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Review of IoT Applications in Indian Smart Campuses:A Theoretical Survey

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Introduction:

The smart campuses are intelligent and offer a quick return on investment for the stakeholders. The focus is on operational efficiency, such as energy savings, reduced downtime, and end-user comfort, utility, and experience. The Internet of Things (IoT) represents an interconnected ecosystem of physical objects embedded with sensors and connectivity features. Through cloud computing platforms, these devices can communicate with each other, exchange real-time data, and interact with their environment in intelligent ways. The study identifies critical components within a "Smart and Digital Green Educational Campus" paradigm. Internet of Things technology serves as the enabling infrastructure for implementing smart campus capabilities. Smart campuses are divided into the implementation across three broad areas, which need to have a sustained focus to achieve the smart campus operational efficiency and functionalities.

Overview:

In recent years, as per norms, requirements raised by various educational agencies and Indian campuses have been changing. Nowadays, to transform administrative workflows, academic environments, campus sustainability, and the student experience, the use of the IoT is essential. University campus infrastructure to lay the foundation for the evolution of smart campuses. Indian scholars have addressed various issues in several foundational papers and blueprints for IoT-based smart campuses, with an emphasis on scalable infrastructure, intelligent energy management, real-time monitoring, and personalized services. This review paper consolidates insights from 31 significant academic papers authored by Indian and foreign researchers, highlighting key IoT use cases, challenges, and the technological trajectories envisioned for smart campus development in India. This review paper includes 2019 onwards theoretical work and highlights the following 7 points.

1. Infrastructure and Systems Design
2. Smart Classrooms and Academic Facilities
3. Security, Surveillance, and Health Monitoring

4. Smart Energy and Resource Optimization
5. Environmental Monitoring and Sustainability
6. Transportation and Mobility
7. Adoption Barriers and Implementation Challenges

Amaral et al. (2015) note that sustainability debates have engaged the international community since the 1970s. While early discussions were ongoing, the formalization of sustainability concepts occurred after the 1980s, reaching a milestone with the 1987 World Commission on Environment and Development report, referred to as "The Brundtland Report," which provided precise terminology. “Nejati and Nejati, (2013) explain sustainability as development that meets the needs of the present without compromising the ability of the future generations to meet their own needs”. Velazquez et al. (2006) observe that sustainability subsequently emerged as a priority across higher education, government, and corporate sectors.[1]

Agarwal et al. (2020) research paper a five layered IoT Framework has been presented for smart campuses which can help in quickly implement the use cases. The proposed framework can be used to onboard new COVID-19 use cases quickly. A three-step process consisting of ideate, validate and implement can be utilized to identify, develop and implement use cases. These cases implemented can be integrated with the enterprise layer of the organization with ease.

Security and surveillance are becoming increasingly stagnant as the area of campus is wider and it is situated in various cities and number of footsteps are more. During the COVID-19 pandemic situation further increased the campus operational challenges with design and implementation of interconnected IoT devices, sensors, and communication protocols for campus-wide monitoring. Application Areas are health monitoring, occupancy tracking, contact tracing, environmental sensing, and resource management systems. Educational institutions and large organizational campuses requiring pandemic-ready infrastructure. Creation of a systematic approach to integrate various IoT components into a cohesive smart campus ecosystem. The scope likely encompasses both theoretical framework development and practical implementation guidelines for IoT-based smart campus systems with specific emphasis on COVID-19 preparedness and response capabilities. Carbon neutral, energy efficiency, water usage reduction, green energy requirement are included in sustainability focuses. IoT based implementation to deploy new projects and use cases. The paper presents a five layered Framework helping in implementing the sustainability leveraging basic ecosystem. It integrates the new use cases towards the connected ecosystem and responding to requirements quickly. These large campuses are replica of smart cities and multiple Smart Campus development relies on combining contemporary

technologies—including IoT sensors, AI systems, and ML algorithms—to create interconnected solutions that enhance operational efficiency and improve campus experiences.[2]

Researchers Aruna, K. and Pradeep, G. explored how containerization enables diverse applications across various domains to meet evolving technological demands. Containers facilitate multitasking capabilities and allow integration of different frameworks, technologies, fields, and application types. This flexibility accommodates growing user and system demands, with scalability options based on specific requirements. The container approach provides self-organizing capabilities that enhance application performance.

Their research proposes using container technology within IoT and Fog of Things environments to deploy numerous IoT services. These services operate through gateway devices, delivering specialized functionality to connected endpoints. Beyond traditional data processing and storage, fog computing infrastructure maintains IoT services through distributed FoT servers.

The primary objective of their study is to evaluate how container-based architectures with cluster management can scale IoT systems effectively. This methodology supports larger numbers of connected devices while improving network performance, computational efficiency, control mechanisms, and data storage capabilities.[3]

“Ashish P. Dhakan, MD and CEO, Prama Hikvision India Private Limited wrote an article on Smart Campus trend.” This case study focuses on India’s fast growing education sector through digital transformation and smart security solutions. A Smart Campus is an aspirational mandate in the Indian educational scenarios, where most of the educational institutions grapple with challenges of resources and fund allocations. Practitioner-oriented piece outlining steps and available product categories, budget considerations and Indian case examples. The Indian government has launched policy initiatives such as bills addressing accreditation standards for higher education institutions and foreign university operations. The country's education industry is anticipated to expand to approximately US$ 225 billion within the next few years. Now the Smart Campus concept is getting popular in India and some of the few high profile educational institutions have implemented the Smart Security, Automation, Sustainability and Digital Transformation mandate in all their branches and affiliate institutions. [4]

British council detailed report for global higher education sector today internationalisation of teaching and research are critical objectives for most tertiary institutions for many reasons. Policy reforms by India's government include proposed legislation for institutional accreditation oversight and guidelines for foreign educational entities. The domestic education market is expected to achieve a valuation of

approximately US$ 225 billion in the near future. pages detailed report includes various figures, charts based on primary data from various countries. International academic partnerships in research rose from 25 percent fifteen years prior to more than 35 percent by 2010. Although precise figures for cross-border collaboration in teaching and research for 2020 remain challenging to determine, the overall trajectory shows continued growth. [5]

Cavus, N., Mrwebi et. al. written a systematic literature review (SLR) in 2022 on IoT and its applications to Smart Campus. The objective of this investigation is to pinpoint critical IoT components necessary for smart campus development. Using systematic review methods and PRISMA protocols, the study analyzed quality research articles on IoT campus applications from a five-year period (2017-2022) across three academic databases: Scopus, ScienceDirect, and IEEE. The analysis demonstrates that IoT-integrated campus systems deliver significant value, though certain challenges remain that require further research attention. Implementation of IoT-based smart campuses shows many benefits and advantages that are identified key challenges. IoT-based smart campus is helpful for every one like researchers, policymakers, teachers, and students. The study reveals that IoT-based smart campus implementations offer significant advantages and benefits, including improved university services and processes, enhanced teaching and research activities, progress toward sustainability goals and integration of advanced technology into higher education.[6]

The study by I. A. Ghashim et.al examines the current state of the Internet of Educational Things and how it can be used to improve educational outcomes. It highlights how IoT can lead to enhanced learning experiences, increased operational efficiency, and the collection of real-time, actionable insights into student performance.

The high cost and technology awareness gaps are a big barrier to implement the Smart Campuses in India. As India's economy and stature is on the rise, we can be hopeful that there will be many more smart campuses along with smart cities in near future. One thing is for sure, Smart Campus trend can help to achieve Viksit Bharat -2047 goal through Digital Transformation and Smart Security initiatives. Main points are Personalized Learning by using IoT devices like smart tablets, wearable technology, and sensors can track student behavior, performance, and engagement in real time. IoT emphasis on Smart Classrooms which is based on cloud-synced smartboards, voice-activated assistants, and sensors that automatically adjust lighting and temperature and automated attendance tracking through RFID tags or facial recognition saves valuable time for teachers.[7]

"Lessons Learned: A Smart Campus Environment Using LoRaWAN (Long Range Wide Area Network)" wrote by Hari Prabhat Gupta focuses on Long Range Wide Area Network deployment in smart

campuses, tackling issues like network parameter tuning, mobility, and reliable communication. The implementation of LoRaWAN technology in constantly changing settings like smart campuses introduces complex optimization challenges. Network administrators must carefully balance multiple parameters—including spreading factor allocation, transmission power levels, and device mobility management—to maintain dependable connectivity throughout the network.

This research begins by examining the foundational principles that distinguish short-range from long-range wireless protocols, highlighting why LoRaWAN offers particular benefits for specific use cases. We then explore intelligent spatial computing architectures that leverage the synergies between Edge, Fog, and Cloud layers. These distributed computing models, when properly integrated with both proximity-based and extended-range communication technologies, enable sophisticated real-time data analytics and responsive decision-making capabilities. The core contribution focuses on our campus-wide LoRaWAN deployment experience. Our work offers a thorough examination of the techniques implemented and the outcomes obtained, providing practical insights for similar deployments. Implications for future research and practical applications in IoT-enabled smart environments. [8]

IoT plays a critical role in environmental awareness and smart waste management. IoT-based environmental monitoring systems, such as the one described by Hossain et al. (2019), are crucial for promoting environmental awareness and sustainable practices. These systems integrate various sensors to collect real-time data on key environmental parameters. For instance, air quality sensors measure pollutants like carbon monoxide and particulate matter, while meteorological sensors gather data on temperature, humidity, and wind speed. This data is then processed and presented on sustainability dashboards, providing administrators and the public with a clear, actionable overview of environmental conditions. This real-time visibility helps in decision-making, such as implementing stricter pollution controls or adjusting campus operations to reduce environmental impact. The integration of such technology not only enhances environmental management but also serves as an educational tool, raising awareness among students and staff about their environmental footprint.[9]

IoT is a key tool for improving the sustainability of educational institutions. Smart meters and sensors Significant energy savings are achievable through adaptive environmental control mechanisms that modulate illumination, space heating, and climate control systems based on detected occupancy levels.

This reduces operational costs and promotes environmental conservation. It also improves asset and inventory management, such as tracking lab equipment and library books, which further enhances efficiencies. IoT-based systems, including surveillance cameras, smart locks, and access control, can

monitor buildings in real time and send alerts during emergencies, ensuring the safety of students. Modern technology provides more inclusive learning opportunities for students with disabilities. IoT-enabled devices like connected hearing aids, voice-to-text applications, and assistive technologies help learners access quality education. A smart campus integrates servers, peripheral devices, physical infrastructure, and users through Internet of Things (IoT) technology. By leveraging interconnected networks and IoT systems, various campus facilities are unified on an IP-based network. This includes exterior lighting systems, building management systems for illumination and HVAC, energy distribution networks, video monitoring systems, electronic access control, and vehicle parking areas.

This integrated approach allows all campus facilities to operate on a shared IoT infrastructure. The implementation of smart campus technology enables innovative services such as location-aware applications, context-sensitive features, automated parking management, adaptive lighting systems, intelligent transportation solutions, and responsive building climate management.

Safety and security within the campus with connected surveillance IP cameras, smart locks, asset tracking and smart emergency services. It enables tracking of the facilities / resources and use them more efficiently. This helps in reducing the cost by the intelligent use of water, electricity and building controls. Innovative learning environment in a smart campus Smart campus technology improves both educational results and the overall student experience while upgrading institutional facilities and streamlining operations. Additionally, these systems promote environmental sustainability by optimizing energy consumption and minimizing carbon emissions, contributing to an eco-friendly campus environment.

This study explores the significance of implementing sustainable campus infrastructure. An environmentally conscious campus utilizes networked computing systems and server infrastructure built on proven technological foundations to support its operations.[10]

“Narrowband-IoT (NB-IoT) and IoT Use Cases in Universities, Campuses, and Educational Institutions: A Research Analysis focus on comprehensive literature review of use cases of NB-IoT and general IoT in educational settings. Covers applications such as smart campus management, asset tracking, monitoring, and safety/security systems. It clearly outlines strengths and future potential of Narrow band IoT adoption in campuses. [11]

The paper presented M. A. El. Zuway and H. M. Farkash, on "IoT Security: Requirements, Attacks on SH-IoT Platform," focus on smart building security systems typically consist of sensors and controllers that monitor power operating systems, alarms, camera monitoring, access controls, and many other

important information and security systems. These systems are managed and controlled through online platforms. This paper discusses the security requirements in the application layer of any IoT system were discussed. The role of IoT platforms in dealing with the security problems that smart buildings are exposed to and the extent of their strength to reduce the attacks they are exposed to, where an experimental platform was designed to test the presence of security vulnerabilities. A successful attack on one of these platforms may result in the failure of one or more critical intelligent systems in the building. This was done by using the Zed Attack Proxy (ZAP) tool, according to the OWASP standards and security level assessment. This paper comes as a contribution in providing information about the most famous IoT platforms and stimulating work to explore security concerns in IoT-based platforms. [12]

Another work presented by Meenaxi Mahabaleshwar Raikar and Nagaratna Yaligar focused on "Internet of Things for Sustainability: A Case Study of University Campus" A practical case study demonstrating IoT for campus sustainability, aligning with UN SDGs. It covers use cases like water and waste management, energy control, parking, disaster and garden management, security, Event management. Demonstrates IoT-enabled resource optimization via mobile apps. Sustainability plays a key role in three different dimensions namely environmental, societal and economics. In line with the seventeen goals set by Sustainable Development Goals (SDG), the objective is to foresee the different options in building a sustainable University campus enabled using IoT technology. The different building blocks of sustainable campus infrastructure are water resource administration, waste management, electric appliance management, parking space management, disaster management, garden area management, renewable energy, security aspects and electric vehicle management. The remote monitoring and control of the devices in the campus is facilitated for optimal utilization of the resources thereby achieves sustainability. The device connected to the internet fall in three different sectors namely Personal Area Network (PAN), Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX). This is not strictly a "review paper," it offers a well-structured, India-oriented practical implementation that can support a literature review.[13]

Energy conservation and automated utilities are central goals in campus modernization. "IoT – based smart campus – a review" by Kantipudi and Velamuri is a conference paper that reviews the application of IoT technologies in creating smart campuses. The authors aim to provide an overview of the different ways IoT can be used to enhance the university environment. The review likely covers various aspects of a smart campus, such as energy management, security, and smart learning systems. It serves as a comprehensive literature review for researchers and administrators interested in adopting these

technologies. The paper identifies and classifies key aspects of smart campus applications and their underlying IoT technologies. The authors also likely highlight challenges and propose future research directions in this area. Ultimately, the paper provides a foundational understanding of the "smart campus" concept.[14]

Impacts of digitalization on smart grids, renewable energy, and demand response: An updated review of current applications. Decarbonization, decentralization, and digitalization are essential for Advanced Energy Systems (AES), which encompass smart grids, renewable energy integration, and demand response initiatives. Digitalization is a significant trend that transforms societal, economic, and environmental processes globally. This shift moves us from traditional power grids to decentralized, intelligent networks that enhance efficiency, reliability, and sustainability. By integrating data and connectivity, these technologies optimize energy production, distribution, and consumption.[15]

Roadmap to smart campus based on IoT covered by Pandey, J. et.al in 2020 covered issues related with education ideas, methods, models, pedagogies and technological concepts can fix up with this tool. There are many seen and unseen difficulties and problems faced by education institutions and management. This paper introduces the worth of smart campus system which focused on IoT. College-wide infrastructure is obviously connected via the external or third-party service provider online. There are many terms such as Big Data, Communication Technologies, Smart Campus, Online Learning, Cloud Computing introduced in this paper. Smart schooling, and smart classrooms will eventually develop teaching and learning practices in a more relaxed, effective and efficient way for staff and students.[16]

Smart bus tracking and management system using IoT focus on Real-time Tracking: The system uses Global Positioning System (GPS) and Radio-Frequency Identification (RFID) to track buses in real-time. GPS provides the exact location of the bus, while RFID can be used to monitor passenger boarding and alighting. IoT Integration: IoT devices, such as sensors and GPS modules, are installed in buses to collect and transmit data to a central server or cloud platform. This allows for continuous monitoring and data analysis. System Components: The proposed system typically includes a GPS module on the bus, a central server to process the data, and a mobile application for users to access information. This paper provide following benefits such as the system provides passengers with accurate, real-time information on bus locations and estimated arrival times, reducing waiting times and improving the overall public transport experience. It also helps transport authorities to manage their fleet more efficiently.[17]

Innovative integration of digital infrastructure with pedagogical practices in rapidly transforming educational environments in IoT-Enabled Smart Classrooms for Enhanced Learning Environments. Traditional classrooms have many limitations like poor resource management, less individualized learning experiences, and real-time performance monitoring. The research focuses on these issues and answers them by designing and implementing an IoT-enabled smart classroom included prototype development, systematic data collection, and iterative performance analysis using advanced analytics and user experience assessments. [18]

Ramani et al. (2023) proposed a smart attendance monitoring system leveraging IoT to address the inefficiencies of traditional attendance practices in educational institutions. The system integrates RFID tags with sensors and cloud storage to enable automatic and real-time recording of student attendance, thereby reducing errors and eliminating the possibility of proxy entries. Attendance data is transmitted to the cloud, where it can be accessed and analysed through web or mobile interfaces, providing transparency and ease of monitoring for faculty and administrators. By minimizing human intervention, the approach improves efficiency, accuracy, and security compared to manual or biometric methods. The authors further emphasize the scalability of the model, suggesting that such IoT-driven solutions can be extended beyond attendance tracking to support broader smart campus management applications. The paper presents an IoT-based Smart Attendance Monitoring System designed to automate and secure student attendance in educational institutions. Traditional methods like manual registers and biometric systems are considered inefficient, error-prone, and time-consuming. The proposed solution integrates RFID technology, sensors, and cloud storage for real-time attendance tracking. Each student carries an RFID card, which automatically records entry/exit without human intervention. Data is transmitted to the cloud for storage and processing, ensuring easy access and scalability. Faculty and administrators can monitor attendance through a web or mobile application interface. The authors highlight IoT's role in improving efficiency, accuracy, and transparency in campus management. The paper concludes that this system can be extended to broader smart campus applications, enhancing automation and security. [19]

In recent years, many new radio-based connectivity solutions for the Internet of Things have been proposed. At the same time, development towards the 6G has brought on the stage the new business concepts. One of them is the concept of a micro-operator and implies the local entities to act as the telecom infrastructure owner and provider in their premises. "NB-IoT Micro-Operator for Smart Campus: Performance and Lessons Learned in 5GTN" discuss the deployment and report the practical performance of a single-cell NB-IoT deployed as a part of the 5G Test Network (5GTN) and controlled

by a smart-campus micro-operator. The practical measurements reported in the paper have been carried in the University of Oulu and the results demonstrate that the NB-IoT technology is a viable connectivity solution for various non-critical machine-based applications deployed indoors, highlight the practical performance of this technology, and reveal some practical specifics and challenges of acting as an IoT micro-operator. [20]

Hossain ey.al, in 2019 develop a smart campus model integrating air quality sensors and meteorological data into sustainability dashboards.Ubiquitous sensing enabled by Wireless Sensor Network (WSN) technologies cuts across many areas of modern-day living. This offers the ability to measure, infer and understand environmental indicators, from delicate ecologies and natural resources to urban environments.

Mobility and vehicle tracking systems integrated via IoT refers to the network of physical objects ("things") embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet. In the context of mobility and vehicle tracking, this means vehicles are equipped with IoT devices (like GPS and RFID tags) that collect and transmit data in real-time. This refers to increasing the capacity of a single resource or system. In the context of a university transit system, it would mean the system can handle a growing number of vehicles and users without a drop in performance. Real-time GPS (Global Positioning System) provides precise location data, while RFID (Radio-Frequency Identification) tags can be used to identify and track objects, like vehicles or even students' ID cards, as they pass through specific checkpoints. By using these technologies in real-time, the system can provide up-to-the-minute information on vehicle locations and movements. Razzaq and Mahar (2020) proposed a system using vertical scalability simulations for university transit systems. The system integrates real-time GPS and RFID to monitor and track the movement of university buses. This allows for efficient management of the transit fleet, providing real-time updates on bus locations and estimated arrival times for students and staff.[21]

In this era of smart classroom technology, students are demanding more innovative university campus life, and willing to use innovative learning methods. IoT and Cloud computing technologies can provide solutions for smart and a sustainable campus to improve learning methods of the students and improve the efficiency of everyday activities in the Institution. Revathi and Suganya (2020) propose a hybrid IoT-cloud smart classroom framework improving energy efficiency and faculty mobility and this paper focus on the IoT paradigm in the teaching process with the integration of cloud for education system. IOT in education provide student to learn new technologies that helps the students to create new ideas and logical for the social problems. IoT based cloud computing technology provide intelligence system,

unified campus portal services, security and maintenance system connected campuses enhance student learning and environmental sustainability those who are geographically widely situated. Students can use smartphones, personal digital assistant (PDA)to access their homework assignments and test performance through online portals. For easy learning teachers can uploaded videos, Case study or articles, online video lecturing in the cloud enables students to attend classroom lectures remotely and it is called as flip learning. IoT devices are used to track students who skip their classes, send alerts help students to concentrate academic work regularly, and to find lost personal items. Through digital devices payments can be made easy at cafeteria, office and in other admin activities. The hardware component of IoT consists of microcontroller board, sensor module, wireless and wired connections. Using the software module the information to and from sensor modules is processed and transmitted to cloud storage. This paper describes how efficiently IOT and Cloud Infrastructure restructure the traditional education and learning methods.[22]

"A study on IoT enabled smart classroom environment to enhance the students' learning activity" by S. Vijayakumar et. al. discusses the use of IoT to create a smart classroom that can improve student engagement and learning smart classroom which will be useful to study the use of IoT devices and can be used for things like attendance management, interactive learning, and performance tracking.[23]

Another way focus on Building smart infrastructure by following ways:

- Data centre for catering to IT needs
- Cloud based infrastructure
- Building Management Systems
- Unified Communication system
- Smart Parking - Automated
- Automated Transport
- Installation of Sensors and measuring right parameters

Enhancing the user experience leveraging the data captured from various end points and developing the applications to enhance the user experience in the campus by way of Smart Cafeteria, Health and Wellness Application, Intelligent Access control, Smart Indoor Navigation, Visitor Management, Safety and Security related applications, Room Booking, Smart Occupancy, and Dynamic Seat Allocation. [24]

Indian researchers also explore the socio-technical gaps in campus IoT implementation. Sneesl et al. (2023) examine barriers using a hybrid model combining structural equation modelling and artificial neural networks. This research likely explores the factors that influence the adoption of IoT (IoT) technologies in university or college environments. A "smart campus" uses interconnected devices and

systems to improve various aspects of campus life, such as energy management, security, transportation, and learning. The paper probably presents a model a framework of variables and their relationships that helps explain why some institutions successfully implement IoT solutions while others face challenges. The goal of the study would be to offer practical recommendations for educational institutions looking to transition to a smart campus model. It likely identifies key factors like:

- Technological aspects: The readiness of the campus's IT infrastructure.
- Organizational aspects: Support from leadership and the availability of funding.
- Social aspects: Acceptance by students, faculty, and staff.
- Environmental aspects: The perceived benefits, such as sustainability and efficiency.

To support the model Quantitative or qualitative research methodology has been used, such as a survey or case study. [25]

Sustainability Focus on one of the key focus areas for organization. It focuses on reducing energy consumption, increasing energy efficiency, Green Computing and use renewable energy sources to lower Green House Gas (GHG) impact. Its emphasis on continue to reduce per capita freshwater consumption in campus. It introduced structured approach to manage different kinds of waste get generated during various process. Reducing the GHG emissions, target to become carbon neutral. [26]

S. Tyagi et.al. in their book, "Building Smart Campuses: Integrating AI", explores the transformative potential of artificial intelligence in revolutionizing educational environments in 2024. The authors delve into how AI technologies can be leveraged to create more efficient, secure, and personalized campus experiences for students and staff. Key topics covered include AI-driven security systems, intelligent energy management, and smart learning tools that adapt to individual student needs. The book serves as a comprehensive guide for educational administrators and technologists seeking to implement AI solutions. It also addresses the ethical considerations and challenges associated with integrating such advanced technologies into campus infrastructure. The book offers a practical roadmap for creating the next generation of intelligent, connected campuses. It emphasizes the importance of data analytics in optimizing operations and enhancing campus services. This book is a valuable resource for anyone interested in the intersection of AI and higher education.[27]

IoT applications in Indian smart campuses influence interconnected sensors, devices, and systems to transforms traditional campuses into responsive, efficient smart environments with resource management. There is use of key applications include smart classrooms with automated lighting and climate control, campus-wide Wi-Fi analytics for crowd management, RFID-based attendance and

access control systems, and energy management through smart meters and grid optimization. Systems design considers interoperability standards, data security protocols, and integration APIs that allow diverse IoT components to communicate seamlessly across the campus ecosystem.This infrastructure-systems synergy enables predictive maintenance, automated resource allocation, and data-driven decision making that V. Subbarao and K. Srinivas, wrote a paper on a survey on IoT based smart, digital green and intelligent campus in 2019[28].

Another important work based on impact of IOT on campus comprise system in the educational sector. The evolution of smart technology has led to significant advancements in various aspects of urban infrastructure, including the management of educational campuses. Through the integration of comprehensive dashboards, decision-makers can access essential information related to building performance, occupancy rates, energy consumption, and maintenance needs. The study underscores the potential of smart campus management systems to optimize resource allocation, improve operational workflows, and create more responsive environments to meet the evolving needs of stakeholders within educational institutions. The usage of IoT in smart campuses, aiming to identify key trends, applications, challenges, and future directions in this domain. The proliferation of IoT technologies has sparked interest in their application within educational settings, leading to the emergence of smart campuses. By connecting physical objects and systems to the internet, IoT enables the collection, analysis, and utilization of real-time data to enhance campus efficiency, sustainability, and user experience. This systematic literature review aims to provide insights into the usage of IoT on smart campuses, shedding light on its applications, benefits, challenges, and prospects.[29]

One more paper supports the implementation of IoT based smart classroom for improving interactive learning which seeks to transform conventional learning environments. This essay explores the design, use, and advantages of IoT-based smart classrooms, emphasizing how these spaces have the power to revolutionize education by enhancing its interactivity, adaptability, and effectiveness. To provide a more dynamic and responsive learning environment, this smart classroom architecture makes use of IoT devices like smartboards, sensors, interactive displays, and wearable technology. The technology optimizes comfort and focuses in the classroom by allowing real-time monitoring of environmental elements like temperatures, lighting, and ventilation. It also offers statistical insight into student behaviour and performance. Furthermore, IoT-enabled solutions facilitate more student participation and individualized learning experiences by promoting interactive learning through real-time quizzes, rapid feedback, and collaboration platforms. [30]

This study aims to develop a measuring tool which can address two independent research areas in the literature. Both subjects are studied independently in the literature, showing a need for an integrated approach that bridges these areas. For achieving this purpose, a new scale was developed based on a questionnaire applied to two universities in Turkey. The scale aimed to measure the perceptions of the students regarding the quality of sustainable campus services. The questionnaire consisted of 22 questions on several aspects of campus services which are related to sustainability. A total of 234 samples were used for Exploratory Factor Analysis for determining the underlying structures in the data set. The scale was validated with satisfactory Kaiser-Meyer Olkin and Bartlett's test results. Five dimensions were extracted, which represent sustainable service quality. After validation, the scale was applied to two universities located in geographically and socio-economically different regions of Turkey. [31]

Findings:

From the previous entire works indicate that AI significantly improves Demand Response strategies by enhancing the prediction, optimization, and management of energy consumption. Techniques like linear regression effectively predict power demand and aggregated loads, while more complex methods such as Support Vector Regression (SVR) and Reinforcement Learning (RL) optimize appliance scheduling and load forecasting. The integration of IoT technologies into Energy Management Systems (EMS) further enhances efficiency and sustainability through real-time monitoring and automated control. Additionally, DT technology aids in simulating energy scenarios and optimizing consumption in both residential and commercial smart grids. It also emphasize blockchain's role in creating decentralized energy trading platforms, facilitating peer-to-peer transactions, and enhancing trust through smart contracts. The insights gained from this review highlight the essential role of these emerging technologies in supporting decentralized, intelligent energy networks, offering valuable strategies for stakeholders to navigate the complexities of the evolving digital energy landscape.

All research papers highlight the important components of a model "Smart and Digital Green Educational Campus". It describes the importance of constructing the green campus and it provides the use of technology by connecting computer and servers. A Smart campus links server, peripherals, campus infrastructure and people connected to the IoT and the smart campus uses inter-connected with networks. Smart campus is included as outdoor lighting, building, lighting, heating, cooling power systems, security surveillance and physical access systems, parking facilities, and more. Smart campus brings in new experiences like location based and context - aware services, smart parking, smart lighting, smart transits and smart building climate control. It also increases safety and security within the campus with connected surveillance IP cameras, smart locks, asset tracking and smart emergency services. It

enables tracking of the facilities / resources and use them more efficiently. This helps in reducing the cost by the intelligent use of water, electricity and building controls.

Conclusion

Indian academia has made substantive contributions to the conceptualization, design, deployment, and analysis of IoT-based smart campuses. These efforts span infrastructure, education, energy, mobility, security, and policy. Despite technological maturity, challenges persist in funding, stakeholder alignment, and policy standardization. However, the momentum gained through initiatives like Digital India, Smart Cities Mission, and NEP 2020 is likely to bolster widespread adoption of smart campuses across Indian universities.

Today, a growing number of higher education institutions are trying to integrate sustainability into their systems and subsystems, operations, and curricula. According to Ragazzi and Ghidini (2017), this interest has two main reasons. First, universities have a significant impact on the environment through on-campus activities. Second, they play a crucial role in promoting sustainability by training future generations. Wright (2002) described this progress as a moral imperative for the universities mandated by hundreds of declarations. Despite all these efforts in the universities on sustainability, differences in definitions and interpretations indicated by Van Weenen (2000) continue. Consequently, practical applications and strategies vary significantly.

Outcome:

As reported in the literature section, these differences and varieties have led to a theoretical dispersion, which has led to efforts to formalize the conceptual framework of sustainability in higher education. In the current era of digitally connected ecosystem, campuses need to respond to business and operational requirements quickly and comprehensively. Increasing demand for university education is putting pressure on campuses to make better use of their real-estate resources. Evidence indicates that enrolments are rising, yet attendance is falling due to diverse demands on student time and easy access to online content. This paper outlines the efforts to address classroom under-utilization in a real university campus arising from the gap between enrolment and attendance. By instrumenting classrooms with IoT sensors to measure real-time usage, using AI to predict attendance, and performing optimal allocation of rooms to courses to minimize space wastage. Several IoT sensing approaches for measuring class occupancy, and comparing them in terms of cost, accuracy, privacy, and ease of deployment/operation. There is use of 250 courses over two sessions, and draws insights into attendance patterns, including identification of cancelled lectures and class tests, while also releasing data openly

to the public. Third contribution is to use AI techniques for predicting classroom attendance, applying them to real data, and accurately predicting future attendance with an root-mean-square error as low as 0.16. Final contribution is to develop an optimal allocation of classes to rooms based on predicting attendance rather than enrolment, resulting in over 10% savings in room costs with very low risk of room overflows. This article presents a comprehensive literature review.

References:

1. Abdusamiev Dilmurod Abdugani Ugli, V. S. Binu, V. G. Anisha Gnana Vincy, Khabibullayeva Sayyorakhon Makhamadali Kizi; Implementation of IoT based smart classroom for improving interactive learning. *AIP Conf. Proc.* 5 June 2025; 3306 (1): 030073.
2. P. Agarwal, R. Kumar G.V.V. and P. Agarwal, "IoT based Framework for Smart Campus: COVID-19 Readiness," *2020 Fourth World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4)*, London, UK, 2020, pp. 539-542, doi: 10.1109/WorldS450073.2020.9210382.
3. Aruna, K., Pradeep, G. Performance and Scalability Improvement Using IoT-Based Edge Computing Container Technologies. *SN COMPUT. SCI.* **1**, 91 (2020). 1(2):1–7. https://doi.org/10.1007/s42979-020-0106-9
4. *Ashish P. Dhakan,*"How institutes in India can be converted into a Smart Campus?" industry/insight article with Indian case examples, https://www.commercialdesignindia.com/insights/how-institutes-in-india-can-be-converted-into-a-smart-campus?utm_source=chatgpt.com
5. B. Council, "The shape of things to come: Higher education global trends and emerging opportunities to 2020," Brit. Council, London, U.K., Rep., Jan. 2012. [Online]. Available: https://www.britishcouncil.org/sites/default/files/the_shape_of_things_to_come_-_higher_education_global_trends_and_emerging_opportunities_to_2020.pdf
6. Cavus, N., Mrwebi , S. E., Ibrahim, I., Modupeola, T., & Reeves, A. Y. (2022). Internet of Things and Its Applications to Smart Campus: A Systematic Literature Review. *International Journal of Interactive Mobile Technologies (iJIM)*, *16*(23), pp. 17–35. https://doi.org/10.3991/ijim.v16i23.36215
7. Ghashim, I. A Arshad, M. (2023). Internet of Things (IoT)-Based Teaching and Learning: Modern Trends and Open Challenges. *Sustainability*, *15*(21), 15656. https://doi.org/10.3390/su152115656
8. Hari Prabhat Gupta, "Lessons Learned: A Smart Campus Environment Using LoRaWAN" October 13, 2024, https://doi.org/10.48550/arXiv.2410.09927
9. Hossain, I., Das, D., & Rashed, M.G. (2019 IoT model for smart campus: Challenges and limitations. Journal of Cleaner Production, 234, 1256–1268. IEEE. https://doi.org/10.1016/j.jclepro.2019.06.121
10. Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, Marimuthu Palaniswami,

Internet of Things (IoT): A vision, architectural elements, and future directions, Future Generation Computer Systems, Volume 29, Issue 7,2013, Pages 1645-1660, ISSN 0167-739X,https://doi.org/10.1016/j.future.2013.01.010.

11. Lyberius Ennio F. Taruc, Arvin R. De La Cruz ,"Narrowband-IoT (NB-IoT) and IoT Use Cases in Universities, Campuses, and Educational Institutions" in August 6, 2024, https://doi.org/10.25147/ijcsr.2017.001.1.202
12. M. A. El. Zuway and H. M. Farkash, "Internet of Things Security: Requirements, Attacks on SH-IoT Platform," *2022 IEEE 21st international conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA)*, Sousse, Tunisia, 2022, pp. 742-747, doi: 10.1109/STA56120.2022.10019124.
13. Meenaxi Mahabaleshwar Raikar & Nagaratna Yaligar, "Internet of Things for Sustainability: A Case Study of University Campus" December 2023 (ICIMIA conference paper)https://www.researchgate.net/publication/379931900_Internet_of_Things_for_Sustainability_A_Case_Study_of_University_Campus
14. M. P. Kantipudi and S. Velamuri, "Internet of things – based smart campus – a review," *4th Smart Cities Symposium (SCS 2021)*, Online Conference, Bahrain, 2021, pp. 490-495, doi: 10.1049/icp.2022.0392.
15. Mou Mahmood, Prangon Chowdhury, Rahbaar Yeassin, Mahmudul Hasan, Tanvir Ahmad, Nahid-Ur-Rahman Chowdhury, "Impacts of digitalization on smart grids, renewable energy, and demand response: An updated review of current applications," Energy Conversion and Management: X, Volume 24,2024,100790, ISSN 2590-1745, https://doi.org/10.1016/j.ecmx.2024.100790.
16. *Pandey, J., Singh, A. V., & Rana, A. (2020). Roadmap to smart campus based on IoT. IEEE.10.1109/ICRITO48877.2020.9197926* https://ieeexplore.ieee.org/document/9197926?utm_source=chatgpt.com
17. Patel, K., & Garg, P. (2018)." Smart bus tracking and management system using IoT", Journal of Engineering Research and Applications, 8(2), 1-5.10.22214/ijraset.2018.2562
18. P. Kumar, P. Negi, P. Sharma and P. Mittal, "IoT-Enabled Smart Classrooms for Enhanced Learning Environments," *2025 2nd International Conference on Computational Intelligence, Communication Technology and Networking (CICTN)*, Ghaziabad, India, 2025, pp. 944-949, doi: 10.1109/CICTN64563.2025.10932356.
19. Ramani, P.,Palanisamy, A. P., Sekhar, V., & Kumar, N. S. (2023). Smart Attendance Monitoring System Using IoT. In 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), 1099–1104. https://doi.org/10.1109/icaccs57279.2023.10112850

20. R. Yasmin, A. Pouttu, K. Mikhaylov, V. Niemelä, M. Arif and O. Liinamaa, "NB-IoT Micro-Operator for Smart Campus: Performance and Lessons Learned in 5GTN," *2020 IEEE Wireless Communications and Networking Conference (WCNC)*, Seoul, Korea (South), 2020, pp. 1-6, doi: 10.1109/WCNC45663.2020.9120621.
21. *Razzaq, M. A., & Mahar, J. A. (2020). Smart campus system using IoT: Simulation and scalability. Indian Journal of Science. PDF*
22. Revathi, R., Suganya, M. and NR, G.M., 2020. IoT based Cloud Integrated Smart Classroom for smart and a sustainable Campus. Procedia Computer Science, 172, pp.77-81. https://doi.org/10.1016/j.procs.2020.05.012
23. S. Vijayakumar, R. Arun Kumar, M. Arun Kumar, and A. Muthukumar, “"A study on IoT enabled smart classroom environment to enhance the students' learning activity" Procedia Computer Science, Volume 171, 2020.
24. Smart CAMPUS UWB. About the Smart CAMPUS UWB Project. Available online: https://www.smartcampus.cz/en/ (accessed on 26 October 2020).
25. Sneesl, R., Jusoh, Y. Y., Jabar, M. A., & Abdullah, S. (2023). Examining IoT-Based Smart Campus Adoption Model: An Investigation Using Two-Stage Analysis Comprising Structural Equation Modelling and Artificial Neural Network. *IEEE Access*, *11*, 125995–126011. doi:10.1109/ACCESS.2023.3331078
26. T. Sutjarittham, H. Habibi Gharakheili, S. S. Kanhere and V. Sivaraman, "Experiences With IoT and AI in a Smart Campus for Optimizing Classroom Usage," in *IEEE Internet of Things Journal*, vol. 6, no. 5, pp. 7595-7607, Oct. 2019, doi: 10.1109/JIOT.2019.2902410.
27. Tyagi, S., Gupta, V., Mehndiratta, V. (2024). Building Smart Campuses: Integrating AI in Higher Education. In: Arya, R., Sharma, S.C., Verma, A.K., Iyer, B. (eds) Recent Trends in Artificial Intelligence Towards a Smart World. Frontiers of Artificial Intelligence, Ethics and Multidisciplinary Applications. Springer, Singapore. https://doi.org/10.1007/978-981-97-6790-8_15
28. *V. Subbarao & K. Srinivas. (2019). A survey on internet of things based smart, digital green and intelligent campus. IEEE. https://ieeexplore.ieee.org/document/8777476/ 10.1109/IoT-SIU.2019.8777476*
29. V. Arunkumar, V. Rengarajan, V. Vijay Anand, K. A. Shreenivasan, S. Thiyagarajan, R. Swaminathan (2024). Impact of IOT on campus; Smart student information system in the educational sector. Journal of Innovative Engineering Research, 4(2) https://doi.org/10.52783/jier.v4i2.836

30. V. S. Binu;V. G. Anisha Gnana Vincy; Khabibullayeva Sayyorakhon Makhamadali Kizi, Implementation of IoT based smart classroom for improving interactive learning *IAIP Conf. Proc.* 3306, 030073 (2025),https://doi.org/10.1063/5.0275790
31. Yasal Ozdemir, Sema Kayapinar Kaya, Erkan Turhan," scale to measure sustainable campus services in higher education:"Sustainable Service Quality, Journal of Cleaner Production,Volume245,2020,118839,ISSN0959-6526, https://doi.org/10.1016/j.jclepro.2019.118839.

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