A Framework for Sustainable and Data-driven Smart Campus

Zeynep Nur Kostepen[a], Ekin Akkol[b], Onur Dogan[c], Semih Bitim[d] and Abdulkadir Hiziroglu[e]
İzmir Bakırçay University, Gazi Mustafa Kemal Mahallesi, Kaynaklar Caddesi Seyrek, Izmir, Turkey

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Abstract: As small cities, university campuses contain many opportunities for smart city applications to increase service quality and use of public resources efficiency. Enabling technologies for Industry 4.0 play an important role in the goal of building a smart campus. The study contributes to the digital transformation process of İzmir Bakırçay University which is a newly established university in Turkey. The aim of the study is to plan a road map for establishing a smart and sustainable campus. A framework including an architectural structure and the application process, for the development of a smart campus have been revealed in the study. The system application is designed to be 3 stages. The system, which is planned to be built on the existing information systems of the university, includes data collection from sensors and data processing to support the management processes. The proposed framework expects to support some value-added operations such as increasing personnel productivity, increasing the quality of classroom training, reducing energy consumption, accelerating interpersonal communication and finding the fastest solution to the problems on campus. Therefore, not only a smart campus but also a system is designed for sustainability and maximum benefit from the facilities.

1 INTRODUCTION

The rise of urbanization brings along to leverage advanced technologies to enable a variety of services while cities promote efficient, environmentally friendly and sustainable ecosystems (Du et al., 2016). Smart city projects provide appropriate information for citizens, companies and tourists to increase the efficiency of government services by utilizing the power of information and communication technology (ICT) (Van Dinh et al., 2018). The global use of ICT has focused on both how cities are operated and managed. Many cities around the world have adopted the concept of a smart city to develop the quality of life and well-being of people, to improve energy efficiency and management services, and to reduce environmental problems such as air pollution (Sotres et al., 2017; Gascó-Hernandez, 2018; Ojo et al., 2015).

The concept of Smart Campus, which is developed by applying the smart city approach to a university area, can provide great advantages (Fortes et al., 2019). The university campuses consist of a large group of eager human resources (students, academicians, and employees) to adopt and develop innovations, and facilities that can be applied the developed smart approaches. Therefore, universities represent a valuable opportunity to strengthen the "Smart Campus" approach. Campuses are "small cities" where include improvements in many areas from management to sustainability, and from learning activities to energy efficiency. Various applications possible in smart campuses are conducted. For example, with the smart university application, it is possible to monitor classrooms or rooms in real time (Huang et al., 2019). In this way, temperature and humidity rates can be monitored and collected in the cloud system. Thus, the temperature and humidity in the classes can be kept at an optimum level. In addition, pollution can be detected by sensors placed in common areas on campuses and thus units can be notified without requiring control. Universities are areas where energy is consumed much due to being crowded areas. This energy consumption can also be controlled in smart universities. Turning off air conditioners and lights that remain on when rooms and classes are empty can result in significant energy savings (De Angelis et al., 2015).

Implementation of all these applications is made possible by industry 4.0 technologies. The main objective of Industry 4.0 is to monitor processes and create a virtual copy of physical events, enabling decen-

[a] https://orcid.org/0000-0001-5773-2411
[b] https://orcid.org/0000-0003-2924-8758
[c] https://orcid.org/0000-0003-3543-4012
[d] https://orcid.org/0000-0002-8456-9514
[e] https://orcid.org/0000-0003-4582-3732

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tralized decisions to be made through these copies. In this way, systems and machines that can control itself can be managed with processes (Santos et al., 2017).

Industry 4.0 technologies, internet of things, big data, augmented reality, additive manufacturing, cloud computing and cybersecurity make it easy to control with internet technologies. Sensors in the internet of things technology enable real-time reading of various data. With cybersecurity, access to the machines becomes secure. All data collected with big data can be stored on various disk systems. All this information is shared with the cloud system. Virtual copies of areas can be created with augmented reality. For example, virtual copies of classes and courses can be created. With additive manufacturing technology, digital designs can be easily transformed into physical objects with 3D printers. By using these technologies, objects can communicate among themselves and thus objects can be smart (Santos et al., 2017; Dogan and Gurcan, 2019).

For the efficient use of public resources, a primary research question is determined as ”What kind of model should be established for more efficient consumption of public resources within the scope of smart university?”. In the age of technology, where objects can communicate with each other, the identified research question brings together with the concepts of industry 4.0, the Internet of Things (IoT) and smart city/campus concepts. In this direction, the use of primary public resources such as costly materials and limited human resources is considered in this study. Therefore, the paper serves as a road map for a university campus to turn into a smart campus with digital transformation.

2 BACKGROUND ON SMART UNIVERSITY

Smart universities can be defined as small cities because they are a way to reach smart cities. The methods applied in cities can be easily integrated into universities. Therefore, many universities around the world want to adopt the concept of a smart university for the purposes of improving the quality of education, ensuring energy efficiency and improving management services. Smart university uses advanced technologies to provide various services. In the literature, there are various studies related to smart universities in academic and administrative domains. In academic domain, many studies focused on digitalization in education (Uzelac et al., 2018; Zhai et al., 2018). It is a very important application area in terms of ensuring that the data can be received and monitored in real time. Internet of Things technologies can also be used in libraries on campuses. In this way, students can see the library density and which books are available online (Zhu et al., 2018). Zhai et al., (2018) developed a game-based learning mechanism in a smart university. In this way, the students defined the relationships between the use of technology and learning. Zhang et al., (2018) have studied that multimedia conferencing systems are possible with cloud systems, one of the industry 4.0 technologies. They also offered the advantage of cloud technologies in smart university studies. Huang et al. (2019) reported that it is possible to create smart classes with the use of IoT technologies. They created a smart class prototype at Ming Chuan University.

Energy is the most popular implementation area in administrative domain due to high level of energy usage in universities. In a study conducted in China (Tan et al., 2014), the green campus project aimed to prevent unnecessary energy consumption. The air conditioner, lights and computers which are not used have been turned off by the internet of things. De Angelis et al. (2015) implemented some energy-oriented works at the University of Brescia. It was stated that 30% energy savings can be achieved with smart campus applications (Kolokotsa et al., 2016). In the study conducted at PGRI Yogyakarta University, smart buildings and smart parking systems have been developed. Remote online access to the university was provided, and a new learning approach was developed (Sari et al., 2017). In another study, recordings can be taken real time by humidity and temperature sensors in the classes and these values can be kept automatically at the optimum level. The optimum level was determined by the values that students could focus on best (Uzelac et al., 2018). Majeed and Ali, (2018) worked on smart rooms and smart parking systems by making training smart with IoT technologies. They integrated sensors and things to ensure communication.

Table 1 shows the focal points of previous studies. Main effects areas of the current studies can be classified as academic and administrative. However, the studies cannot present all sub-titles of these two main areas of applications.

The studies mentioned above concern the academic or administrative units of the universities. Wu’s study (2016) covers applications both in academic and administrative domains. They tested the impact of smart buildings and interactive learning on students’ achievement in Taiwan. In this study conducted with 35 selected students, the connections between smart buildings and learning were observed with statistical results (Wu et al., 2016). Although

Table 1: Previous studies and main working areas.

	Academic Related	Administrative Related
Sari et al. (2017)		+
Majeed and Ali (2018)	+	
Zhang et al. (2018)	+	
Lin et al. (2018)	+	
Alvarez-Campana et al. (2017)		+
Kolokotsa et al. (2016)		+
Chieochan et al. (2017)		+
Tan et al. (2014)		+
Wu et al. (2016)	+	+
Huang et al. (2019)		+
Jain et al. (2017)		+
De Angelis et al. (2015)		+
Uzelac et al. (2018)	+	

this study will lead to innovation in both the administrative and academic units, it does not cover the energy savings of the universities, the applications that can be made around the environmental of campus and the automatic information retrieval systems from the classes. However smart universities are made possible by the integration of all units. For this reason, it is very important to evaluate and integrate administrative and academic departments together. In our study, academic and administrative units of universities will be evaluated as a whole.

3 SUSTAINABLE AND DATA-DRIVEN SMART CAMPUS FRAMEWORK

The aim of the study is offering a model for the digital transformation process of the Izmir Bakırçay University which is a newly established university in Turkey. As a young university, the university aims to have a smart and sustainable campus in addition to its existing facilities. The best way to do this is to develop innovative business models and a comprehensive IoT strategy. At the end of the study, a roadmap will be presented for the digitalization studies of Izmir Bakırçay University. At the end of the digital transformation process, these results are desired to be achieved:

- to reduce energy consumption,
- to reduce waiting times to take advantage of campus facilities,
- to improve staff productivity,
- to improve the quality of classroom education,
- to ensure the contribution of all individuals on campus to problem identification and resolution,
- to analyze the usage of public resources by analyzing all data collected.

The methodological framework, which fully expresses the scope of the study, is shown in Figure 1. The areas shown in the methodological framework will be built on the existing information systems of the university (automation, personnel, procurement, web services, etc.).

As shown in Figure 1, the concept consists of 3 different stages. In Stage 1, a sample building was selected from the university campus. On this selected building, a framework has been established about energy, environment and classroom domains. In Stage 2, the framework is spread across the campus. In addition to the domains in Stage 1, different domains were identified and included in the framework. In Stage 3, the data generated by the systems in Stage 1 and Stage 2 will be stored in integration with existing university data. At this stage of the framework predictive, prescriptive, diagnostic and descriptive analytics can be performed with the data stored. Domains for each stage are given below.

Energy Domain: Energy consumption is the most challenging area of smart city works. High energy consumption brings with it high energy costs. It also accelerates the consumption of limited energy sources. Therefore, improvements in the field of energy have significant financial and environmental impacts. Feasibility studies present that electricity consumption of unknown cause (non-working consumption) are 10% per month. Since the heating of the university is provided with air conditioners, the improvements will directly affect the electricity consumption in this topic. In order to save electricity, it is envisaged to develop a system for the automatic activation or deactivation of lighting devices and air conditioners in unused environments.

To improve this system, presence sensors can be used to detect small movements in the environment. Presence sensors will help to understand whether classes or rooms are in use. The temperature and humidity sensor will operate the air conditioner if it is not suitable temperature and humidity of the environment. At the same time, the photocell will measure the amount of light and, if not appropriate, turn on the lights.

Environment Domain: Providing a clean and tidy environment will help to improve the quality of life in universities. It is also important for the cleaning staff to make plans such as work load and working hours. Along with the proposed systems, operational efficiency can be enhanced and environmental arrangements can be improved. For example, when it is time to clean the toilets, the touch screen service kiosks and the university mobile app can send notifications to cleaning staff about the need for cleaning.

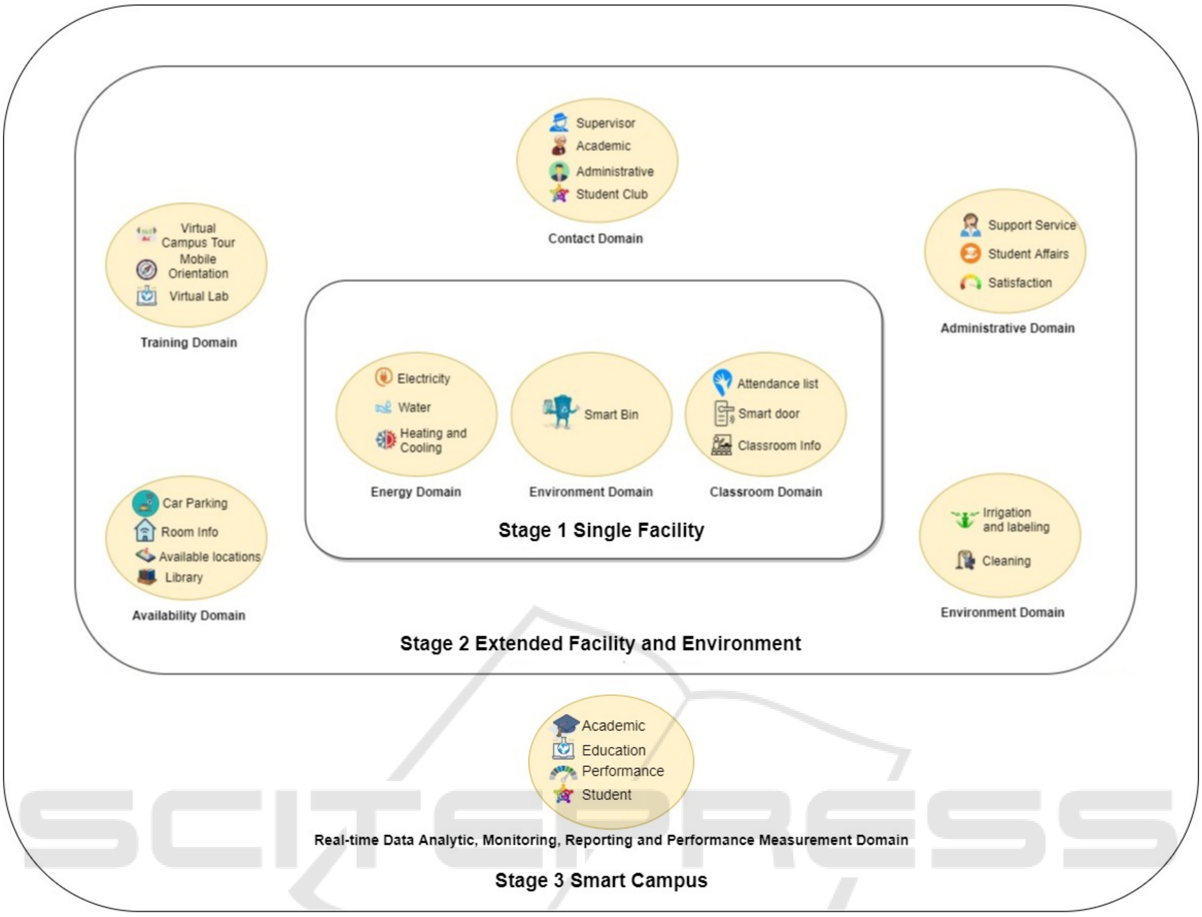

Figure 1: Sustainable and data-driven smart campus framework.

This will prevent the cleaning staff from wasting effort with continuous cleaning control, and at the same time ensure continuous cleaning. Furthermore, it will be possible to inform the cleaning staffs automatically according to the occupancy status of trash cans and soap containers. In addition, automatic irrigation systems which will be activated according to the soil moisture and weather conditions can be given as an example for the studies that can be done in this field. It is not possible to accurately distinguish the objectives of the identified study domains. Sometimes the objectives of one area overlap with the objectives of other areas. For example, the intelligent waste bin reduces both environmental pollution and improves the working conditions of cleaning staff (eliminating the need to walk around for cleaning control).

Clasroom Domain: İzmir Bakırçay University aims to increase efficiency in educational activities by using technological infrastructures. Classes are one of the most important areas in universities. Improving the physical environment of the classes will also improve the quality of education. In the survey conducted to İzmir Bakırçay University students, 30% of the students complained about various problems such as temperature and airlessness related to the classes. Therefore, it is important to control the environmental factors such as temperature, humidity, amount of light in the class that may affect the efficiency of the course and disrupts the students' concentration. The study to be carried out in this field is also related to the energy field. Factors affecting the quality of education, such as temperature, humidity and amount of light, also affect energy consumption. At the same time, the proposed smart attendance system aims to prevent the students from being interested in signing the attendance sheet during the course. Therefore would help them not to get distracted during the course.

The second stage of the study consists of 5 different domains. Information about the environment domain is provided in Stage 1. This stage covers the proposed activities to be carried out throughout the campus.

Availability Domain: From time to time, there are densities in common areas such as dining hall, libraries and cafeterias. The purpose of the proposed system is to utilize the physical facilities of the university campus with maximum benefit. With the efficiency-oriented strategy, it is desired to reduce waiting times in common areas. The availability domain includes sub-application titles such as parking, library, dining hall, cafeteria, class/room information.

Training Domain: Training domain covers many different fields. The aim of the domain is to find practical solutions to some problems with digitalization and to prevent loss of manpower and time. There are three sub-application titles: virtual campus tour, smart orientation and virtual laboratories. The virtual campus tour will enable virtualization of university promotion and orientation meetings with a website or mobile application. The smart orientation application will help new staff and students get to know the university and its facilities. Virtual laboratories include both AR/VR supported applications and desktop virtualization applications. In particular, virtualization applications reduce software installation time considerably. Software installation time will be reduced by 98% with a virtual laboratory.

Administrative Feedback Domain: In some cases it is either not possible to determine the problem with the sensors or the application is impractical. In such cases, it is aimed to support the smart campus feature with the feedback from the users. For example, defect of a projection in classes will not be controlled by sensors. However, a digital display or mobile application can be developed where students or faculty members can report the problem to the relevant unit when it fails. Thus, quick solution of the problems will be ensured by the feedback received from the users. Similarly, a digital display can be designed that can always measure the level of satisfaction of the services provided to increase the satisfaction of the users. The areas of administrative feedback and fast contact are complementary. There are three sub-application titles as support services, student affairs and satisfaction. Students or staffs will be able to report their requests, complaints and satisfaction to the relevant administrative units with the mobile application to be developed. With this application, satisfaction surveys can be conducted easily. With instant notifications, authorities will also be aware of emergencies in the university.

Contact Domain: The most important element in an organization is fast and accurate communication. In universities, it is very important that academic staff, students and administrative staff communicate quickly with each other. In this area, a proposal will be made in which interpersonal communication can be realized with an intelligent system. Contact Domain has subheadings such as supervisor, academic staff, administrative unit, student club. Interpersonal communication can be made fast and effective with a mobile or web application that can be developed. In addition, the user experiences from the application can be processed and converted into useful information and used in administrative processes.

Real-time Data Analytic, Monitoring, Reporting and Performance Measurement Domain: A completely data-oriented approach is adopted in the proposed system structure. Sensor data and data collected from individuals will form very large data stacks. Adding the data obtained from external sources to these raw data, processing the data and converting it to useful information, and establishing models that can be made for future predictions are of great importance for the university. Information that can be useful at every stage of decision-making levels, including tactical, operational and strategic, can be used by developing a user-friendly and dynamic reporting system. Reports about academic, education, performance, and student will be effective for the improvement of physical conditions, more sustainable and high quality campus objectives.

4 SYSTEM ARCHITECTURE AND IMPLEMENTATION

Industry 4.0 technologies play an important role in the goal of building a smart and sustainable campus. This technologies to be used in the stages of the framework are shown in Table 2. Cloud and IoT technologies will be used in the first stage which consists of energy, environment and classroom domain. Cloud, IoT, big data, mobile and augmented reality technologies will be used in the second stage which consists of environment, availability, training, administrative feedback, and contact domain. Cloud and big data technologies will be used in the third stage of the study.

Table 2: Applicable Industry 4.0 Technologies for Sustainable and Data-Driven Smart Campus Framework.

Stages	Cloud	IoT	Big Data	Mobile and AR
Stage 1	✓	✓		
Stage 2	✓	✓		✓
Stage 3	✓		✓	

System application is designed to be 3 stages in Figure 2. In the first stage, called Single Facility, studies will be carried out in the fields of *Energy Domain, Classroom Domain* and *Environment Domain using cloud* and *IoT technologies*.

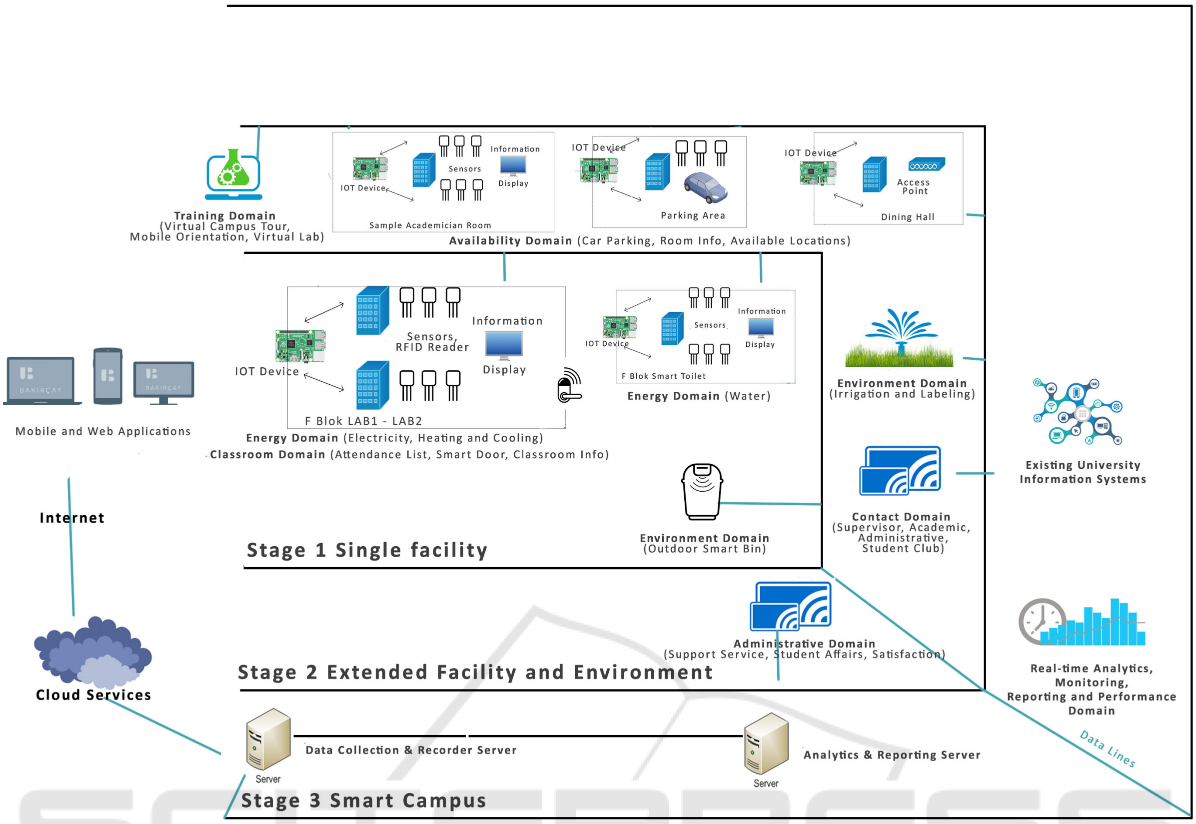

Figure 2: System Architecture.

For *Energy Domain*, temperature, light intensity, humidity and mobility values of the laboratories will be collected with sensors. This data will be stored on a data collecting-recording server to be configured with various internet protocols. If the values are beyond the specified range, the light or heating cooling systems are automatically switched on or off using internet protocols with the data sent to the IoT unit. If no motion is detected in the laboratories for a certain period of time, the light and heating-cooling sources will receive an automatic shutdown signal. This will allow more productive use of energy resource consumption and huge savings.

For *Environment Domain*, trash boxes to be fitted with wireless occupancy detection sensors would ensure that alerts are sent to the appropriate units from the trash boxes exceeding a certain occupancy rate. In this way, human resource planning will be made more efficient.

Studies will be performed in the second stage called Extended Facility and Environment using cloud, IoT, and Mobile and Augmented Reality technology in the fields of Environment Domain, Availability Domain, Contact Domain, Training Domain, and Administrative Feedback Domain.

For *Classroom Domain*, RFID cards will provide the data entry and exit information of the students and teachers to the Data Collection-Recording Server in the 2 laboratories to be prepared for the classroom domain. In this way, student attendance lists can be automatically transferred to Student Information System automation. It will be ensured that the relevant areas are closed for use outside the hours specified in their schedules thanks to the smart doors to be configured for laboratories. With the information screens to be installed at the laboratory entrance, class occupancy rates, the next course, etc. will be shown.

For *Availability Domain*, wireless sensors will track the parking spaces on our campus, and data on the occupancy of these parking spaces will be sent to the IOT system. This data will be processed with different internet protocols on a data acquisition-recording server. In this way, parking guidance, parking management and warning systems for occupancy can be designed. Wireless access points and private wireless networks will be built in the Dining Hall and Library entrance areas. This will determine the number of devices that provide instant wireless network access. Occupancy rates of related fields will be monitored and students will be shown occupancy rates through information screens, mobile devices and various platforms.

For *Training Domain*, Three sub-application titles are included in this domain: virtual campus tour, mobile orientation and virtual labs. The virtual campus tour would allow students to visit the campus for promotion and orientation events with a website and mobile application. In addition, the mobile orientation application includes the trainings required by newly recruited employees, identification by newly enrolled students of the university and its services, and support by regular training for current staff and students. Virtual laboratories include both AR/VR supported applications and desktop virtualization applications.

For *Administrative and Contact Domain*, In some situations, either identifying the problem with the sensors is not possible or practical. Feedback from the users will be forwarded to the data collection-recording server with the interactive information screens to be built and the mobile application.

For *Environment Domain*, With the smart irrigation system to be designed; the IOT device will irrigate the amount of water the predefined vegetation requires. This device will measure the soil's moisture content and allow the transfer of relevant data through internet protocols to the data collection server. This smart irrigation system will make a significant contribution to the efficient use of water resources.

For *Real-time Data Analytic, Monitoring and Performance Measurement Domain*, Cloud and Big Data technologies will be used in the third stage called Smart Campus. Data collection-recording server will perform the task of recording data from all sensors, IoT devices, etc. Data sent to the Analytics&Reporting Server will be processed and converted into useful information. With the web-based software that will run on this server, all data can be tracked in real time, notifications can be created in accordance with the defined rule sets, and they can be transmitted to people or units automatically.

5 CONCLUSIONS

The increase in the urban population results in management and complexity problems in cities for governments in various domains such as energy supply, waste management, the use of public resources, and educational services. At the same time, the growing population creates a huge amount of data by contacting many devices. A notable improvement in device variety, the volume of data and sensor technologies have proposed chances to build smart cities for authorities. Because university campuses are small cities, all implementations in smart cities can be adapted to campuses to build smart campuses.

The use of industry 4.0 technologies on campuses is a powerful factor that increases efficiency both in academic and administrative operations. By integrating Industry 4.0 systems into campuses, efficiency can be increased in sustainable universities. Uncontrolled use and excessive consumption of energy, materials, and manpower in universities can cause many problems. Sustainable systems on campus offer many opportunities to manage these problems. The regulation of both academic and administrative processes and sustainability in universities is of great importance for the formation of self-sufficient campuses.

In this study, a framework on smart university and the sustainable campus is presented for İzmir Bakırçay University to have a sustainable and data-oriented smart campus. A roadmap was prepared to create a model for the digital transformation process of the university, which aims using resources effectively, being technology oriented, being productivity oriented, strengthening communication between employee, providing the best physical opportunities. Some enabling technologies for Industry 4.0 such as Cloud, IoT, big data, mobile and augmented reality are associated with the framework considering the previous smart campus studies. The determined road map consists of three stages. The first stage includes the single facility applications, the second one consists of the extended facility and environment applications, and the last stage covers smart campus applications with real-time data analysis. The system architecture that represents all stages in the framework is discussed. It includes all processes from modeling to data collection, sharing, conversion, and analysis. The possible benefits of the proposed framework are twofold: to prevent waste of limited public resources and support academic services by increasing the service quality. Because of the dynamic structure of the proposed framework, new universities in digital transformation process can adopted the sustainable and data-driven smart campus framework according to their strategic goals.

The proposed framework has two main limitations. Since the domains in the study are determined with respect to the university needs, some popular application areas, such as transportation, are excluded in the study. Therefore, they may be extended or changed according to the university conditions in other studies. Stage 3 is not detailed in this study because it needs collected data to interpret and support decision makers. Therefore, the first two stages present an infrastructure for real time analytics.

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