

A Frame work for Sustainable and Data-driven Smart Campus

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Abstract: University campuses provide a wealth of options for innovative city applications to improve service quality and optimize the use of public resources since they are tiny cities. The construction of an intelligent campus mainly depends on Industry 4.0 enabling technologies. The research aids İzmir's digital transformation process. Turkey's newest university, Bakırçay University, was just founded. The study provides a roadmap for building a sustainable and intelligent campus. The research has disclosed a framework, including an architectural structure and an application procedure, enabling the establishment of an innovative campus. Three steps are intended for the system application. Based on the university's current information systems, the system will help management operations by collecting and analyzing sensor data. The suggested framework aims to facilitate certain value-added activities, including raising staff output, improving classroom instruction quality, cutting energy use, accelerating interpersonal interactions, and identifying the quickest fixes for issues on campus. As a result, a system is built for sustainability and maximizing the use of the assets, in addition to an innovative campus.

Keywords: Smart Campus, Smart University, Digital Transformation, Industry4.0, Internet of Things.

1 Overview

As cities encourage effective, sustainable, and eco-friendly ecosystems, urbanization also brings the opportunity to use cutting-edge technology to offer various services (Du et al.,

2016). Through information and communication technology (ICT), innovative city initiatives provide the public, businesses, and visitors the knowledge they need to improve the effectiveness of government services (Van Dinh et al., 2018). The widespread usage of ICT has impacted the management and operation of cities. The idea of a “smart city” has been embraced by numerous cities worldwide to enhance people’s quality of life and well-being, increase energy efficiency and management services, and lessen environmental issues like air pollution (Sotres et al., 2017; Gasco´-Hernandez, 2018; Ojo et al., 2015).

When the intelligent city method is applied to a university location, the idea of a “smart campus” may provide several benefits (Fortes et al., 2019). There are several buildings on university campuses.

A collection of willing human resources (workers, academics, and students) to embrace and create innovations and facilities where the generated clever ways may be used. Consequently, colleges provide a great chance to reinforce the “Smart Cam-pus” strategy. Campuses are “small cities” with advancements in various fields, such as management, sustainability, educational activities, and energy efficiency. Numerous applications are carried out on smart campuses. For instance, real-time room or class monitoring is feasible using the Smart University application (Huang et al., 2019). Temperature and humidity levels may be monitored and gathered inside the cloud system. This makes it possible to maintain ideal classroom humidity and temperature levels. Furthermore, sensors installed in public spaces on cameras may identify pollution, allowing units to be alerted without the need for control. Because universities are populous places, energy is used a lot there. Intelligent universities can also regulate this energy use. Considerable energy savings may be achieved by turning off air conditioners and lights that automatically turn on when rooms and classrooms are vacant (De Angelis et al., 2015).

All of these applications may be implemented thanks to Industry 4.0 technology. Industry 4.0’s primary goal is to track procedures and produce a virtual replica of actual occurrences, allowing for the decent-

Centralized choices are to be made with these duplicates. Process management is, therefore, possible for devices and systems that possess self-control (Santos et al., 2017). Controlling using Internet technologies is made simple by Industry 4.0 technologies, the Internet of Things, big data, augmented reality, additive manufacturing, cloud computing, and cybersecurity. Real-time reading of various data is made possible by sensors in the Internet of Things technologies. Access to the machines is made secure via cybersecurity. Extensive data collection allows for the storage of all data on a variety of disk systems. This whole set of data is exchanged with the cloud system. Augmented reality allows for the creation of virtual replicas of locations. For instance, it is possible to construct virtual versions of classes and courses. With 3D printers and additive manufacturing technologies, digital drawings are quickly translated into tangible items. These technologies allow things to interact with one another, making them intelligent (Santos et al., 2017; Dogan and

Gurcan (2019).

One of the primary research questions for the effective use of public resources is, "What type of model should be built for more efficient consumption of public resources within the scope of a smart university?". This identified research issue combines ideas from Industry 4.0, the Internet of Things (IoT), and intelligent city/campus concepts in an era of technology where items may interact. This research takes into account the use of primary public resources, such as expensive materials and scarce human resources, in this approach. As such, the document functions as a roadmap for converting a university campus into a digitally transformed innovative campus.

2. Smart University History

Because they provide access to smart cities, small towns may be considered home to brilliant colleges. Universities may readily incorporate the methods used in urban areas. For these reasons, many colleges worldwide are embracing the idea of a "smart university" to enhance management services, guarantee energy efficiency, and raise the standard of instruction. Intelligent universities use advanced technologies

to provide a range of services. Research on brilliant universities in the academic and administrative sectors may be found in the literature. Numerous scholarly investigations have concentrated on digitalization in education (Uzelac et al., 2018; Zhai et al., 2018). This application area is crucial when it comes to making sure that the data can be received and processed.

They investigated in real time. Campus libraries may also take advantage of the Internet of Things technology. Students may see the density of libraries and the books that are accessible online in this manner (Zhu et al., 2018). Zhai et al. (2018) created a game-based learning system in an intelligent university. The students characterized the connections between technology usage and learning in this manner. Zhang et al.'s (2018) research has shown that cloud systems—one of the industry 4.0 technologies—make multi-timed conferencing systems feasible. They also discussed the benefit of cloud computing for intelligent academic pursuits. IoT technology may be used to develop smart classrooms, according to Huang et al. (2019). They developed a prototype for an intelligent class at Ming Chuan University.

Because universities use a lot of energy, the administrative domain's most favored implementation area is energy. Preventing needless energy use was the goal of the green campus initiative, according to Chinese research (Tan et al., 2014). The Internet of Things has shut off the computers, lights, and air conditioners that are not in use. De Angelis et al. (2015) launched a few energy-oriented projects at the University of Brescia. According to a report by Kolokotsa et al. (2016), intelligent campus apps may save 30% on energy use. PGRI Yogyakarta University undertook research that created intelligent parking systems and intelligent buildings. A new method of instruction was created, and the university was accessible remotely over the Internet (Sari et al., 2017). In different research, classroom temperature and humidity sensors can capture data in real-time and automatically maintain the values at the ideal level. The values students could concentrate on the best indicated the optimal level (Uzelac et al., 2018). Majeed and Ali (2018) used IoT technologies to

brighten training for intelligent parking systems and rooms. To guarantee connectivity, they combined sensors and other devices.

Table 1 shows the focus points of earlier investigations. Academic and administrative categories best describe the main impact areas of the present investigations. However, the research cannot present all of these two primary fields of application's sub-titles.

The studies above focus on the academic or administrative departments inside institutions. Wu (2016) examined applications in the administrative and academic spheres. They investigated how interactive learning and intelligent buildings affected Taiwanese students' academic performance. The relationships between intelligent buildings and learning were examined in this research, which included 35 carefully chosen students, and the findings were statistically significant (Wu et al., 2016). Nevertheless,

This research will spur innovation in academic and administrative departments alike. However, it does not address university energy savings, campus environmental applications, or automatically retrieving classroom material. However, the integration of all components makes brilliant universities possible. This is why assessing and working jointly to combine the academic and administrative divisions is critical. Our research will assess universities' academic and administrative departments together.

Three data-driven and sustainable, innovative campus frameworks

The study aims to offer a blueprint for the digital transformation process of Turkey's newest institution, Izmir Bakircay. The institution, which is still in its infancy, hopes to create an innovative and sustainable campus in addition to its current amenities. The most effective approach to do this is to create creative business plans and a thorough IoT strategy. A road plan for Izmir Bakircay University's digitalization studies will be given at the study's conclusion. Following the digital transformation process, the following outcomes are anticipated:

- in order to lower energy use,
- to shorten wait times to use the camera facilities,
- to increase employee output,
- to raise the quality of instruction in the classroom,
- to guarantee that everyone on campus contributes to the discovery and solution of problems,
- to examine how public resources are used by examining all of the data that has been gathered.

The figure illustrates the methodological framework, which expands the study's scope.

1. The domains (automation, personnel, procurement, online services, etc.) depicted in the methodological framework will be developed on the university's current information systems.

The notion has three distinct phases, as seen in Figure 1. A model building from the university campus was chosen for Stage 1. A framework for the realms of energy, environment, and classroom has been built on this particular building. The framework is dispersed over the university in Stage 2. Different domains were found and added to the framework in addition to the ones in Stage 1. The data produced by the Stages 1 and 2 systems will be integrated with the university's current data in Stage 3 storage. Predictive, prescriptive, diagnostic, and descriptive analytics may be carried out with the data recorded at this point in the architecture. The stages' respective domains are listed below.

Energy Domain: Energy consumption is the most challenging aspect of working with smart cities. Excessive energy expenses are a result of excessive energy use. Additionally, it quickens the depletion of finite energy resources. As a result, advancements in the energy sector have a significant financial and environmental impact. According to feasibility studies, 10% of monthly power use is attributed to non-working consumption. Since the university has air conditioners for heating, the improvements will directly impact the amount of power used for this issue. It is being considered to create a system that automatically turns on or off air conditioners and lights in unoccupied spaces to save power.

Presence sensors may be utilized to pick up on minute movements in the surrounding area, which will enhance the system. Knowing whether classrooms or other spaces are in use will be made easier with the introduction of presence sensors. If the environment's temperature and humidity are inappropriate, the temperature and humidity sensor will turn on the air conditioner. Simultaneously, the photocell will gauge the quantity of light and trigger the lights if necessary.

Environment Domain: Creating a neat and orderly atmosphere will enhance university students' quality of life. Preparing the cleaning crew's workload and working hours is also crucial. The suggested methods may improve environmental arrangements and operational efficiency. For instance, when it is time to clean the restrooms, cleaning workers may receive notifications via the university mobile app and touch-screen service kiosks.

This will guarantee continual cleaning while preventing the crew from squandering effort with constant cleaning management. Additionally, it will be feasible to automatically notify the cleaning crew based on the occupancy status of the soap and garbage cans. Furthermore, autonomous irrigation systems that adjust their scheduling based on soil moisture content and meteorological circumstances might serve as a model for future research. Accurately differentiating the objectives of the listed research areas is not feasible. Occasionally, the goals of many domains coincide with one other. By removing the need to go around for cleaning control, the intelligent trash bin, for instance, reduces environmental pollution and improves the working conditions of cleaning workers.

Classroom Domain: Şİzmir Bakırc, ay University uses technology infrastructures to boost the effectiveness of its teaching operations. One of the most significant aspects of universities is the classroom. Enhancing the classroom's physical layout will help raise student achievement. Within the poll conducted,

Talking to students at ŞİzmirBakırcşay University, 30% complained about various issues, including classroom airlessness and temperature. As a result, it is critical to regulate

the classroom's environmental elements, which include humidity, temperature, and light levels, since they may impact student focus and the course's overall effectiveness. There is a connection between this branch of research and the energy field. Temperature, humidity, and light levels impact education quality and energy use. Simultaneously, the goal of the suggested innovative attendance system is to discourage students from signing the attendance sheet while they are in class. Consequently, it would assist them in avoiding distractions during the lesson.

The study's second phase has five distinct domains. In Stage 1, details on the environment domain are given. This stage covers the suggested activities that will take place throughout the university.

Availability Domain: Occasionally, communal facilities like the dining hall experience densities.

Cafeterias and libraries. The proposed system aims to maximize the university campus's physical resources. Its efficiency-oriented approach hopes to shorten wait times in public spaces. Sub-application names like parking, library, dining hall, cafeteria, and class/room information are included in the availability domain.

Training Domain: This domain encompasses a wide range of disciplines. The domain aims to stop time and labor waste and identify workable solutions to various digitalization-related issues. The three sub-application names are the virtual campus tour, innovative orientation, and virtual labs. With a website or mobile application, the virtual campus tour will allow virtual orientation sessions and university marketing. Students and new employees will benefit from the intelligent orientation application as they get familiar with the university and its resources. Applications for desktop virtualization and AR/VR are both included in virtual laboratories. Applications that use virtualization, in particular, significantly shorten the time needed to install software. A virtual laboratory will save 98% of the time it takes to install software.

Administrative Feedback Domain: In some situations, the application is not feasible or cannot identify the issue

with the sensors. In these situations, the goal is to leverage user input to promote the intelligent campus feature. For instance, teachers do not influence a projection problem in a classroom. On the other hand, when it malfunctions, a mobile application or digital display may be created so that instructors or students can report the issue to the appropriate department. As a result, user input will ensure that issues are resolved quickly. To improve user happiness, a digital display that is simple to use and always able to gauge customers' satisfaction with the services they have received may be created. Quick communication and administrative comments are complimentary. The sub-application names include satisfaction, student affairs, and support services. Through the soon-to-be-developed mobile application, staff members or students can send their requests, grievances, and satisfaction levels to the appropriate administrative divisions. This application makes conducting satisfaction surveys simple. Authorities will also be informed of crises on campus thanks to immediate alerts.

Contact Domain: Accurate and prompt communication is the most crucial component of every firm. Quick communication between academic staff, students, and administrative personnel is crucial at universities. This field will present an intelligent system-based approach to achieving interpersonal communication. The contact domain has subheadings for supervisors and academics.

Staff, department, and student organization. A mobile or web application that may be created to facilitate interpersonal communication quickly and efficiently. Furthermore, user experiences from the program may be analyzed, transformed into meaningful data, and used for administrative procedures.

Real-time Data Analysis, Monitoring, Reporting, and Performance Measurement Domain: The suggested system structure takes a wholly data-oriented approach. Massive data stacks will be created from sensor data and personal data collected. For the institution, it is crucial to combine the raw data with information from other sources, process the data to turn it into meaningful information, and create models that can be used to make predictions. By creating an intuitive and

dynamic reporting system, information that may be helpful at all levels of decision-making—tactical, operational, and strategic—can be used. Academic, educational, performance, and student reports will help improve the campus's high-quality, sustainable, and physical conditions.

The architecture and implementation of the system

In order to create an innovative and sustainable campus, industry 4.0 technologies are crucial. Table 2 lists the technologies that will be used at each framework level. Energy, environment, and classroom domains comprise the first stage, where cloud and IoT technologies will be used. The second stage will include the usage of cloud, IoT, big data, mobile, and augmented reality technologies. This stage will cover environment, availability, training, administrative feedback, and contact domain. The third phase of the investigation will take advantage of big data and cloud technology.

Figure 2 depicts the three phases of the system application design. In the first stage, called Single Facility, investigations in energy, classroom, and environment will be conducted using cloud and IoT technologies.

Sensors will gather data on the labs' temperature, light intensity, humidity, and motion for the Energy Domain. This information will be kept on a data collection and recording server that uses several internet protocols. The lighting or heating and cooling systems automatically turn on or off using internet protocols if the values are outside the designated range, sending the information to the Internet of Things device. The lighting and heating/cooling sources will automatically switch off if there is no lab movement for a specific time. This will enable significant cost reductions and a more efficient use of energy resources.

Trash boxes equipped with wireless occupancy detection sensors would ensure that alarms are transmitted to the necessary units on behalf of the Environment Domain if a specific occupancy rate is exceeded. This method would make human resource planning more effective.

In the second stage, Extended Facility and Environment, studies in Environment, Ability, Contact, Training, and Administrative Feedback will be conducted using cloud, IoT, mobile, and augmented reality technologies.

In order to prepare for the classroom domain, RFID cards will provide the Data Collection-Recording Server in the two labs with the professor's and students' data entry and exit information. The automatic transmission of student attendance lists to the Student Information System may be done in this manner. As stated in their schedules, the bright doors configured for labs will guarantee that the appropriate sections are locked for usage after hours. Class occupancy rates, the next course, and other information will be shown on the information displays at the laboratory entrance.

Wireless sensors will monitor the parking spots on our campus for the Availability Domain, and the IOT system will get data on the occupancy of these spots. This information will be handled on a data acquisition-recording server using several internet protocols. Designing parking advice, parking management, and occupancy alert systems may be done in this manner. The dining hall and library entry areas will have wifi access points and private wireless networks. This will discover the quantity of gadgets that provide instantaneous wireless internet connection. Students will be shown the occupancy rates of relevant fields and the monitoring of these rates.

Rates via mobile devices, several platforms, and information panels.

The Training Domain has three sub-application titles: virtual laboratories, mobile orientation, and virtual campus tour. Thanks to the virtual campus tour, students can visit the school through a website and mobile application for orientation and promotion activities. Furthermore, the mobile orientation application encompasses the orientations needed by recently hired staff, the orientations needed by recently enrolled students to familiarize themselves with the institution and its offerings, and the ongoing training provided to existing staff and students. Applications for desktop virtualization and AR/VR are both included in virtual laboratories.

Sometimes, detecting sensor issues in the administrative and contact domains is impossible. User feedback will be sent to the mobile application, the data collection recording server, and the interactive information panels that must be developed.

After the innovative irrigation system is established, the Internet of Things device will irrigate the predetermined quantity of water the plant needs in the Environment Domain. This instrument will determine the moisture content of the soil and enable the transmission of pertinent data to the data-collecting server via Internet protocols. This intelligent irrigation system will contribute to the economical use of water resources.

In the third stage, dubbed Smart Campus, Cloud and Big Data technologies will be employed for Real-time Data analysis, Monitoring, and Performance Measurement Domain. Data from all sensors, IoT devices, etc., will be recorded by a data collection-recording server. The Analytics & Reporting Server will process and transform data into meaningful information. All data can be monitored in real-time, alerts can be made based on established rule sets, and they can be automatically sent to individuals or units using the web-based software that will operate on this server.

5 Final Thoughts

Governments face management and complexity issues in cities due to the growing urban population in several areas, including trash management, energy supply, public resource utilization, and education. Contacting several gadgets, the expanding population simultaneously generates massive data. An appreciable increase in diversity, data volume, and sensor technologies has presented opportunities for governments to develop smart cities. Due to the tiny size of university campuses there fore, every intelligent city installation may be transferred to a campus to create an innovative campus.

One of the most effective ways to boost productivity in academic and administrative activities on campuses is through Industry 4.0 technology. Universities prioritizing sustainability may boost productivity by incorporating

Industry 4.0 technologies into their campuses. Excessive and uncontrolled energy, materials, and labor usage in universities may lead to several issues. On campus, sustainable systems provide several chances to address these issues. For campuses to become self-sufficient, regulation of academic and administrative procedures and sustainability in higher education are crucial.

This paper presents a framework for brilliant universities and sustainable campuses, which Izmir Bakırçay University can use to establish a data-driven, sustainable campus.

They focused on an intelligent campus. The university's digital transformation plan was established to optimize resource use, foster technological innovation and productivity, enhance interdepartmental communication and offer top-notch physical facilities. A few Industry 4.0 enablers, including cloud, IoT, big data, mobile, and augmented reality, are linked to the framework when considering earlier research on intelligent campuses. The finalized road plan is divided into three phases. Single facility applications are covered in the first stage, extended facility and environment applications are covered in the second, and intelligent campus applications with real-time data analysis are covered in the last step. We talk about the system architecture that stands in for each framework step. It covers every process step, from modeling to data exchange, collection, conversion, and analysis. The suggested framework can potentially improve academic services by raising service quality and preventing the wastage of scarce public resources. New universities in the digital transformation process may adopt the data-driven and sustainable, innovative campus framework by their strategic objectives due to its dynamic structure.

The suggested structure is mainly limited to

tions. The research does not include typical application areas, including transportation, since the domains are determined based on the institution's requirements. As a result, they might be expanded upon or altered in other subjects based on the institution's requirements. Since stage 3 requires data collection to analyze and support decision-makers, this

research does not cover it in depth. The foundation for real-time analytics is therefore provided in the first two steps.

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