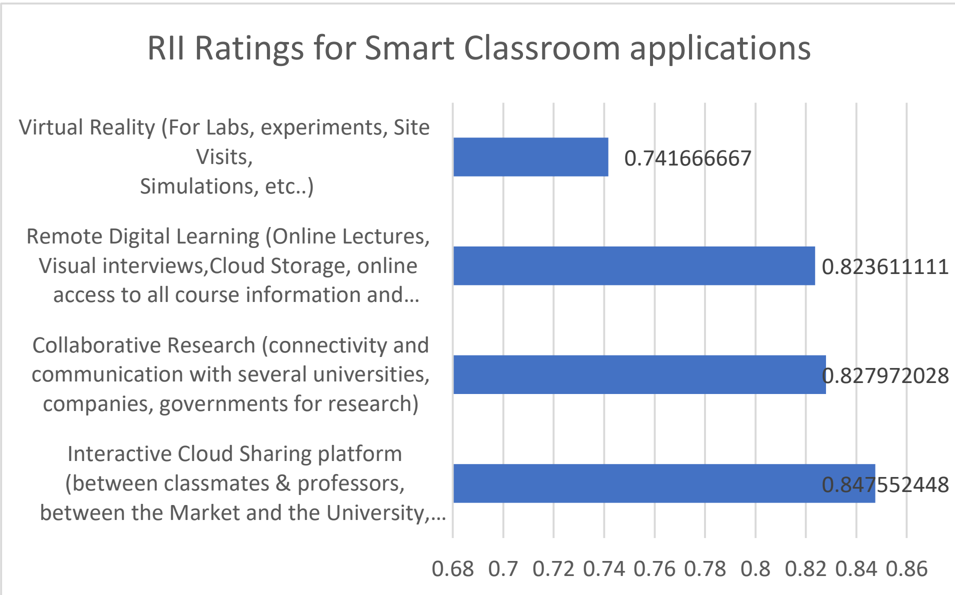


Figure 24: RII Values for Question 9

To conclude, question 9 results show the highest RII value for Smart Classrooms applications given to Interactive Cloud Sharing platform (between classmates & professors, between the Market and the University, between Government and University, etc...) with a value of 0.847552448. Then, the second place was for Collaborative Research (connectivity and communication with several universities, companies, governments for research) with an RII value of 0.827972. Thirdly, Remote Digital Learning (Online Lectures, Visual interviews, Cloud Storage, online access to all course information and lectures, etc..) had an RII value of 0.823611. Finally, the 4th place was for Virtual Reality (For Labs, experiments, Site Visits, Simulations, etc...) with a value of 0.7416667.

4.2.3.3. *Question 10: Rate the importance of each of the following applications (for Energy Management) in a smart campus.* Similar to question 8 and 9, the respondents were asked to rate some selected applications in the field of energy management for a smart campus. The applications in this question are as follows:

- Buildings Energy Management System (Monitoring and Automated: Heat & Air Conditioning, Lights, and Power Devices).
- Sustainable Energy (Solar Power, Sustainable design Buildings, CCS)
- Smart Street Lights.
- House Management System (for residential end users usage).
- Energy Trading System (for Electric Vehicles inside parking).

The answers and results of this questions are presented in Figure 25.

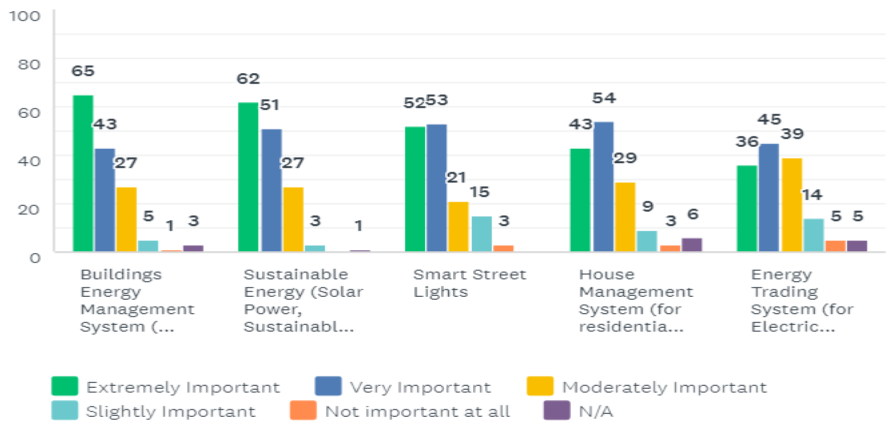


Figure 25: Question 10 Responses -Rate the importance of each of Energy Management applciation.

The data and weights were extracted from the survey results to Microsoft Excel in order to calculate the RII for each application as shown in Table 10.

Table 10: Answers to Question 10

		Number of Responses / Ranking					
Criteria	Values or Weight for each response -->	5	4	3	2	1	
Smart Energy Management System	Application	Extremely Important	Very Important	Moderately Important	Slightly Important	Not Important at all	RII
	Buildings Energy Management System (Monitoring and Automated :Heat & Air Conditioning, Lights, Power Devices)	65	43	27	5	1	0.8355
	Sustainable Energy (Solar Power, Sustainable design Buildings, Carbon Capture Storage)	62	51	27	3	0	0.8406
	Smart Street Lights	52	53	21	15	3	0.7889
	House Management System (for residential end users usage)	43	54	29	9	3	0.7812
	Energy Trading System (for Electric Vehicles inside parking)	36	45	39	14	5	0.7338

Consequently, the next step was to organize the RII results from highest to lowest and present it in Table 11 and Figure 26.

Table 11: RII Results organized for Question 10

Application	RII
Sustainable Energy (Solar Power, Sustainable design Buildings, Carbon Capture Storage)	0.8405594
Buildings Energy Management System (Monitoring and Automated :Heat & Air Conditioning, Lights, Power Devices)	0.835461
Smart Street Lights	0.7888889
House Management System (for residential end users usage)	0.7811594
Energy Trading System (for Electric Vehicles inside parking)	0.7338129

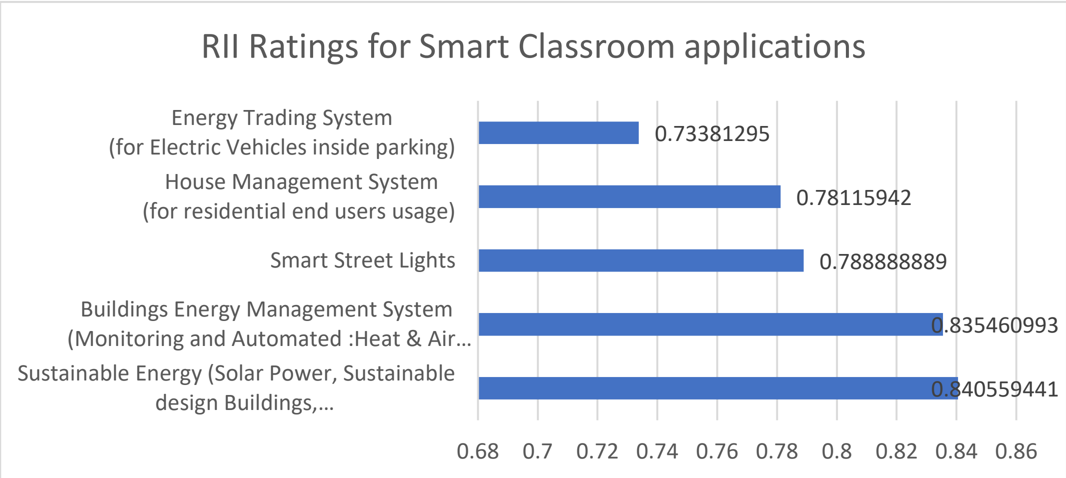


Figure 26: RII values for Question 10

To conclude, question 10 allowed end users to assess the importance of energy management applciations inside the campus. The results show the highest RII value given to Sustainable Energy (Solar Power, Sustainable design Buildings, Carbon Capture Storage) with a value of 0.840559441. Then, the second highest RII rating was for Buildings Energy Management System (Monitoring and Automated :Heat & Air Conditioning, Lights, Power Devices) with an RII value of 0.835460993. In the third place, Smart Street Lights had an RII value of 0.78888889. Finally, the 4th place was for House Management System (for residential end users usage) with a RII value of 0.78115942, and the 5th place was for Energy Trading System (for Electric Vehicles inside parking) with a RII value of 0.73381295.

4.2.3.4. *Question 11: Rate the importance of each of the following applications (for Adaptive Learning) in a smart campus.* For this question, three main applications were designated as Sub-applications for the adaptive learning criteria. Thus, the respondents were requested to assess these three applications in terms of importance to end users. These applications can be summarized in three bullet points:

- Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points).
- Optional Supplementary Courses in specialized fields (Beside Curriculum).
- Computerized adaptive testing (CAT) - (Tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, Deep assessment).

Accordingly, the results obtained from the survey were presented as per Figure 27.

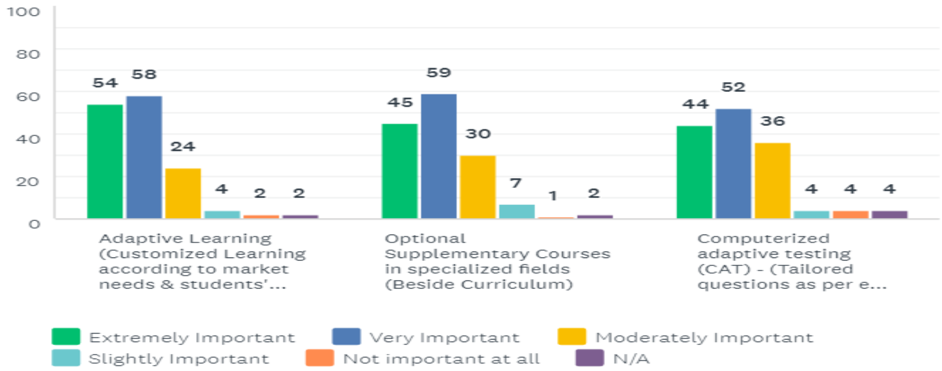


Figure 27: Question 11 Responses -Rate the importance of each of Adaptive Learning application.

All responses were then gathered and organized in Microsoft Excel in order to calculate the RII for each application as shown in Table 12.

Table 12: RII Calculations for Question 11

		Number of Responses / Ranking					
Criteria	Values or Weight for each response -->	5	4	3	2	1	RII
	Application	Extremely Important	Very Important	Moderately Important	Slightly Important	Not Important at all	
Adaptive Learning	Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points)	54	58	24	4	2	0.822535
	Optional Supplementary Courses in specialized fields (Beside Curriculum)	45	59	30	7	1	0.797183
	Computerized adaptive testing (CAT) (Tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, Deep assessment).	44	52	36	4	4	0.782857

As a result, the RII results were organized from highest to lowest and presented in Table 13 and Figure 28.

Table 13: RII Results organized for Question 11

Application	RII
Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points)	0.822535
Optional Supplementary Courses in specialized fields (Beside Curriculum)	0.797183
Computerized adaptive testing (CAT) (Tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, Deep assessment).	0.782857

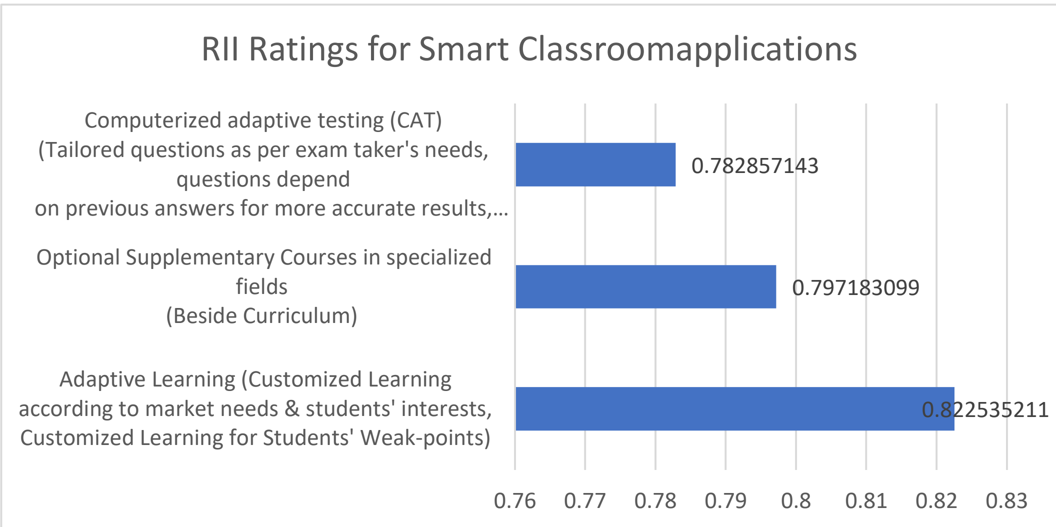


Figure 28: RII Values for Question 11

To conclude question 11, end users were requested to assess the Adaptive Learning applications in terms of their importance to end users. After converting the responses to RII values, the highest RII value was for Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points) with a value of 0.822535211. After that, the second highest RII rating was for Optional Supplementary Courses in specialized fields (Beside Curriculum) with a RII value of 0.797183099. Finally, the 3rd place was for Computerized adaptive testing (CAT) (Tailored questions as per exam taker's needs, questions depend on previous answers for more accurate results, Deep assessment) with a RII value of 0.782857143.

4.2.3.5. ***Question 12: Rate the importance of each of the following applications (for Smart Transportation) in a smart campus.*** Similar to previous questions, the responses were collected in order to assess importance of Smart Transportation applications form the perception of campus stakeholders. The applications mentioned in the survey were as per the following:

- Smart Parking.
- Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc...).
- Intelligent Signage (for Navigation, Broadcasting, etc...).
- In-Campus Navigation (Smart Kiosks, Way-Finding for Offices, Room, Mobile App, Facilities, Events, etc...).

Similarly, the results obtained from survey response are presented in Figure 29.

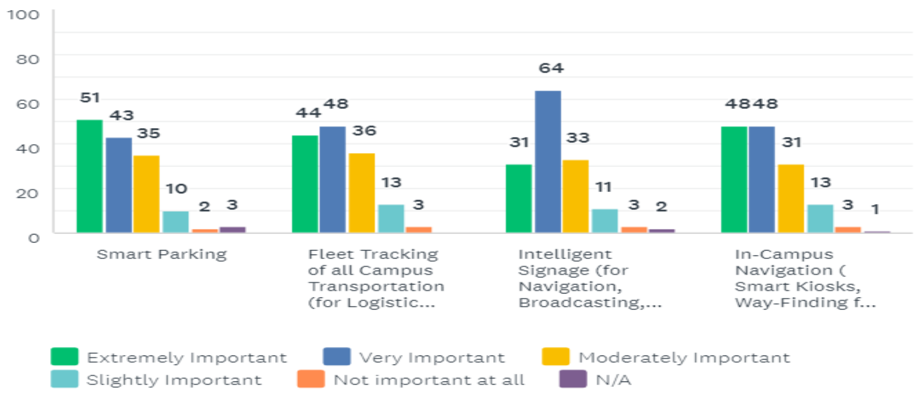


Figure 29 : Question 12 Responses -Rate the importance of each of Smart Transportation applciation

After that, all responses were imported to Microsoft Excel in order to do the RII calculations as shown in Table 14.

Table 14: RII Calculations for Question 12

		Number of Responses / Ranking					
Criteria	Values or Weight for each response -->	5	4	3	2	1	RII
	Application	Extremely Important	Very Important	Moderately Important	Slightly Important	Not Important at all	
Smart Transportation	Smart Parking	51	43	35	10	2	0.78582
	Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc..)	44	48	36	13	3	0.7625
	Intelligent Signage (for Navigation, Broadcasting, etc..)	31	64	33	11	3	0.75352
	In-Campus Navigation (Smart Kiosks, Way-Finding for Offices, Room, Facilities, Events, etc..)	48	48	31	13	3	0.77483

Finally, the applications were sorted from greatest to lowest RII values as shown in Table 15 and Figure 30.

Table 15: Organized RII values for Question 12

Application	RII
Smart Parking	0.7858156
In-Campus Navigation (Smart Kiosks, Way-Finding for offices, Room, Facilities, Events, etc...)	0.77482517
Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc...)	0.7625
Intelligent Signage (for Navigation, Broadcasting, etc...)	0.75352113

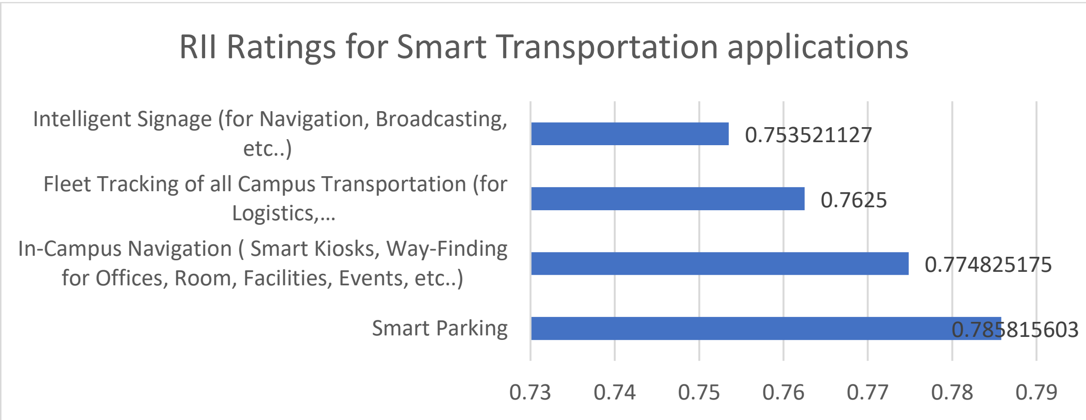


Figure 30: Figure 30: RII Values for Question 12

To conclude question 12, end users were requested to evaluate the Smart Transportation applications according to it's importance to them. After converting the responses to RII values, the highest RII value was for Smart Parking with a value of 0. 7858156. After that, the second highest RII rating was for In-Campus Navigation (Smart Kiosks, Way-Finding for Offices, Room, Facilities, Events, etc...) with a RII value of 0. 77482517. In the third place, Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc...) had an RII value of 0. 7625. Finally, the 4th place was for Intelligent Signage (for Navigation, Broadcasting, etc...) with a RII value of 0. 75352113.

4.2.3.6. *Question 13: Rate the importance of each of the following applications (for Smart Security, Data Centers, Facilities & Social) in a smart campus.* The following question requested the respondents to evaluate applications from 3 different criteria that are: Security & Safety, Optimization & Analytics Data Center, and Smart Facilities Services. The applications in this question are as per the following:

- Smart Safety & Security Systems (Tracking, Surveillance, Evacuation, etc...).
- Optimization & Analytics Data Center (Operations, Data Storage, Research Center, etc...).
- Smart Facilities Services (Sports Fields and Centers/Libraries/Restaurants/Student Center/Activities).
- Private Campus Social Network (Events, Broadcasting, Easy Access to information, etc...).

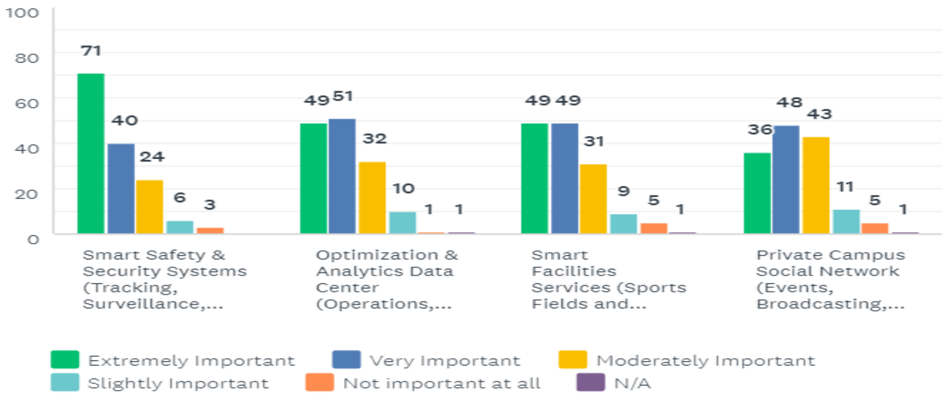


Figure 31: Question 13 Responses -Rate the importance of each of the following applications (for Security, Data Centers, and Facilities & Social) in a smart campus.

Afterwards, responses of question 13 were imported to Microsoft Excel in order to do the RII calculations as shown in Table 16.

Table 16: RII Calculations for Question 13

		Number of Responses / Ranking					
Criteria	Values or Weight for each response -->	5	4	3	2	1	RII
	Application	Extremely Important	Very Important	Moderately Important	Slightly Important	Not Important at all	
Smart Security, Data Analytics, Smart facilities and social network	Smart Safety & Security Systems (Tracking, Surveillance, evacuation etc..)	71	40	24	6	3	0.83611
	Optimization & Analytics Data Center (Operations, Data Storage, Research Center, etc...)	49	51	32	10	1	0.79161
	Smart Facilities Services (Sports Fields and Centers/Libraries/Restaurants/Student Center/Activities)	49	49	31	9	5	0.77902
	Private Campus Social Network (Events, Broadcasting, Easy Access to information, etc..)	36	48	43	11	5	0.73846

In the end, the applications ranks were sorted from greatest to lowest based on RII values as shown in Table 16 and Figure 31

Table 17: Organized RII values for Question 13

Application	RII
Smart Safety & Security Systems (Tracking, Surveillance, evacuation etc...)	0.8361111
Optimization & Analytics Data Center (Operations, Data Storage, Research Center, etc...)	0.7916084
Smart Facilities Services (Sports Fields and Centers/Libraries/Restaurants/Student center/Activities)	0.779021
Private Campus Social Network (Events, Broadcasting, Easy Access to information, etc...)	0.7384615

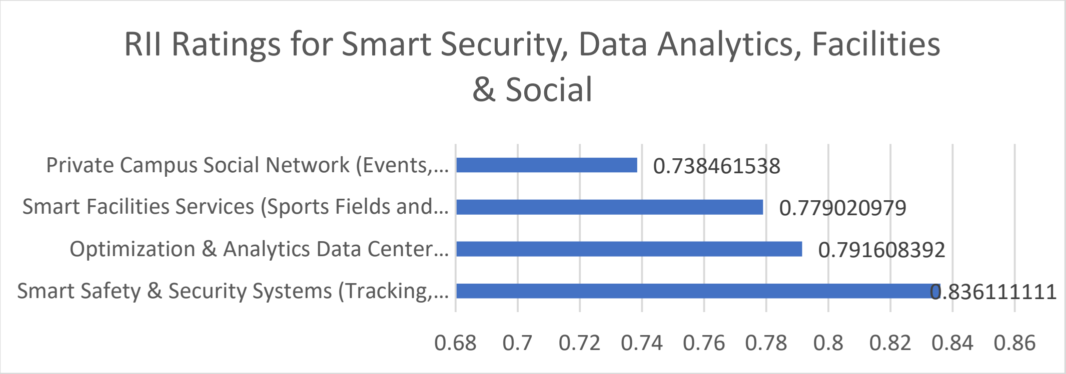


Figure 32: RII values for Question 13

Question 13 was the last question for the RII analysis. Similar to previous questions, end users were supposed to evaluate the Smart Security, Data Centers, and Facilities & Social applications based on their perception and importance point of view. After conducting the RII analysis for this question, the highest RII value was for Smart Safety & Security Systems (Tracking, Surveillance, evacuation etc...) with a value of 0. 8361111. Secondly, the 2nd highest RII rating was Optimization & Analytics Data Center (Operations, Data Storage, Research Center, etc...) with a RII value of 0. 791608. In the third place, Smart Facilities Services (Sports Fields and Centers/Libraries/Restaurants/Student Center/Activities) had an RII value of 0. 77902. Finally, the Private Campus Social Network (Events, Broadcasting, Easy Access to information, etc...) with a RII value of 0.738461538.

4.2.3.6. *Summary of RII Results.* This sections combines the RII values of all applications from questions 8 to 13 from the student's smart campus survey. All applications were sorted in a descended manner from highest RII values to the lowest as shown in Table 18. According to Akadiri [58] five important levels are transformed from RII values: 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) ($0 \leq RI \leq 0.2$). Accordingly, these ranks will be presented in Table 18.

Table 18: RII values for All Applications.

#	Criteria	Application	RII	Imp. Level
1	Smart Card	To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...)	0.8545	H
2	Smart Classroom	Interactive Cloud Sharing platform (between classmates & professors, between the Market and the University, between Government and University, etc...)	0.8476	H
3	Smart Card	For Library usage (booking, borrowing, registration, printing, etc...)	0.8458	H
4	Smart Energy Management System	Sustainable Energy (Solar Power, Sustainable design Buildings, Carbon Capture Storage)	0.8406	H

#	Criteria	Application	RII	Imp. Level
5	Smart Safety & Security	Smart Safety & Security Systems (Tracking, Surveillance, evacuation etc...)	0.8361	H
6	Smart Energy Management System	Buildings Energy Management System (Monitoring and Automated :Heat & Air Conditioning, Lights, Power Devices)	0.8355	H
7	Smart Classroom	Collaborative Research (connectivity and communication with several universities, companies, governments or research)	0.8280	H
8	Smart Classroom	Remote Digital Learning (Online Lectures, Visual interviews, Cloud Storage, online access to all course information and lectures, etc..)	0.8236	H
9	Adaptive Learning	Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points)	0.8225	H
10	Smart Card	E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...)	0.8181	H
11	Adaptive Learning	Optional Supplementary Courses in specialized fields (Beside Curriculum)	0.7972	H–M
12	Optimization & Analytics Data Center	Optimization & Analytics Data Center (Operations, Data Storage, Research Center, etc...)	0.7916	H–M
13	Smart Energy Management System	Smart Street Lights	0.7889	H–M
14	Smart Transportation	Smart Parking	0.7858	H–M
15	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
16	Smart Energy Management System	House Management System (for residential end users usage)	0.7812	H–M
17	Smart Facilities Services	Smart Facilities Services (Sports Fields and Centers/Libraries/ Restaurants/Student Center/Activities)	0.7790	H–M

#	Criteria	Application	RII	Imp. Level
18	Smart Transportation	In-Campus Navigation (Smart Kiosks, Way-Finding for Offices, Room, Facilities, Events, etc...)	0.7748	H–M
19	Smart Transportation	Fleet Tracking of all Campus Transportation (for Logistics, Transportation, Smart Bus Shelters, etc...)	0.7625	H–M
20	Smart Transportation	Intelligent Signage (for Navigation, Broadcasting, etc...)	0.7535	H–M
21	Smart Card	Dorms (All residential activities and administration)	0.7449	H–M
22	Smart Classroom	Virtual Reality (For Labs, experiments, Site Visits, Simulations, etc...)	0.7417	H–M
23	Smart Facilities Services	Private Campus Social Network (Events, Broadcasting, Easy Access to information, etc...)	0.7385	H–M
24	Smart Energy Management System	Energy Trading System (for Electric Vehicles inside parking)	0.7338	H–M
25	Smart Card	For Attendance (Classrooms, Labs, access to facilities, etc...)	0.7264	H–M

As shown in Table 18, student chose 10 applications to be in the High Importance range for the most important features and applications inside a smart campus, these applications are:

1) Smart Card: To Record all Personal Data (Student Information, admission, transcript, graduation information, student records and activities, etc...)
2) Smart Classroom: Interactive Cloud Sharing platform (between classmates & professors, between the Market and the University, between Government and University, etc...)
3) Smart Card: For Library usage (booking, borrowing, registration, printing, etc...)
4) Smart Energy Management System: Sustainable Energy (Solar Power, Sustainable design Buildings, Carbon Capture Storage)
5) Smart Safety & Security (Tracking, Surveillance, evacuation etc...)

6) Smart Energy Management System: Buildings Energy Management System (Monitoring and Automated :Heat & Air Conditioning, Lights, Power Devices)
7) Smart Classroom: Collaborative Research (connectivity and communication with several universities, companies, governments or research)
8) Smart Classroom: Remote Digital Learning (Online Lectures, Visual interviews, Cloud Storage, online access to all course information and lectures, etc...)
9) Adaptive: Learning: Adaptive Learning (Customized Learning according to market needs & students' interests, Customized Learning for Students' Weak-points)
10) Smart Card: E-Wallet (Payments and verification with E-invoice for: Registrar, administration, cashier, restaurants, financial holds, fees, etc...)

These High important applications (RII score above 0.80) from the students' perspective include: 3 Smart Card applications, 3 Smart Classroom applications, 2 Energy Management applications, 1 Adaptive learning application, and 1 Smart Security and Safety application. Moreover, the rest of applications were above 0.72 RII value and inside the (H-M) range. This indicates and clearly proves that all the designated criteria and applications are important features of smart campus as previously illustrated in literature review. In the beginning, it wasn't expected to have all applications above the high-medium level (above 0.60 RII value), but the results were extremely aligned with the selected applications and criteria for smart campuses. All in all, campus stakeholders' perception is definitely important to validate the smart applications since they are targeted people who will deal directly with these features and changes in educational institutes, and it was observed that the designated criteria was extremely aligned with the end users preferences.

4.2.4. Preferences and Perceptional Questions. In this section, the student's perception of Smart Applications will be further assessed by questioning their preferences and perception of smart campus and AUS. The questions' responses will show the preferences of students to apply these designated applications, the limitations from students' perspective, and may other indicators.

4.2.4.1. ***Question14: Which of the following applications you would love to see applied in your campus? (You Can Select Multiple, All, or None).***

The previously selected criteria were questioned to students in order to hear their preferences about applying these criteria inside the AUS campus. Student were requested to select the criteria (including all its' applications) that they would love to see applied in the near future. In this questions, respondents had the complete freedom to select any, all, or none of the mentioned criteria with applications. By ticking next to the criteria, it will be recorded as a preference to see it applied in the near future for that respondent. The most demanded criteria was the Smart Card with 114 responses out of 144, and that represents 79.17% of total respondents were demanding Smart Cards to be applied in the near future inside their campus. Secondly, Smart Classroom with 72.22% or total responses demanded this feature to be applied in the near future, and this represents 104 out 144 respondents. The total respondents demanding each of the designated criteria is demonstrated in both figures 33 and table 19.

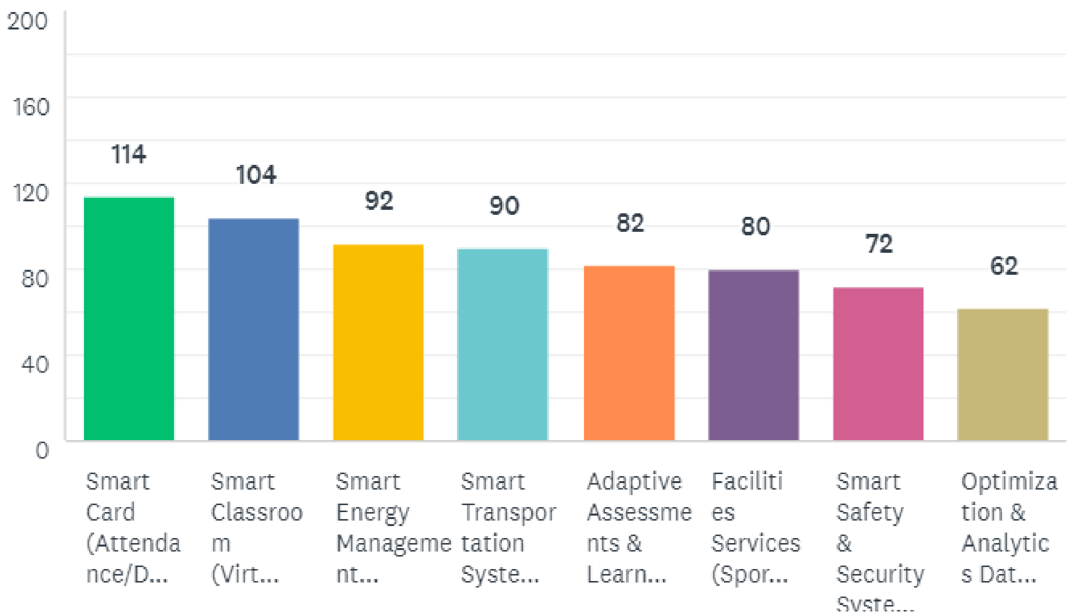


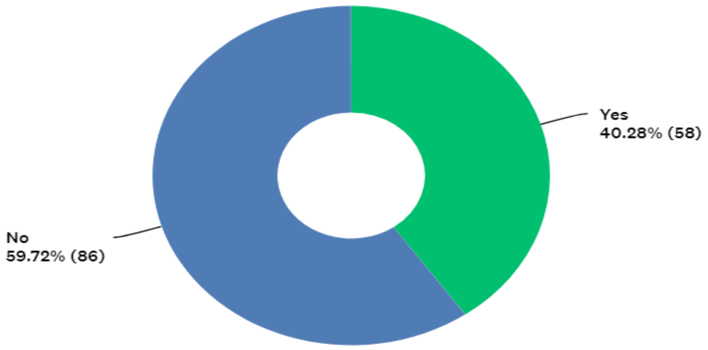
Figure 33: Total responses on each criteria for Question 14

The most demanded criteria had 114 votes while the least demanded had 62 votes only. Although the least demanded criteria by students had 43.06% of total response, it is still solid to state that all criteria have a strong base of audience, who want to see a real implementation of the smart campus application, and to see it coming as a true feature in the near future. Finally, Figure 33 shows that there is no big gap between each criteria and the one it follows, in terms of students' demands.

Table 20: Total percentage &responses on each criteria for Question 14

ANSWER CHOICES	RESPONSES	
Smart Card (Attendance/Dorms/Library/E-Wallet/Personal Data and Records/Registration/Administration)	79.17%	114
Smart Classroom (Virtual Reality/ Remote Digital Learning/Interactive Sharing Platform/Collaborative Research, etc..)	72.22%	104
Smart Energy Management System (Heat & Air Conditioning, Indoor Lighting, Street Lights, Sustainable Energy, etc...)	63.89%	92
Smart Transportation System (Smart Parking, Transportation tracking & monitoring, Intelligent Signage, Campus Navigation Way-Finding, Smart Kiosks& Bus Shelters, etc..)	62.50%	90
Adaptive Assessments & Learning (Customized Learning to market needs & students' interests, supplementary courses, Computerized adaptive testing, etc..)	56.94%	82
Facilities Services (Sports Fields and Centers/Libraries/Restaurants/Student Center&Events/Social network, etc..)	55.56%	80
Smart Safety & Security System (Tracking, Surveillance, etc..)	50.00%	72
Optimization & Analytics Data Center (Operations, Data Collection, Research Center, etc...)	43.06%	62
Total Respondents: 144		

4.2.4.2. *Question15: Do you think it is difficult to implement Smart Campus in AUS?* In this question students were asked to present their honest opinion regarding the current AUS campus readiness to adopt the idea of smart campus. This will give a clearer understanding of AUS campus status from the students' perspective. As shown in Figure 34, 40.28% of the total responses stated that yes it is difficult to implement the smart campus in AUS now, while 59.72% stated the opposite by saying that it is not difficult for AUS to implement smart campus in the near future.



ANSWER CHOICES	RESPONSES	
Yes	40.28%	58
No	59.72%	86
TOTAL		144

Figure 34: Students' answers on Question 15

4.2.4.3. ***Question16: If you answered Yes for the previous Question, What are the reasons? (You can select multiple reasons).*** This question is a completion for the question before, since students who answered with (Yes it is difficult to implement Smart Campus in AUS) were requested to say why it is difficult? Respondents were given multiple answers to select from a list of challenges and limitations of smart campuses. However, if one of the challenges and limitations is not mentioned in the list, respondents were able to write down their own opinion on why it is difficult to implement smart campus in AUS.

As shown in table 20, the major obstacles from student's perspective were the high cost of implementation, non-reliability of current buildings' infrastructure, and faculties' resistance to change. The detailed results are shown in table 20. On a side note, only 90 student responded to this question since it was only required to answer it if you have selected (Yes) in the previous question 19.

Table 21: Students' responses to Question 16

ANSWER CHOICES		RESPONSES	
High cost of implementation		66.67%	60
Colleges' buildings are not ready/reliable enough		48.89%	44
Faculties ability to adapt with the change (Resistance to change)		33.33%	30
Other (please specify)	Responses	21.11%	19
No guaranteed positive results of implementing such ideas (Not Necessary)		18.89%	17
Students' ability to adapt with the change (Resistance to change)		16.67%	15
It penetrates the Pesronal Privacy		11.11%	10
Lack of Technologies in the market		7.78%	7
It will backfire and have bad effect on education quality		6.67%	6
Too Early to think about smart campus		3.33%	3
It is not aligned with AUS mission and vision		3.33%	3
The Smart Campus idea is not practical and cannot be implemented		1.11%	1
It is not aligned with UAE Vision		1.11%	1
Total Respondents: 90			

4.2.4.4. ***Question17: Do you think Professors will use "Smart Campus applications" effectively?*** This question targets students' perception towards their professors, and whether they believe that professor will use the smart tools effectively during the learning process.

The question marks the relationship between students and professors, as it will show how optimistic are the students towards the smart learning when it comes to an interaction between students and professors. Figure 35 shows that 65.28% of the respondents said yes, while only 34.72% said that the professors will not use the smart applications efficiently inside the campus.

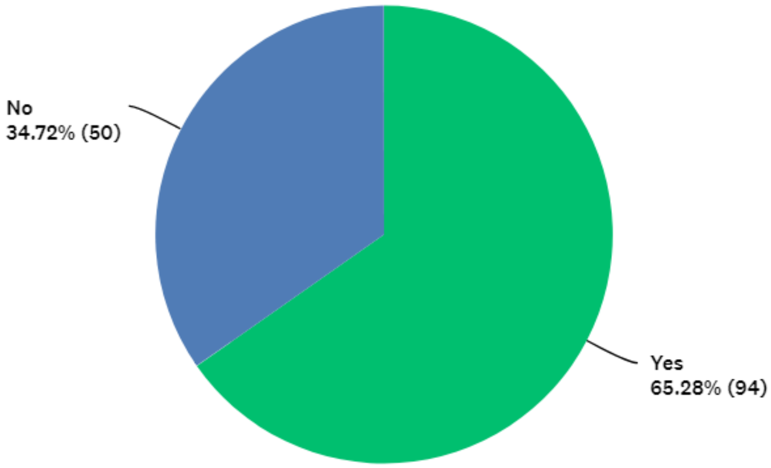


Figure 35: Students' answers on Question 17

4.2.4.5. ***Question18: Do you think AUS Students will use "Smart Campus applications" effectively?*** Question 18 aims to check and test the students' capabilities and willingness to use the smart campus applications efficiently if it was available between their hands today. Figure 36 shows that 81.25% of AUS students are excited to use the smart campus features if it was available today between their hands.

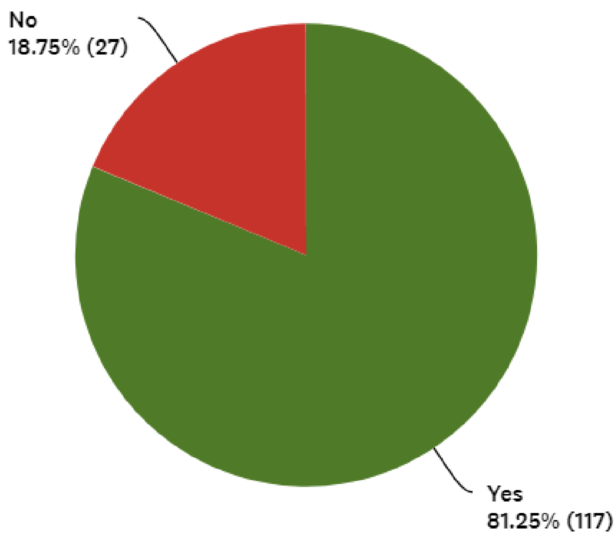


Figure 36 :Students' answers on Question 18

4.2.4.6. Question19: Rank the following applications in order of Priority to implement first (1 for first to implement, 7 for last to implement). This questions allowed respondents to express their interests in implementing the smart campus applications inside AUS. By giving priority ranks from 1 to 7 according to what smart applications they would like to see first implemented inside their campus. Rank 1 means they would like to see it implemented the 1st application on the smart campus agenda, then followed by rank 2, until rank 7 which means they would like to see it lastly implemented on the smart campus agenda. The 7 main applications included: Smart card, Smart classroom, Smart energy management system, Smart Safety and security system, Smart facilities' services, Adaptive learning & assessment, and Smart transportation system. Figures 38 and 39 shows the distribution of the responses collected for this question. As an example, the Smart Classroom was in total the most demanded application as per the received responses. The responses shows is details that it was requested 42 times to be the 1st application implemented inside the campus, and it was requested 35 times to be the 2nd application implemented inside the campus, and 17 times to be the 3rd application implemented etc… Similarly, the distribution of all applications and the collected responses are shown in Figures 37, and 38.

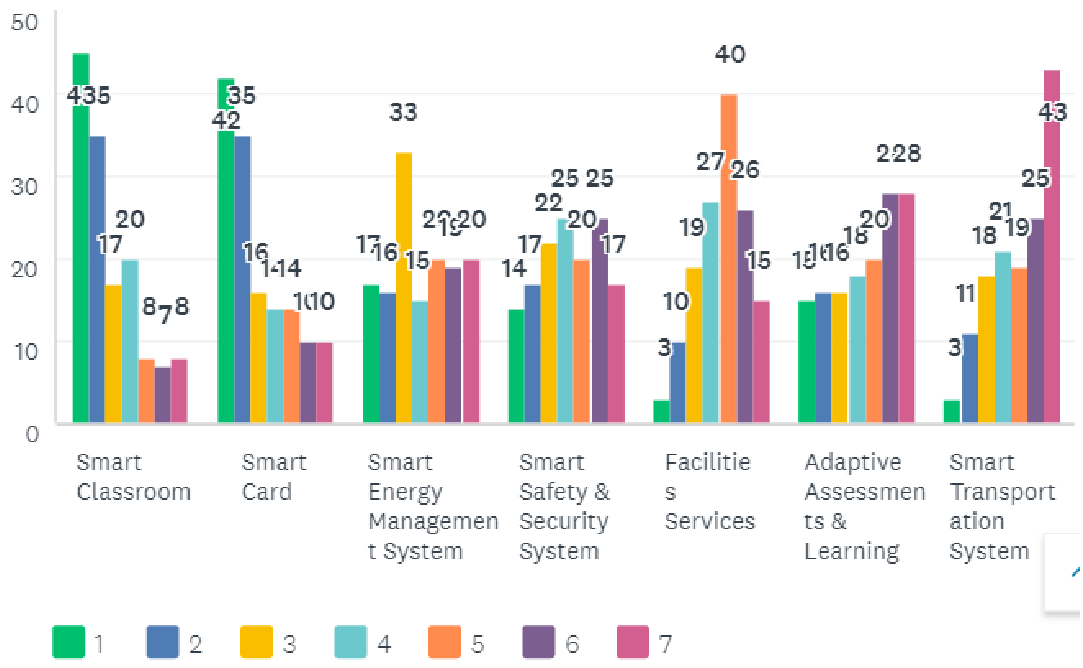


Figure 37: Students' answers on Question 19 Responses distribution

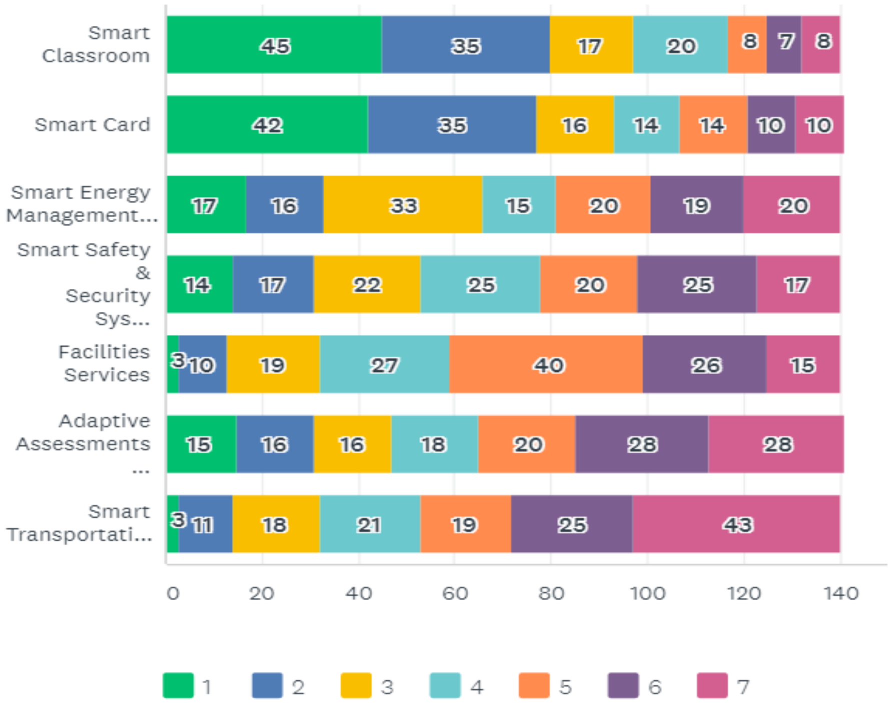


Figure 38 :Students' answers on Question 19 responses distribution horizontally

Finally, to rank the 7 applications from the most demanded application by students, to the least demanded; the weighted average method was used to calculate and graph the ranks as per Figure 39. The figure shows Smart classroom in the 1st place, and smart transportation in the 7th rank.

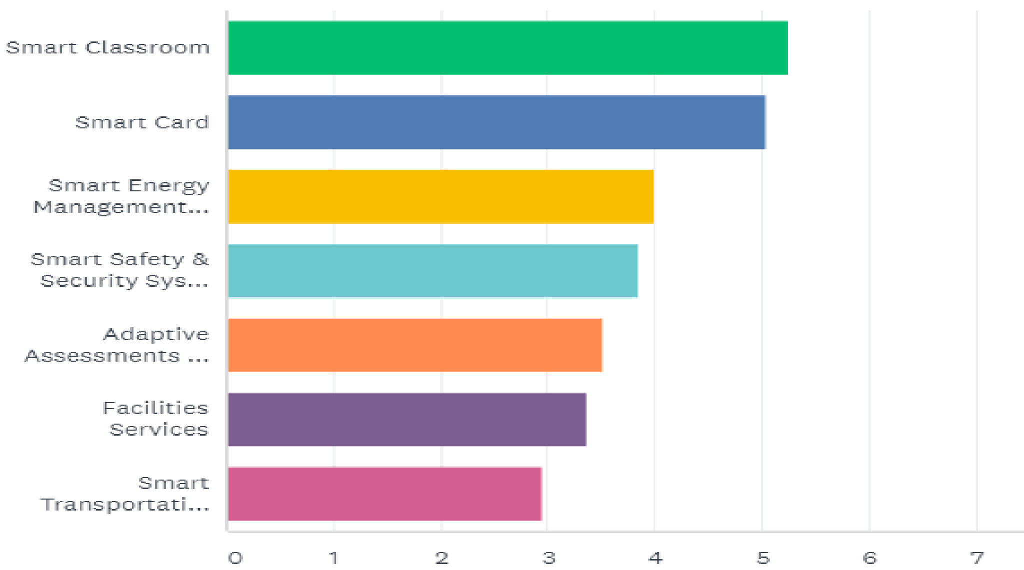


Figure 39: Ranks of Smart applications as per students' demands

4.2.4.7. Question20: From a Student Point of view, are you satisfied with the current campus features? Question 20 aims to test how AUS students perceive their campus, and whether they are satisfied with the current features or no. Surprisingly, around 50.69% of the respondents stated that they are not satisfied with the existing features in AUS. This also accords with the fact that technology emerges on a quick pace, and the future generations will demand a more flexible smart education; especially when they see technologies penetrating all other life aspects. Figure 40 and table 21 present the student's responses to question 20.

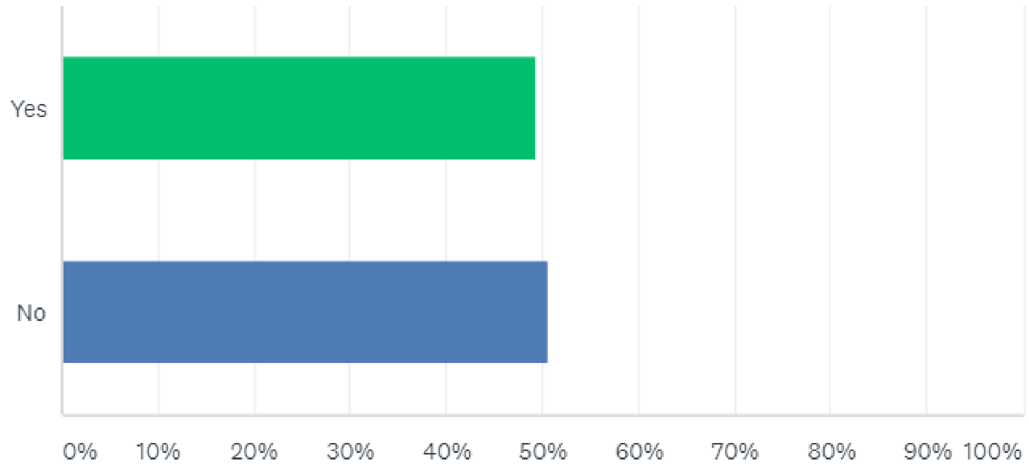


Figure 40: Answers and responses to question 20

It is quite alarming to see 50% of the respondents are not happy with the current campus features. This might seem as a logical result considering the technology penetration in every aspect of this generation lives. Moreover, the availability of many smart initiatives from governments and several startups, would enhance the thought of something is missing in this campus, and reduce the level of satisfaction for students.

Table 22: Students' responses to Question 20

ANSWER CHOICES	RESPONSES	
Yes	49.31%	71
No	50.69%	73
TOTAL		**144**

4.2.4.8. ***Question21: In your opinion (after completing the survey) How Smart is AUS Campus?*** Students responded differently to this question, where some students gave scores above 70, while others voted for scores less than 10. Finally, the average of 144 responses with 36 points, which is quite low for a university that is considered one of the top in its region. Figure 41 presents the average score on a bar chart.

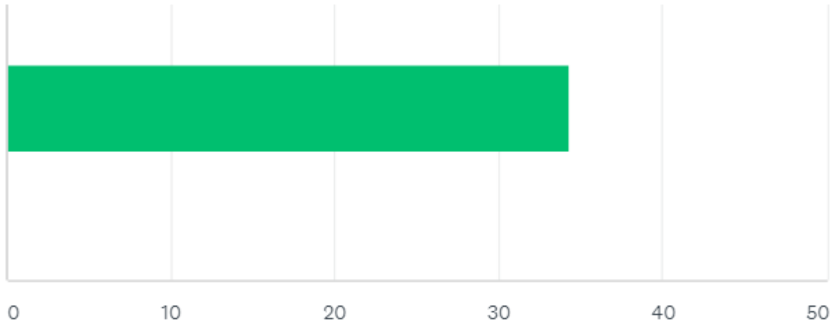


Figure 41: Answers and responses to question 21

4.2.4.9. Question22: How important is it for you to have a smart campus? Question 22 is the final question in this survey, and it highlights the students' demands on how much important is having a smart environment for the campus. Students were asked to use a slider to pick a number between 0 and 100. The average score of 144 students is 46%, and it indicates that there is a real demand for this idea, and it matters for the students to have such an improvement in their educational lives. Table 22 presents the average score from the survey that was distributed to the students.

Table 23: Students' responses to Question 22

ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
Responses	46	6,686	145
Total Respondents: 145			

4.3 Semi-Structured Interviews

As part of gathering data and validation, interviews were conducted with four professors in the American University of Sharjah and the IT director in AUS. The four professors belonged to different departments with different expertise. P1 is a professor in the industrial engineering department, P2 is a professor in the computer engineering department, P3 is a professor in the civil engineering department, P4 is a professor in the industrial engineering department, and P5 is the IT Director in AUS. The aim of the interview section is to determine whether the criteria and applications in this research are enough to transform a traditional campus to a smart one, discover if there are other applications that could be added, and discuss the enablers and challenges facing the implementation of a smart campus. As such, during the interview, 3 main questions were presented:

1) Do you see these criteria and applications are enough to transform a traditional campus to a Smart Campus?
2) What other applications would you love to see applied in this Campus? Or what other criteria can be added?
3) What are the challenges and enablers for promoting Smart Campus?

The responses of experienced professors, fond of the criteria and applications of a smart campus and directly relevant to the implementation of such applications, will ameliorate the approach of the research and clarify the spectrum of smart campus applications. Responses of each professor to the interview questions will be presented in tables as per the following sections.

4.3.1 Q1: Do you see these criteria and applications are enough to transform a traditional campus to a Smart Campus? The answers of this question are presented in the following Table 24:

Table 24: Semi-Srtuctured Interviews, Question 1 Answers

Interviewee	**Interview answer**
P1	Yes, it is comprehensive enough to make a campus smart as an initial step.
P2	Yes, it can be considered enough. The mentioned criteria encompass the majority of smart campus applications, and the entirety of key applications.
P3	Yes. The mentioned criteria and applications are similar to those adopted by smart campus models worldwide.
P4	Yes, the smart campus criteria are enough to transform a traditional campus to a Smart Campus.
P5	Yes it is, it is subjective to say so, but it is in the right directions.

4.3.2 Q2: What other applications would you love to see applied in this Campus? Or what other criteria can be added?

The answers of this question are presented in the following Table 25:

Table 25: Semi-Srtuctured Interviews, Question 2 Answers.

Interviewee	Interview answer
P1	- Responsive Buildings - Intelligent Buildings - "Ambient Learning" to be able to teach anywhere and anytime internationally - Automatically controlled projectors - Smart rooms were computers, air conditioning, and all required machines are turned on before arrival of occupant(s). - To be able to communicate with students in their learning space and I am in my office during office hours - Automatic doors instead of push/pull to open - Responsive phones to call anyone in campus - A mechanism to tell students whether I am occupied or available in my office without them knocking on the door - Campus entry without presenting an ID - Having students living in the learning environment especially in laboratory and during experiments - Augmented reality applications that give sense to experiments - Finger print recognition for security purposes
P2	- Smart technological rooms where every component can be controlled remotely and effortlessly

Interviewee	Interview answer
	- Automatic building envelope, where doors open and close using sensors, and windows open and close based on indoor and outdoor temperature - Smart university plan to show students their exact location and direct them to their destination of choice
P3	- Smart communication portal between students and professors to make office hours more accessible to students - Classroom components should be connected to a remote controller where all components, such as computers, projectors, slides, and pointers are all controlled - Smart buildings
P4	- Smart student desks which include power supply and screens for more personalized learning experiences - Smart communication between faculty and students where video communication is possible - Sensor doors - Automatic windows - Smart environment control in classrooms
P5	- Data governance (classification of data: secure / accessible / confidential / who access to what in a readable format). - Virtual whiteboard in virtual classroom (raising hands live and synchronize the class virtually instead of cancelling the class.) - Collaborative teaching and modern physical classes, two way teaching and learning, devices to support interactive screens. - Wearable technology (not a card if forgot you lose everything), a cloud card on mobiles and wearable devices.

Interviewee	Interview answer
	- Automation of all operations and workflows (petitions, forms, workflows, tracking, notifications for people working on that case). - Reporting and analytics on traffics for buildings: for events (the most suitable dates for students, and staff) best case scenario for all students for exam timings and main projects. - Smart data capture and forecasting, machine learning and artificial intelligence. - Data transparency and openness of data, data pools (lakes) and data warehousing.

4.3.3 Q3: What are the challenges and enablers for promoting Smart Campus?

The answers of this question are presented in the following Table:

Table 26: Semi-Srtuctured Interviews, Question 3 Answers. Continued.

Interviewee	Interview answer
P1	Challenges: - Academic culture - Resistance to change - Resources for material and training - Mission and vision of university - Understanding the technology and its capabilities - Lack of previous tests in this field under similar conditions - The traditional roots of the Ministry of Education - Regulation and policies - Obtaining ministry approval for teaching aspects that do not require physical presence

Interviewee	Interview answer
	Enablers: - Believing in change - Using well-tested technologies - Updating the curriculum to enhance students’ understanding of the concept of a smart campus - Training and educating staff - Learning from successful examples
P2	Challenges: - The investment cost associated with implementing smart campus applications - Required approvals to adjust the learning system as per the smart campus applications - The adjustment period required by professors and students to get used to a smart campus Enablers: - Incentivising professors and students to successfully implement smart campus applications - Assigning professionals to conduct proper change management to control the transition from a traditional campus to a smart one
P3	Challenges: - Significant cost - All stakeholders are comfortable with the currently existent learning strategies - The transition might take some time until it matures and exhibit the expected results

Interviewee	Interview answer
	- The lack of a leading example Enablers: - Starting to implement smart campus applications in small doses and increasing dose in a systematic manner - Training all relevant parties on how to implement smart campus applications - Monitoring the results of smart campus applications and restructuring where necessary
P4	Challenges: - Initial investment is high - Academic society and culture are traditional - Resistance from stakeholders - Disruption of the traditional system that was adopted. - Most faculty and students are not very fond of smart campus applications Enablers: - Willpower and continuous ambition to achieve the best learning experience for students - Change management - Incentivising stakeholders to adopt smart campus applications
P5	Challenges: - IT support and skilled manpower - Failover system to ensure redundancy and business continuity.

Interviewee	Interview answer
	Enablers: - Technology Awareness: raise the awareness of smart campus capabilities and that this campus have these technologies (marketing communications, gatherings, events to announce new services, and workshops).

4.3.4 Discussion of Interview Responses. Based on the interview answers, it can be deduced that there is a positive response to the concept of implementing smart campus applications in the American University of Sharjah. The interviewed professors made valid points regarding the matter and shed light on some important aspects.

The professors' response to the first question one "Do you see these criteria and applications are enough to transform a traditional campus to a Smart Campus?" was positive in consensus. All the interviewed professors believe that the smart campus applications and criteria mentioned in this research are sufficient to transform a traditional campus into a smart campus. P1 and P2 both hinted 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. However, it is still quite prevalent that the interview confirms the findings of the literature review and assures that the applications and criteria analysed and studied to fit the American University of Sharjah are sufficient. Moreover, P3, P4 and P5 confirmed that the studied criteria and applications are very much similar to those implemented worldwide and are in the right directions of Smart transformation.

The second question was more targeted toward future research, where professors are asked "What other applications would you love to see applied in this Campus? Or what other criteria can be added?" The goal of asking this question is to understand that further criteria is required to take the extra mile and ultimately achieve a world class smart campus. All professors explained additional criteria and applications that can be added to achieve a better smart campus, and specific recommendations were mentioned by 2 or more professors. For example, smart buildings are clearly emphasized by P1, P2, P3, and P4, where doors open and close due to sensors, and classrooms are equipped with remotely controlled devices. Smart building facilities enhance both teaching and learning experiences and allows all students and professors to be comfortable both inside and outside the classroom. Moreover, smart communication means, using video and similar communication facilities, were recommended by P1, P3, P4 and P5. Due to limited office hours, and due to the hectic nature of communication between professors and students outside the classroom, the professors believe that a smart communication tool would solve a problem. Furthermore, P1 explained that a smart campus also includes smart applications for professors, such as a mechanism to let students know whether a professor is occupied or available in the office without having to knock on the door. Applications of this kind help professors notify students of their availability and occupancy without hindering their working hours. All the recommendations made by the professors are of great value and offer rich material for further research in this field.

The third question is directly related to the results of this research, as it puts results into context by asking “What are the challenges and enablers for promoting Smart Campus?” Professors were asked this question to determine whether the benefit and demand of smart campus applications are enough reason to implement them or are there other factors which might postpone and negate their benefit. P2, P3, and P4’s immediate response when asked about challenges is the initial cost required to implement smart campus applications. Although the literature notified that smart campus applications are costly to implement, but there are studies which showed that the benefit, even the monetary one, eventually outweighs the cost. However, managing to allocate financial resources to implement smart campus applications is still a challenge. Moreover, all professors either explicitly stated or hinted that smart campus applications require training for students and professors. Although the benefit is great, most students and professors are not used to dealing with smart campus applications; hence, getting all stakeholders on board is a challenging feat. In addition, P1 and P4 explained that the academic culture is not nurturing of newly devised educational methods. The educational culture in the American University of Sharjah leans on traditional educational means; therefore, introducing smart campus applications will have to withstand the friction of culture until it bears its results. On the other hand, P2, P3, P4 and P5 stated that the challenges can be overcome if proper change control and management is deployed. By handing over the implementation phase to professionals in charge of planning, execution, and monitoring, the challenges can be toned down significantly. Furthermore, P1 and P4 expressed that the will of the American University of Sharjah to deliver the best results and be the leading example incentivises it adapt to the changes in educational methods, even adopting smart campus applications. 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. By educating students and professors, the demand for a smart campus will increase, altogether with a profound understanding of its challenges and enablers in a realistic context which can be applied to the American University of Sharjah.

4.4. Main Findings and Conclusion of Results

In the analysis section, both quantitative and qualitative analysis were conducted to validate the designated smart criteria, and to analyse the perception of the campus end users in the American University of Sharjah. The campus end users in this study were the students, faculty, and IT service providers. The quantitative analysis was performed based on a survey distributed to AUS students, and the survey gathered 144 responses. The main finding in the quantitative analysis was the most important smart applications for students, and the applications are:

- Smart Card: to record all personal data (Student Information, admission, transcript, graduation information, student records and activities, etc...)
- Smart Classroom: interactive cloud sharing platform (between classmates & professors, between the market and the university, between government and university, etc...)
- Smart Card: for library and facilities usage (registration, booking, borrowing, printing, etc...).
- Smart Energy Management System: Sustainable Energy (Solar Power, Sustainable design Buildings, Carbon Capture Storage).

In addition, students were asked to rank the smart criteria based on what do they like to see firstly implemented in their campus, and their answers show the following ranks:

1. Smart Classroom.
2. Smart E-Card.
3. Smart Energy Management System.
4. Smart Safety and Security Systems.
5. Adaptive Learning and Assessment.

6. Smart Facilities and Services
7. Smart Transportation.

Moreover, the main challenges for implementing the smart campus inside AUS were highlighted by the students as: High cost of implementation, Reliability of the current buildings, and Resistance to change by faculty. In addition, 60% of the students believe that AUS is capable to implement the Smart Campus concept in future. Finally, most of the respondents showed a positive feedback when asked whether students and faculty will use these smart application effectively if it was to be applied in their current campus.

Nevertheless, for the qualitative analysis, semi-structured interviews were conducted with four professors from different engineering disciplines and with the IT Director in the American University of Sharjah. These interviews validated the designated criteria and shed light on three important points in this research. Firstly, the smart campus applications and criteria mentioned in this research are sufficient to transform a traditional campus into a smart campus. All professors and the IT director, in consensus, stated that the mentioned criteria are sufficient at least as an initial step towards a smart campus. Moreover, when asked about additional smart campus criteria and applications to be added, the professors were elaborative on additional points which can take the smart campus to the next step, the most important of which are smart buildings, smart communication means with students, and smart office applications for professors. Finally, when asked about the challenges and enablers of a smart campus, almost all interviewee agreed that the set-up cost of smart campus applications is a great challenge, in addition to the need of training for all professors and students to such applications. However, the majority agreed that the challenges can be overcome if proper change management takes place, where a team of professionals are assigned to planning, executing, and controlling the introduction of smart campus applications. Although the challenges facing the implementation of smart campus applications are not easy to overcome, the right expertise in the field is able to devise efficient plans and execute them to achieve a world class smart campus in the AUS

Finally, based on the smart criteria validation and analysis done in chapter 4, a smart campus conceptual framework can be proposed in Figure 42:

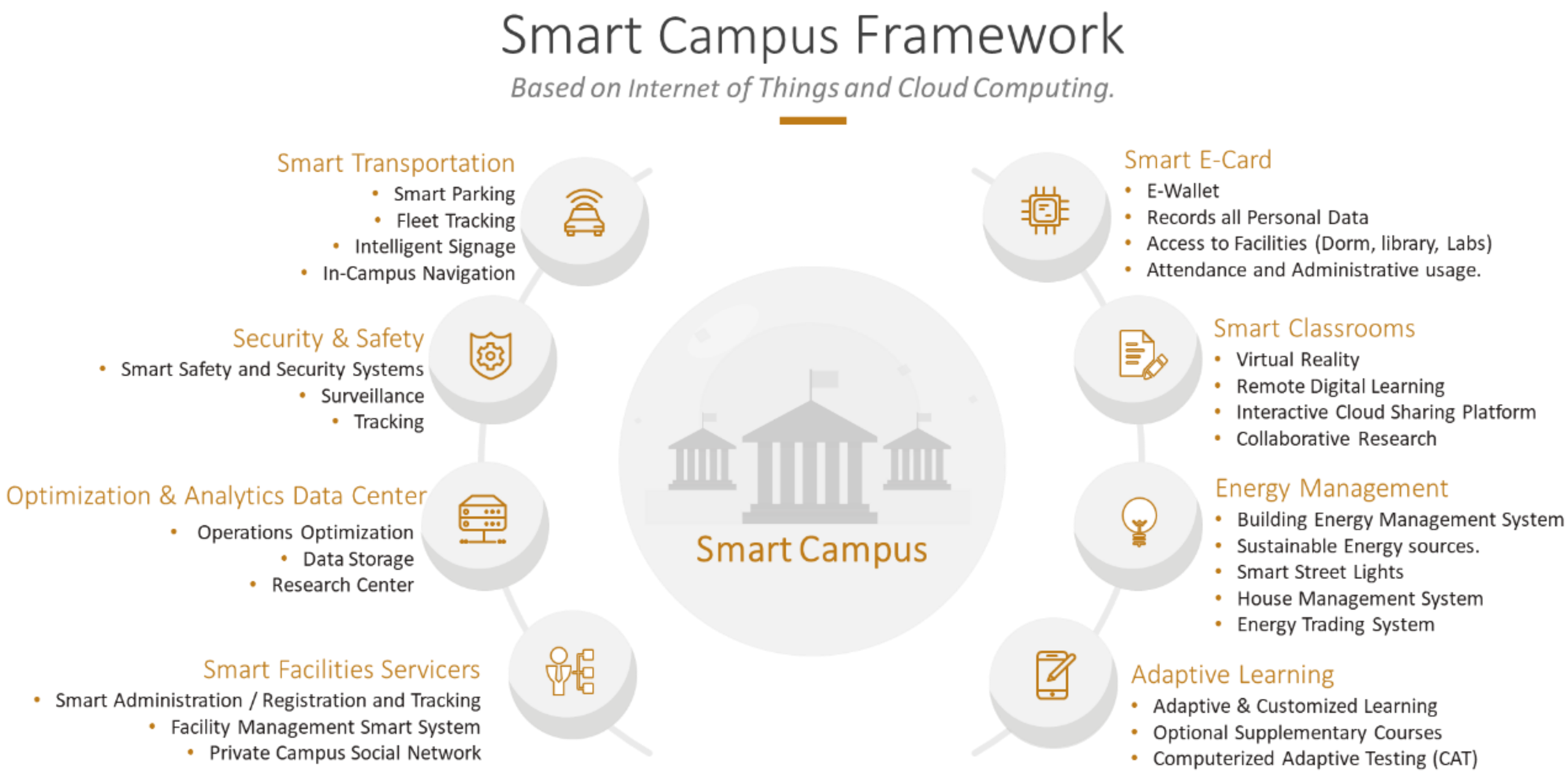


Figure 42: Smart Campus Framework based on Internet of Things and Cloud Computing

Chapter 5 . Conclusion and Future work

5.1 Discussion

This research achieved its goal in investigating and exploring the underpinning criteria that promote the concept of Smart Campus, and in proposing a strategic framework for a Smart Campus. This proposed framework was achieved throughout the following steps:

1. An exploratory research to identify and understand the recent achievements in the fields of: smart campus, smart cities, and smart supporting technologies.
2. Establish the smart campus criteria based on the exploratory research and literature review.
3. Evaluate and validate the designated criteria of a smart campus by conducting a case study in AUS. A case study that targets the end users' perception using both quantitative and qualitative analysis.
4. Propose a conceptual framework for the smart campus based on the designated criteria, and draw a set of recommendations to empower the framework and the research results.

Using the research literature review, AUS case study, and the final suggested framework, the research was able to answer the following questions:

- What are the underpinning criteria of a smart campus?
- What is the end users' perception of implementing smart campus applications in the American University of Sharjah?
- What are the most important enablers and challenges facing the implementation of smart campus in the American University of Sharjah?

For the first question, the underpinning criteria were defined inside the literature review section, and they were further validated by conducting and case study inside AUS. The students' responses showed a high RII values for all criteria and smart application, which clearly indicates their support and validation to the suggested criteria. Moreover, in the semi-structured interviews, AUS professors from different engineering departments and the AUS IT director were clearly asked about their opinion on the proposed smart campus framework, and they all agreed on the smart campus criteria as sufficient to transfer the traditional campus to a smart campus. For the second and third questions, they were both answered in the AUS case study either inside the survey responses or inside the semi-structured interviews with AUS professors and IT director. As observed in the professors and students responses, when it comes to challenges and enablers in a smart campus, they highlighted the following:

The main challenges that found consensus are:

- Resistance to change in the academic learning methods.
- Investment costs in smart application and guaranteeing positive results.
- Privacy agreements for data collection
- Lack of leading example
- IT support and skilled End users.
- Failover system to ensure redundancy and business continuity.

The main Enablers that found consensus are:

- Change management, willpower and clear vision or smart transformation.
- Technology Awareness: raise the awareness of smart campus capabilities.
- Incentivising professors and students to implement smart campus applications.
- Sufficient training and motivation to all campus stakeholders
- Industrial companies participating closely with the academic institutions to further improve their smart application and continuous support.

5.2 Main Findings and Conclusion

The main finding of the research was defining the smart campus criteria and its smart application which can form the strategic framework of a smart campus. The research categorizes the smart campus criteria into 8 main categories, and under each category there was proposed a bunch of smart application. First of all, the main infrastructure of the smart campus is going to be Internet of Things and Cloud Computing. Having all the campus stakeholders connected in an interacting data pool is vital to the success of any smart campus. In addition, Internet of Things and Cloud Computing will give the smart campus features of being Instrumented, Interconnected, and Intelligent when it comes to interacting with all campus end users. Nevertheless, all the 8 smart campus criteria must operate under Internet of Things and Cloud Computing to guarantee the highest levels of connectivity and strong supporting infrastructure. To conclude, the research summarizes the eight designated criteria and there smart applications in the following list and in Figure 42:

1. Smart E-Card :
    a. E-Wallet
    b. Records all Personal Data
    c. Access to Facilities (Dorm, library, Labs, etc…)
    d. Attendance and Administrative usage.
2. Smart Classroom
    a. Virtual Reality
    b. Remote Digital Learning
    c. Interactive Cloud Sharing Platform
    d. Collaborative Research
3. Smart Energy Management System
    a. Building Energy Management System
    b. Sustainable Energy sources.
    c. Smart Street Lights
    d. House Management System
    e. Energy Trading System
4. Adaptive Learning
    a. Adaptive & Customized Learning
    b. Optional Supplementary Courses
    c. Computerized Adaptive Testing (CAT)
5. Smart Transportation
    a. Smart Parking
    b. Fleet Tracking
    c. Intelligent Signage
    d. In-Campus Navigation
6. Smart Safety & Security
    a. Smart Safety and Security Systems
    b. Data Collection and Surveillance
    c. Tracking
7. Optimization and Analytics Data Centre
    a. Operations Optimization
    b. Data Storage
    c. Research Center

8. Smart Facilities and Service
    a. Smart Administration / Registration and Tracking
    b. Facility Management Smart System
    c. Private Campus Social Network

To conclude, Figure 42 presents and summarizes the research final results, which is the framework for a Smart Campus. It consists of 8 main criteria and they are all based on Internet of Things and Cloud Computing. Furthermore, to assess these criteria from the campus stakeholders' point of view, a survey was distributed to question the importance of these criteria and applications to the campus end users. Moreover, the analysis of the results were build based on the Relative Importance Index (RII) values for each application. Finally, Table 18 shows the following RII scores for smart applications descending from the highest RII value (most important to campus ends users), to the lowest RII values (least important to campus end users).

As observed in the RII table, ten smart applications scored above 0.80 which indicates their high importance to the campus end users. In addition, all the other applications scored above 0.72 RII value and inside the medium high range (M-H), which also indicates the importance of all the other applications from the campus end users' point of view. The RII values are very close to each other, with no big gap between each of the Smart Campus application, and this shows the reliability of data collected in literature review which was then presented to the campus end users for evaluation and validation. The high score of RII is a real indication of the respondents' preferences, and it was clear that almost all of the selected criteria for Smart Campus were preferable and acceptable to campus end users. To conclude, the high RII values for all smart applications shows that the criteria is extremely aligned with the campus stakes holders needs and desires. Finally, although the smart campus criteria were evaluated and validated by scoring high RII values in the student's surveys; another validation step was conducted to further enhance the credibility of the designated smart campus criteria. The final step was questioning professors and IT specialists in the American University of Sharjah through a semi-structured interviews. The interviewees had the complete freedom to express their opinion regarding the designated smart campus criteria in this research. All the interviewees agreed and validated the smart campus criteria as sufficient to transform the traditional campus to a smart campus.

5.3 Limitations

The results of the study are based on the American University of Sharjah only, where the participants of both surveys and semi-structured interviews were students, faculties, and IT support service providers. Therefore, to increase the reliability of the findings of this study to be generalized, more interview could have been conducted from within the campus and outside it. Moreover, this research could have provided a decision making tool to support the smart transformation decisions based on the attained RII value and utility levels of each application. However, due to time limitations, the research provided the RII values only for each smart application which is a very reliable indication on the importance of each smart application from the end users' perception. Therefore, a future study can be conducted to propose a decision support tool based on the methods mentioned previously in this paper.

5.4 Recommendations

It can be concluded that the research achieved its aim in defining the main smart campus criteria, and proposed a framework for the smart campus. Moreover, in terms of the smart applications, this research have ranked the most important applications based on the campus stakeholder's preferences. However, to comply and integrate the concept of smart campus, a set of recommendations is suggested to improve the research results and further integrate the concept of smart campus. The set of recommendations can be categorized into two main categories: recommendations for the field (educational institutes, campus stakeholders, industry, etc...), and recommendations for researchers' future works:

For the field recommendations, it can be summarized but not limited to the following:

- More collaboration between the educational institutes and the industry, in terms of sharing ideas, visions, and mutual capabilities.
- Raise the technology awareness and the competences about smart campus among all campus stakeholders, and open the doors for technology penetration in all campus departments under an experienced mentorship.
- A strong IT support and investment in IT infrastructure in terms of both resources and manpower to enable the utilization of smart campus.

- Failover system to ensure redundancy and business continuity, because the smart campus is highly dependent on connectivity.
- Incentivising professors and students to share ideas and raise demands to the campus management decision makers.

For future researchers and works on this topic, a set of recommendations can be summarized but not limited to the following:

- A deeper, more technical research on each of the designated criteria inside the proposed framework.
- An implementation guidelines on each of the smart applications inside the smart campus framework.
- Cost-Benefit analysis on each of the proposed smart campus criteria.
- Interviewing more people from the industry, so that it can be added to the campus end users point of view, and that would help in developing a full understanding of all challenges and limitations.
- Develop a decision support tool to decide on which of the smart application to invest / not invest, based on budget, vision, and current preferences of campus stakeholders.

Finally, this research contributes in proposing a smart campus framework to promote smart concepts and develop existing traditional universities' campuses. Moreover, the research will provide the pathway for smart applications to take place in future smart campuses' development plans. The smart campuses might not stick to the current practices demonstrated in this research, however; this paper opens the doors for smart services and applications to take place and present itself as real feature in future campuses in UAE, and around the world.

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