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Review Article

Smart Campus Framework for Higher Education Institutions in Tanzania

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ABSTRACT

The deployment of smart campus has gained significance globally as Higher Education Institutions (HEIs) strive to adopt digital technologies for efficient delivery of education and resource management. In achieveing proper deployment, scholars have proposed various features and frameworks for a smart campus of HEIs. However, HEIs around the globe have different needs and priority depending on their context. Establish a context based framework and features, this study examines smart campus features and their applicability in Tanzanian HEIs. It has adopted a trianglation of Systematic Literature Review (SLR) and Survey methods. Through SLR, the study identified 11 key features that various literature associate them with smart campus. Furthermore, though survey method, the study collected opinions from HEIs in Tanzania to test the findings of results that were obtained from SLR. Through ordinal logistic regression, we found that network infrastructure, smart governance, smart people, smart economy, smart living, and smart technology were more likely agreed as significant features of smart campus ($p < 0.05$), followed by smart education features with slightly large p-value ($p = 0.057$). Features like smart environment and smart buildings were perceived as not significant features of smart campus in most of HEIs ($p > 0.05$). Based on these findings, this study proposes a framework for smart campus that is relevant for HEIs in Tanzania.

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1. INTRODUCTION

The concept of smart campus has recently received attention globally as HEIs strive to create efficient methods that adapt to digital and emerging technologies that improve teaching and learning environment [1]. The global market of smart campus services was valued at 191.32 billion U.S dollars in 2019 and are predicted to grow at a compound annual growth rate (CAGR) of 19.6% during the period between 2023 and 2027, with a net worth of approximately 783.48 billion U.S dollars [2]. Several studies link smart campuses with the application of Information and Communication Technology (ICT) or digitalization of processes in HEIs [3][4]. Nevertheless, smart campuses are beyond the use of ICT or digitalization of services in university campuses. In technology-related fields, the term “smart” has evolved to indicate the ability of a system to perform certain duties without human intervention. For instance, in a smart grid, the system monitors the performance of the grid and makes necessary decisions such as load balancing and fault isolation without human intervention [5]. Likewise, smart buildings represent buildings with interactive features to control energy consumption, electronic security access systems, and the environment [6]. Even further, the smart cities reflect a wider scope of smartness to improve communities’ livelihoods. Smart cities involve digital technologies and modern electronic solutions to enhance the monitoring and utilization of infrastructure, upgrade government services, improve accessibility, promote economic growth, and improve sustainability [7]. The idea of harnessing the strengths of digital and other cutting-edge technologies to enhance learning, research and teaching has resulted in HEIs transforming into smart campuses [8]. Several scholar related this concept to that of smart city and smart building models [9]. The study by Zaballos et al. [10] considers a smart campus as a small area that acts within the context of smart cities and offers intelligent services and applications to its citizens to improve their quality of life. This idea is supported by Silva-da-Nóbrega et al. [11] and recommended features such as smart economy, smart education, smart environment, smart living, smart management, smart mobility, smart security, and smart technology as necessary indicators of smart campuses. Further, Ref. [12] argued that in HEIs, a smart campus should provide students and lecturers with a two-way learning environment and access materials online that can be shared to the public. Moreover, Ref. [13] suggested that a smart campus should extend the scope of a smart classroom, offering digital technology assistance and benefits within a classroom, to an intelligent university area that provides services in a campus-wide environment. To achieve that state, different players have adopted the concept of smart campus based on the context of operation depending on the available technology [14][15]. Despite gaining traction in most of HEIs in developed countries, the concept of smart campus in most of HEIs in developing counties is still at its infancy stage. Further, there are limited studies that explain about the features and framework of smart campus for HEIs in the perspective of a developing country.

This study therefore explores a suitable framework and its associated features to describe a smart campus for HEIs of developing countries a case study of Tanzania. The contributions of this paper are twofold; Firstly, it provides a critical review of features that are necessary for smart campus deployment in developing countries and secondly, it proposes a smart campus framework using ordinal logistic regression model. The paper is organized into five sections: Section 2 presents a literature review of smart campus technologies and related works. Section 3 describes the study methodology, followed by section 4 which presents results and discussion, and lastly section 5 presents the conclusion of the study.

2. LITERATURE REVIEW

2.1 Overview of Smart Campus

A smart campus refers to the integration of advanced digital technologies within a HEI to enhance its management, operations, and learning environment. The goal is to create a connected, intelligent, and sustainable campus that improves efficiency, safety, and user experience for students, staff, and administrators [16]. At the core of a smart campus are IoT enabled devices and sensors that collect real-time data from various campus facilities, including classrooms, laboratories, libraries, transportation systems, and energy grids. This data is analyzed using AI and data analytics tools to optimize operations such as energy usage, lighting, temperature control, and maintenance scheduling. For example, smart lighting systems automatically adjust brightness based on occupancy and natural light, while smart security systems use cameras and analytics to monitor safety [17].

In the academic domain, a smart campus supports personalized learning and digital collaboration. Smart classrooms equipped with interactive boards, high-speed networks, and AI-powered learning platforms enable students to access digital resources anytime and anywhere. AI systems can analyze learning patterns to offer tailored content and feedback, promoting more effective education. Additionally, smart campuses incorporate smart administration, where digital platforms automate processes such as attendance, fee payment, scheduling, and record management. Mobile apps or web dashboards provide students and faculty with real-time updates about campus events, transportation, and resources [18]. Overall, a smart campus fosters sustainability, efficiency, and innovation by combining technology with education. It enhances the quality of learning, ensures better resource management, improves security, and creates an environmentally friendly and connected academic ecosystem that prepares students for a technology driven future.

The deployment of smart campus in HEIs of developing countries faces unprecedented challenges one of them being the availability of infrastructure. A smart campus needs to be fully connected to various networks that facilitate communication of interconnected nodes. The meshy type of network combines signals generated by sensors and other computing devices and transmit to the control devices. To achieve this seamless exchange around a campus necessitate HEIs to invest in the network infrastructure [19]. The proper arrangement of campus nodes and network infrastructure to form a smart campus is described by the terminology framework or model of the smart campus. The author in Ref. [20] presented a framework for a smart campus that was developed by CISCO one of the giant vendors of ICT equipment. The proposed framework contained nine main aspects that can be covered under the IoT applications of smart campus. The framework includes Energy Management, Bring Your Device/Mobile Learning, Intelligent Digital Signage, Tele- presence in classrooms, Campus Lighting, Campus Wi-Fi, Building Optimization Analytics, Smart Parking, and Campus Operations Centre. The framework recommends deploying IoT in all these nine aspects as it will result in improving the campus quality and efficiency. A five layered IoT enabled smart campus framework was discussed by scholars in Ref. [21]. The framework contained key layers which are sensor and data acquisition layer, compute and infrastructure layer, platform layer, application layer and monitoring layer. The presented framework aimed to help in implementing the sustainability leveraging basic ecosystem. It further integrates the new use cases towards the connected ecosystem and responding to requirements quickly. These large campuses are replica of smart cities and multiple technological innovations in new technologies such as IoT, Artificial Intelligence (AI), Machine Learning (ML) is leveraged in bringing the ecosystem together for implementing applications and making the campuses smart and efficient. The reviewed works show that emerging technologies play a significant role in transforming HEIs into smart campuses. Furthermore, the studies indicate that the popular emerging technologies for smart campuses are cloud computing, IoT, AI and future networks like 5G network technologies. These technologies are discussed in the following sections.

2.1.1 Cloud computing

Cloud computing is defined as a “model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” (NIST, 2011). It is a technological evolution that organizes information technology resources and presents to users as commodities over the Internet. It allows users to customize their IT needs depending on services and available budgets. Cloud computing is described by its basic features which are (i) On-demand self-services, (ii) broad network access, (ii) elastic resource pooling, (iv) rapid elasticity and measured services [22]. Further, cloud computing comprises three primary service models delivered via the Internet: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

In the IaaS model, users create virtual IT infrastructures to perform computing tasks instead of permanently purchasing hardware. This concept is effectively demonstrated through server virtualization, which is enabled by a hypervisor. The hypervisor abstracts physical resources such as processors, memory, and storage into logical resources for Virtual Machine (VM) operations. These VMs share the same underlying hardware while maintaining isolation, privacy, and security of their contents [23]. On top of this infrastructure such as a VM a platform designed to enhance the running and deployment of applications is established. This is referred to as Platform as a Service (PaaS). It provides a development and deployment environment built on IaaS, enabling users to build, test, and deploy applications without managing the underlying infrastructure. A good example of PaaS is the Windows Azure Platform, which allows .NET developers to create and run applications on Microsoft’s infrastructure. Applications developed using the .NET framework can therefore operate either locally or within the Microsoft cloud environment [24]. The Software as a Service (SaaS) model allows users to access software applications that operate on a cloud platform maintained by a service provider. These applications are typically accessed through the Internet using a web browser. Common examples include Google Apps, Oracle on Demand, and SQL Azure. In this model, the service provider manages the software and underlying infrastructure, allowing users to focus solely on their data and business operations. SaaS significantly reduces software acquisition and maintenance costs for organizations since the same application is shared among employees through the cloud rather than installed individually on each computer [25].

Beyond service models, cloud computing also encompasses four deployment models that offer flexibility depending on user requirements. These include (i) public cloud, (ii) private cloud, (iii) community cloud, and (iv) hybrid cloud. A public cloud is a computing platform where a service provider makes IT resources available to the general public over the Internet. Clients subscribe to the provider’s services and access resources remotely, while the provider manages and maintains the infrastructure. Through virtualization, physical resources are abstracted into logical components that can be securely shared among multiple tenants. Each tenant’s data is encrypted and isolated from others, ensuring privacy and security. A private cloud, on the other hand, is deployed exclusively for a single organization to share computing resources among its branches. The infrastructure may be hosted and managed internally or by a third party and is typically smaller in scale than other deployment models. Private clouds are further classified into on-premise and outsourced private clouds based on their hosting and management arrangements. In an on-premise setup, the infrastructure is hosted within the organization’s own facilities, while in an outsourced model, it is managed externally by another provider. Generally, private clouds offer enhanced security, performance, and control compared to other deployment models. A community cloud serves a specific group of organizations that share common goals, such as security standards or compliance requirements. It may be owned and managed either by one of the organizations or by a third-party provider. Essentially, it is a variation of a private cloud shared among multiple organizations with similar missions, allowing them to share infrastructure costs while maintaining tailored control and security. The hybrid cloud integrates two or more different cloud deployment models most commonly the public and private clouds interconnected by standardized technologies to enable data and application portability. This model leverages the strengths of each cloud deployment models to deliver greater flexibility and efficiency [26]. Collectively, the service and deployment models discussed above make cloud computing an ideal platform for implementing smart campus solutions in HEIs of developing countries, eliminating the need for extensive investment in physical infrastructure.

2.1.2 Artificial Intelligence

Artificial Intelligence (AI) plays a transformative role in developing smart campuses, where advanced technologies integrate to create intelligent, efficient, and sustainable educational environments. A smart campus leverages interconnected systems such as sensors, IoT devices, data analytics, and AI algorithms to optimize campus operations and enhance the overall learning experience [27]. AI helps automate administrative tasks like attendance monitoring, scheduling, and resource allocation, improving efficiency and reducing manual workload. Through intelligent surveillance and predictive analytics, AI systems enhance campus security by identifying unusual activities or unauthorized access in real time. Moreover, AI driven energy management systems analyze usage patterns to optimize lighting, heating, and cooling, thereby reducing energy consumption and promoting sustainability. In smart campus, AI is the cornerstone technology to implement personalized students training. It also helps teachers to perform predictive analysis and identify risks of students and find appropriate preventive measures on time.

In the academic sphere, AI enhances teaching and learning through personalized education and data-driven insights. Intelligent tutoring systems can adapt to each student's learning style and pace, providing customized feedback and recommendations to improve performance. AI powered chatbots and virtual assistants support students by offering high accessibility to information about courses, campus facilities, or administrative services. Predictive analytics can help identify students at risk of poor performance or dropout, enabling early intervention by faculty or counselors [28]. Additionally, AI aids in researching by automating data analysis, pattern recognition, and simulation tasks. Smart campuses also benefit from AI-based traffic and crowd management systems, ensuring safety and efficient movement across facilities. Overall, AI transforms traditional campuses into dynamic, connected ecosystems that foster sustainability, security, and personalized education [29]. By integrating AI technologies, institutions can not only enhance operational efficiency but also create engaging, adaptive, and inclusive learning environments that prepare students for future digital challenges.

2.1.3 Internet of Things

IoT is one of the emerging technologies that enables interconnection of sensors and other devices to monitor and control the environment of a smart campus [21]. Together with other technologies such as AI, the IoT facilitates the creation of an intelligent environment which is one of the features of a smart campus [30], [31]. Usually, the data transferred through IoT require minimum delay between the time of incidence detection and control decision. For this reason, the design of the network should ensure a low latency link between the sensor and controller. IoT has been widely adopted in various fields that target to add intelligence in their business process. For instance, a study by Mandari [32] demonstrated the adoption of IoT to improve the mobile payment system in Tanzania. Another study by Ahammed and I. Khan [33] discussed the enhancement of energy meters using IoT to ensure the balancing between the demand and supply side of energy in the context of developing countries particularly, in Bangladesh. Even further, IoT has widely been deployed in other sectors such as agriculture to improve productivity [34]. In a smart campus of HEIs, the learning environment is monitored by a series of interconnected devices that collect, process and share information through IoT [35].

The general architecture of IoT consists of four layers which are Sensing, network, middleware/processing and application layer. The sensing layer is made up of the physical layer that collect data from the environment using electronic devices such as sensors, actuators, RFID tags, cameras, and GPS modules. Then it converts physical parameters such as temperature, motion, light, or pressure into digital signals. The interaction between the control and the sensing layer is facitated by the actuators that receives and act upon the commands transfered from the control to the sensors through a network [35]. The network layer transmits the collected data from sensing devices to other layers through wired or wireless communication technologies such as Wi-Fi, Bluetooth, ZigBee, LTE, and 5G. It ensures reliable data routing, transmission, and communication between IoT nodes and cloud platforms. This layer also handles device addressing and security during data transfer. The information collected by the sensors, reach the procesing layers for the analysis and decision making to enhance automation. In general, the processing layer provides data storage, processing, and management functions, often implemented using cloud or edge computing. It integrates big data analytics, artificial intelligence, and machine learning to extract meaningful insights from the raw data. Furthermore, the processing layer also offers interoperability among heterogeneous IoT systems through standardized APIs and protocols [36]. The application layer delivers user-specific services based on processed data. It includes a wide range of domains such as smart homes, healthcare, agriculture, transportation, and industrial automation. The layer evetually interfaces with end users through dashboards, mobile apps, or web portals to enable decision-making and control. Leveraging the benefit of IoT powers HEIs to efficiently utilize their real estate resources such as electricity, water and infrastructure capacity. Also by taking advantages of other technolgies such as AI and Bigdata analytics, HEIs can predict class students enrolment and class attendance that helps in preparing sufficient budegt that meet the actual demands of the institutioin [37].

2.1.4 5G Network Technology

In the last two decades, the mobile network technologies have experienced a tremendous growth from 1G through 5G mobile network technology. Studies suggest that 5G is key technology for achieving most of the sustainable development goals, and hence several countries have started adopting this technology [38][39]. For example, the report by the Tanzania Communication Regulatory Authority (TCRA) reveals that the penetration of 5G network among the Tanzania population has reached 13% [40]. Unlike its predecessors, 5G supports data broadband services up to 10Gbps download speed. Further, it supports ultra-reliable and low-latency communication (uRLLC) with a delay less than 1ms [41]. Additionally, 5G supports massive machine-type communication (mMTC) with the ability to connect up to 1 million IoT devices per square kilometer [42]. This feature is essential for deploying many sensing devices for data collection in a smart campus. Also, 5G network presents a solution for most of HEIs that struggle to maintain infrastructure for local area networks (LANs). Its supports virtual campus LANs known as 5G smart campus where HEIs can deploy LANs without required to build physical LAN [43]. The 5G Campus network may be implemented using a stand-alone (SA) or non-standalone (NSA) structure. In the NSA architecture, 5G campus network is deployed by using a legacy 4G Long Term Evolution (LTE) base station. The end devices transfer packets via a control plane to the evolved packet core (EPC). In contrast to SA architecture, the data plane is provided exclusively by a 5G New Radio (NR) base station and 5G core (5GC) which neither access 4G LTE base station nor its spectrum resources [44]. With these features, 5G technology presents itself as the most suitable communication technology for cost effective deployment of smart campus in developing countries [45].

2.2 Related Studies

The studies on smart campus are increasingly becoming a hot area of research as HEIs strive to modernize the methods to deliver education by using cutting-edge ICT technologies. These technologies reduce human intervention by automating processes through digital means. Several studies have been documented that investigate various issues relating to smart campus. The study by Dong et al. [36] focused on the introduction to the concept of smart campus. It further highlights the technologies on some of important technologies that makes a campus smart. In an attempt to harness the strength of smart campus in to benefit University education the study by Wahid et al. [46] proposes a smart campus framework that focused on some services such as smart academic services, smart learning system, smart blended system, and smart equipment solution. The framework presented aims at solving most of university level education system problems based on multimedia and information systems available on the campus. Studies reported by Ref. [47]–[49] further delve into smart campus frameworks and important indicators for assessing the smartness of university campuses. These studies reveal a critical point to the deployment of smart campus in HEIs. The study by Polin et al. [47] uses a narrative literature review to identify indicators for assessing smart campus followed by developing its corresponding smart campus framework. The identified indicators for smart campus proposed by Polin et al. [47] were also supported in the studies by Achmad et al. [48] and Szendi [49].

Several HEIs have attempted to transform their campuses into smart campuses by using various technologies such as IoT [20][50]. For instance a study of Ref. [51] presents a framework for a smart campus of a Covenant University. The framework aimed to improve energy efficiency and management in the University using IoT enabled system. Similariy, another study reported by Ref. [9] describes a different framework for smart campus of Universiti Tun Hussein Onn Malaysia (UTHM). The framework is expected to improve features such as academic, research, student experience and services. Furthermore, the authors in Ref. [9] argue that different actors of smart campus have different needs that may different frameworks to transform/migrate into a smart campus. Scholars in Ref. [52] also state that currently there is not a generic framework for smart campus deployment and each player identify the context needs to derive smart campus.

2.3 Limitation of the Present Studies

There are a lot of information in the literature about the frameworks for the deployment of smart campus in HEIs. Smart campuses improve efficiency of HEIs in delivering educations services and living experience through the use of technologies. Scholars argue there is no a general framework for the deployment of smart campus, because most of the frameworks depends on the needs, requirements and context of a given actor [9][52]. To the best of our understanding, this study is of its own as it explores the features of smart campus from literature by using a Systematic Literature Review (SLR). Further, by using a survey method, this study assesses the status of smart campus in HEIs of Tanzania and identify the most relevant features that are essential for developing of smart campus framework in the context of Tanzania.

3. RESEARCH METHODS

This study uses two methods called SLR and Survey to review features of a smart campus and assess their status in HEIs of Tanzania. Through SLR, we carefully examined the features that were deployed in most of HEIs in developing countries. Then, the survey was used to investigate the status of smart campus in some selected HEIs of Tanzania. The triangulation of these methods is useful for understanding the relevance of smart campus features extracted from the literature in the context of Tanzanian HEIs. Further, we used an ordinal logistic regression model to determine an appropriate framework that maps the predictor variables to the smart campus of HEIs in Tanzania.

3.1 SLR Method

The Systematic Literature Review (SLR) was conducted to systematically identify smart campus features that are significant in the context of developing countries. The review followed the guidelines established by Kitchenham and Charters which outline structured procedures to assist researchers throughout the research process [53]. These guidelines help in recognizing potential biases, methodological flaws, and gaps in existing knowledge, while also suggesting directions for future research. Additionally, the study in Ref. [54] outlines the key steps involved in conducting a SLR which are (i) Formulating a clear research question, (ii)

Defining inclusion and exclusion criteria, (iii) Identifying relevant studies, (iv) Selecting studies for inclusion or exclusion, (v) Assessing the quality of the selected studies, (vi) Extracting pertinent data, (vii) Summarizing and synthesizing the evidence, and (viii) Interpreting the findings.

3.1.1 Planning the Review

The first step of the proposed methodology was to formulate strings to guide the searching process. The key strings used for searching are *"smart campus framework*" OR *smart campus model*" OR *smart campus in developing countries*". The exclusion criteria were as follows; (i) all articles that were not written in English language, (ii) reports from thesis, and (iii) non-reviewed publications. The search was conducted using four electronic research database which are (i) Google scholar, (ii) Science Direct, (iii) IEEE Xplore Digital Library, and (iv) Semantic Scholar. In total, 90 publications were collected from the databases. Twenty-seven (27) articles were from Google Scholar, 37 from ScienceDirect, 17 articles from Semantic Scholar, and 9 articles from IEEE Xplore Digital Library as shown in Figure 1.

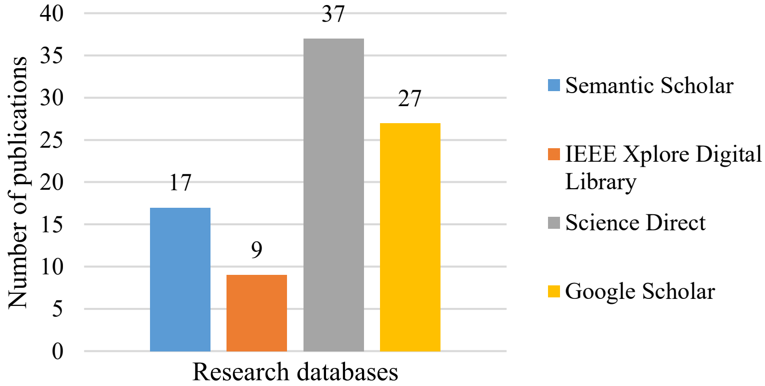

Figure 1. Extracted articles from the selected research databases

3.1.2 Executing the Review

The articles were tabulated in a column of a table that recorded the names of authors, titles and abstracts. The team scanned the titles, abstracts, and conclusion of each article to understand the content presented in the articles. By considering inclusion and exclusion criteria articles that qualified for the review were selected by following a PRISMA method as indicated in Figure 2.

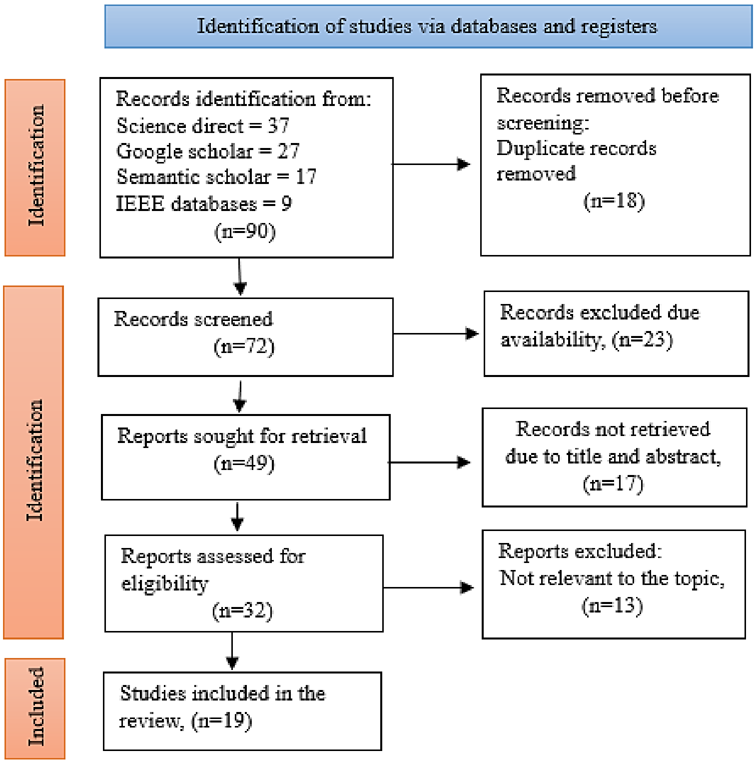

Figure 2. PRISMA flow diagram of the study

3.1.3 Observations from the Literature

This study collected 90 publications related to the research questions under investigation and later reduced to 19 articles that were used for a SLR. It was found that eleven (11) indicators were frequently used in various smart campus frameworks. The most occurring indicator is smart environment with 15.6 % of occurrence frequency. It denotes means of preserving environment of the campuses. These include lifestyles at the campus which promote clean and natural environment by protecting the environment to ensure zero waste. Furthermore, it involves secured and connected areas that integrate renewable energy sources as opposed to other sources that pollute the environment. Smart buildings and smart technology were the second and third indicators each with 13% of occurrence frequency in the frameworks. On one hand, smart buildings, they present interactive buildings that efficiently utilizes resources such as water and electricity. They also recognize authentic users and grant them access to the facility. On the other hand, the smart technology presents mechanisms for collecting data through sensors, transmitting through IoT, processing and making decision through data analytics and AI. Besides that, smart education ranked fourth among smart campus indicators, and scored 10.4% of occurrence frequency in the reviewed frameworks.

Furthermore, smart governments involve procedures and guidelines to ensure the protection of information and data in the storage. It also defines the level of authority in accessing information essential for the running of an organization. In this review, smart government ranked as the fifth indicator of smart campus and scored 9.0% of occurrence frequency. Another smart campus indicator called smart people scored 7.8 % and ranked sixth, followed by smart economy, smart society, smart living and smart mobility were ranked as seventh, eighth, ninths and tenth respectively and both indicators scored 6.5% of occurrence frequency. The features that received the least score is smart security with a score of 5.2% and ranked eleventh in the list of indicators extracted from the literature as shown in Table 1.

Table 1. Smart campus features

S/N	Reference	Indicators										
		SEC	SS	SEN	SGV	STE	SED	SL	SMB	SSC	SB	SPP
1	K. Polin et al. [47]	√	√	√	√	√						
2	K. Polin et al. [1]	√	√	√	√							
3	N. Li et al. [15]					√						
4	P I. Silva-da-Nóbrega et al. [11]	√		√		√	√	√	√	√		
5	M. Musa et al. [9]				√			√		√	√	
6	D. E. Popescu et al. [8]					√	√					
7	Z. Y. Dong et al. [36]	√	√	√		√					√	
8	Z. N. Kostepen et al. [50]			√	√		√				√	
9	E. M. Malatji [55]	√		√			√	√	√			√
10	H. Al Akbar et al. [18]			√				√	√	√	√	√
11	K. AbuAlnaaj et al. [20]					√	√		√	√	√	
12	W. Muhamad et al. [3]		√	√	√		√					√
13	S. Luckyardi et al. [35]		√	√	√		√					√
14	N. Chagnon-Lessard et al. [14]				√	√		√	√		√	√
15	D. Das et al. [56]			√		√						√
16	T. Omotayo et al. [19]					√	√				√	
17	T. M. John et al. [51]										√	
18	M. Al Rawajbeh [57]			√							√	
19	R. Jurva et al. [58]			√		√					√	
Indicator frequency		5	5	12	7	10	8	5	5	4	10	6
Indicator percentage frequency (%)		6.5	6.5	15.6	9.0	13	10.4	6.5	6.5	5.2	13	7.8

Key: SEC= Smart Economy, SS= Smart Society, SEN= Smart Environment, SGV= Smart Government, STE=Smart Technology, SED=Smart Education, SL= Smart Living, SMB= Smart Mobility, SSC= Smart Security, SB= Smart Buildings, and SPP= Smart People.

3.2 Survey Method

A survey was conducted to investigate the status of smart campus deployment in HEIs of Tanzania. The study aimed at all registered HEIs that are currently operating in the country. An online questionnaire was prepared and distributed to HEIs in Tanzania to collect the opinions of staff and students on smart campus status in their institutions. A list of fifty-five (55) HEIs that formed a sampling frame was extracted from the website the Tanzania Commission for Universities (TCU)[1]. An online questionnaire remained active receiving responses from respondents for two months of June and July, 2025.

A random sampling method was used to select twenty-eight (28) HEIs from the extracted sampling frame. Further, convenient sampling was used to recruit respondents from the selected HEIs, where a link of the questionnaire was sent to a contact person who then shared it to the respondents. A total of 74 respondents filled in the questionnaire to provide their opinions on the status of smart campus features available in their institutions.

Respondents were asked to fill in their demographic information, experiences on using information and communication technology tools, as well as their understanding on smart campus features. Eventually, respondents were asked to provide their opinions on smart campus features that are present in their campuses. The opinions were measured by using a five-point Likert scale that ranges from 1 to 5. The labels are defined as follows: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly agree.

3.3 Data Analysis

3.3.1 Descriptive Analysis

The total of 74 respondents filled and submitted their responses through the online questionnaire. Their ratio was 70.3% male and 29.7% female with over 1 year experience of using internet and networked services. Their percentage age distribution 15-25 years (70.3%), while those between 26 and 35 years made 12.2%, followed by 36 to 45 years with 9.5% and lastly respondents aged above 46 years made 8.1% of the total respondents. Over 50% of respondents reported that their campuses have attained a feature of SSP due to the presence of mandatory introductory courses on ICT. This awareness to ICT enables them to be in a position of using various available technologies at the campus and hence improve their SL as reported by 43% of respondents. Moreover, 41% of respondents suggest that their campuses have attained a SED by being able to assess teaching and learning materials in their convenience by using ICT. The fifth and sixth features are SVG and SS which had 36% and 35% observations respectively. The availability of guidelines and policies that provide guidance on technology deployment and utilization makes the people involved aware of the technology and its applications, hence creating a SS. Nevertheless, other features such as SEC, SEN, STE and SB were observed to irrelevant for smart campus of some HEIs in Tanzania as depicted in Figure 3.

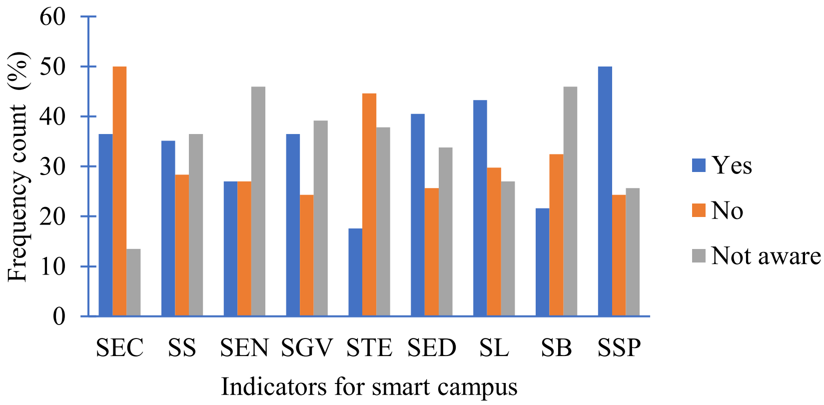

Figure 3. Status of smart campus features in selected HEIs

3.3.2 Inferential analysis

The ordinal logistics regression was conducted to determine the influence of investigated variables on students and staff perception on smart campus status of their HEIs. In this analysis, we examined the opinion of users on the influence of variables that were extracted from literature. To test the validity of the extracted variables, a hypothesis was formulated and tested to understand its validity.

i. Hypothesis:

H_0: The predictors included in the model do not significantly improve the fit of the model compared to the intercept only model.

Since the p-values of the chi-square test is 0.001 which is less than 0.05, we can say that the difference of the model with intercept only and final model is significantly. The predictor variables are age group, gender, experience, network infrastructure, SEN, SB, SED, SGV, SPP, SEC, SS, SL and STE. Because the null hypothesis is rejected, we conclude that the predictor variables significantly improve the model's fit compared to the model with no predictor variables as depicted in Table 2.

[1] https://www.tcu.go.tz/services/accreditation/universities-registered-tanzania?page=2

Table 2. Model Fitting Information

Model	-2Log Likelihood	Chi-Square	df	Sig.
Intercept only	208.746			
Final	127.011	81.735	47	0.001

Link function: Logit.

Goodness of Fit

A goodness of fit test in general refers to measuring how well do the observed data correspond to the fitted(assumed) model. The Pearson Chi-Square statistic tests the extent observed frequencies match the expected frequencies under the model. With high p-value (0.083), it indicates that the model predicted frequencies do not significantly differ from the observed frequencies. Therefore. this observation suggests that the model fits the data well and there is no significant different between observed ad expected values. Similarly, Devance Chi-Square is another static measure of goodness of fit, that compare the likelihood of the fitted model to the likelihood of a saturated model. High p-value (1.000) indicates that the model fits the data well. These results confirm that the ordinal logistic regression model is an appropriate fit for the data as shown in Table 3.

Table 3. Goodness of Fit

	Chi-Square	df	Sig.
Pearson	353.516	318	0.083
Deviance	127.011	318	1.000

Link function: Logit.

Impact of Predictor Variables on Smart Campus

In this study we found that the Age predictor variable has a p-values greater than 0.05, meaning that it has no significant impact on the likelihood of affecting the perception of smart campus observed by different age categories of respondents. Moreover, the male respondents were more likely to perceive smart campus features in their HEIs compared to female respondents as the p-value for this predictor higher than 0.05. Similarly, the experiences of using ICT devices were not found having any significant effect on the perception of smart campus. The network infrastructure predictor variable had a p-value less than 0.05 which indicate that its impact on smart campus n HEIs is significant. Moreover, in this study we found that students who had less access to network infrastructure in their HEIs were more likely to perceive smart campus features compare to those respondents who had good network infrastructure. Other predictor variables such as SEN, SB and SED were found not to be significant in the likelihood of categorizing a HEI a smart campus or not because their p-values was greater than 0.05. This trend was also observed for other features such as SPP and SED, where the presence of smart people programs and smart education facilities were not perceived as critical features for respondents to perceive them as smart campus features in their HEIs. The SGV predictor variable was significant as its p-value was is less than 0.05, and respondents who had experienced this feature were more likely to view a smart campus in their HEIs than those did not have interacted with such phenomenon. This is the same for other predictor variables like SPP, SEC, SL and STE. The scores of each predictor variable are presented in Table 4.

4. RESULTS AND DISCUSSION

The smart campus is a complex concept that embraces the uses of digital technologies to enhance learning at HEIs. Various studies suggest variables that should be included in frameworks that describes a smart campus for HEIs. In the reviewed literature, SEN feature was highly mentioned as key indicator of a smart campus [18]. However, this study found that SEN indicator is not considered as a significant indicator as its p-value was higher than 0.05. This means most students do not view a campus with pre-installed sensors to monitor the surroundings a necessary feature for their campus to be smart. The second most mentioned smart campus indicators are the STE and SB. This involves the deployment of technologies that assist in teaching apart from projectors and a building that possesses a certain level of intelligence to monitor utilities and electricity. Despite its relevance in developed world, SB was not seemed as a necessary indicator of smart campus in HEIs. This perception might be due to its indirect contribution to facilitating teaching and learning. Nonetheless, the study agrees with previous scholars such as in Ref. [11] and [15] that STE was the third most significant feature of a smart campus. The deployment of STE facilitates connectivity and applications of digital technologies that enhances teaching and learning at HEIs. In addition to STE, the literatures suggested that SED as the fourth key feature a smart campus [19]. This feature indicates the application of digital systems and technologies by HEIs to delivering education to its students. This feature significantly influenced the perception of those students who do not have access to the digital systems for e-learning more than those who have access to it.

Table 4. Ordinal logistic regression results

Predictor Variable	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
[Q1_Age_group=1]	-2.758	1.524	3.277	1	0.070	-5.744	0.228
[Q1_Age_group=2]	-2.882	2.095	1.891	1	0.169	-6.989	1.225
[Q1_Age_group=3]	-1.828	1.959	0.871	1	0.351	-5.667	2.011
[Q1_Age_group=4]	0[a]			0			
[Q2_Gender=1]	2.328	1.113	4.372	1	0.037	0.146	4.510
[Q2_Gender=2]	0[a]			0			
[Q3_Respondent_Experience=1]	-2.275	1.804	1.591	1	0.207	-5.810	1.260
[Q3_Respondent_Experience=2]	-0.110	0.851	0.017	1	0.897	-1.777	1.557
[Q3_Respondent_Experience=3]	0[a]			0			
[Q6_Network_Infrastructure=0]	3.036	1.188	6.531	1	0.011	0.708	5.365
[Q6_Network_Infrastructure=1]	0[a]			0			
[Q17_SEN=0]	1.458	1.063	1.880	1	0.170	-0.626	3.542
[Q17_SEN=1]	0.581	1.098	0.280	1	0.597	-1.571	2.732
[Q18_SB=0]	1.600	1.044	2.349	1	0.125	-3.646	0.446
[Q18_SB=1]	0.033	1.268	0.001	1	0.979	-2.519	2.454
[Q19_SED=0]	2.333	1.224	3.634	1	0.057	-0.066	4.733
[Q19_SED=1]	0.654	1.079	0.367	1	0.545	-1.461	2.769
[Q20_SGV=0]	1.035	1.300	0.634	1	0.426	-1.512	3.582
[Q20_SGV=1]	4.009	1.411	8.074	1	0.004	-6.775	-1.244
[Q21_SPP=0]	-2.981	1.239	5.790	1	0.016	0.553	5.409
[Q21_SPP=1]	3.080	1.384	4.955	1	0.026	0.368	5.792
[Q22_SEC=0]	2.802	1.393	4.046	1	0.044	0.072	5.533
[Q22_SEC=1]	-1.828	1.342	1.856	1	0.173	-4.459	0.802
[Q23_SS=0]	-0.073	1.095	0.004	1	0.947	-2.220	2.074
[Q23_SS=1]	1.630	1.183	1.900	1	0.168	-0.688	3.949
[Q24_SL=0]	-3.323	1.601	4.308	1	0.038	-6.460	-0.185
[Q24_SL=1]	-7.182	2.026	12.570	1	0.000	-11.152	-3.212
[Q25_STE=0]	2.332	1.386	2.831	1	0.092	-0.385	5.049
[Q25_STE=1]	5.946	1.816	10.721	1	0.001	2.387	9.506

The fifth indicator discussed in the literature is SGV as a link to access government services through digital applications [50]. In this study, the respondents who had access to government digital systems perceived it is one of necessary features of a smart campus because it got a p-value of less than 0.05. HEIs interact with government systems while accessing for loans and grants for their students. And in this case, a digital platform seems to be relevant to ease the processes and that is why this component has received a significant perception as one of the features of a smart campus. In addition to that, SPP was the sixth recommended feature of a smart campus. It refers to a good level of digital literacy of people to engage with digital platforms and services. The findings of this study agree with the recommendation of scholars such as in Ref. [14] and [35] that SPP should be included in a smart campus feature because its p-value was less than 0.05. The seventh highly ranked features by the literatures were SEC, SS and SL. With SEC features, HEIs students have access to various digital platforms that provide economic services such as digital currencies. The study found that those respondents who did not have access to these services were more likely to perceive SEC as a feature of a smart campus than those who had accessed SEC. With SS feature, it was not considered a significant feature, as it did not seem to affect the respondents in any way. Lastly the SL feature was found to be significant for the smart campus framework in HEIs, because SL summaries the ultimate goal of deploying digital systems, applications and sensors to make HEIs smart campuses [18].

5. CONCLUSION

In this study we have reviewed various smart campus feature and frameworks of different HEIs around the globe. We further collected opinions from different HEIs in Tanzania to test the significcance of smart campus features that were extracted from litearures. We then used an ordinal logistic regression to test the relationship between the found features and smart campus.We found that network infrastructure, smart governance, smart people, smart economy, smart living, and smart technology were more likely agreed to present a smart campus in Tanzania HEIs. Another followed features is the smart education that was marginally accepted as its p-value was 0.057. Features like smart environment and smart buildings were not perceived as an important features for smart campus in HEIs of Tanzania. Based on these findings, we reveal the most important features that one must pay attention when designing and deployng a smart campus for HEIs in Tanzania. The design must give priority to the services and features that are most likely to be accepted by many users and hence, create a campus that will offer a better user experience.Nonetheless, the results of this study may be limited by the sample size of respondents and HEIs that participated in data collection and a convenient sampling method that was adopted during data collection. We therefore recommend future studies to consider other sampling approach. In addition to that, framework provides only description of features that are supposed to be provided by the smart campus of HEIs, but not a technical detail of smart campus architecture. It is important for other scholars to explore the technical details of architecture for the smart campus of HEIs in the context of developing countries.

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