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A perspective on smart universities as being downsized smart cities: a technological view of internet of thing and big data

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ABSTRACT

The integration of internet of things (IoT) and big data technologies is transforming the overall perspective of managing various sectors of modern life; with higher educational sectors being no exception of this transformation. This paper explores the idea of a "smart university" as an extension of the overarching "smart city" framework, emphasizing the blending of IoT and big data technologies within higher education institutions. The study investigates the incorporation of IoT technologies throughout university campuses, including intelligent classrooms, smart infrastructure, and device networking. Moreover, the paper delves into the substantial role played by big data analytics in processing and extracting meaningful insights from extensive data generated by IoT devices in a Smart University. The use of predictive analytics, machine learning algorithms, and data-driven decision-making contributes to personalized learning experiences, adaptive campus management, and proactive maintenance of university facilities. Furthermore, this paper not only emphasizes the potential benefits of deploying IoT and big data in a university setting but also addresses challenges related to security, privacy, and ethical considerations. By embracing a comprehensive approach to technology integration, universities can leverage the capabilities of IoT and big data to establish intelligent, interconnected, and flexible educational environments that align with the broader vision of a smart city.

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1. INTRODUCTION

The internet of things (IoT) may be viewed as a new revolution that makes it possible for digital devices and other peripheries, including different types of sensors, to communicate with one another through the internet for the ultimate goal of efficient and streamlined management of day-to-day life amenities. This incorporation of IoT has transformed the old way of living into a technologically advanced lifestyle by using smart devices and connecting them to the Internet to deliver creative solutions to numerous challenges and concerns pertinent to various modern life schemes. Highly significant information-based developments have been emerging as a result of the various applications of these transformations, including smart cities, smart homes, smart industries, smart transportation, and smart universities. Overall, we now live in a smarter

world where data collected by precise sensors can be routed through different channels for maximum utilization in managing modern life amenities. The world is moving very quickly towards smart cities, demanding higher levels of interactive behavioral patterns within modern societies commensurate with the new pace implicated by the incorporation of IoT. For this reason, the success of smart cities lies in the presence of individuals within these societies who can both adapt and benefit from these new trends of day-to-day life management.

The term "smart city" refers to the new urban century where millions of sensors are employed to facilitate and management of different sectors in a timely manner, yet a smart city may not be all that smart if these technological advancements are not accompanied by a matching responsive scheme experienced by individuals within a particular society. Smart cities have many elements, such as a smart economy, mobility, atmosphere, authorities, and so forth, but the most important aspect is smart people. Smart universities are also considered to be a major element of smart cities. The community with intelligent individuals capable of navigating the new technological era, where every component may now be connected to the internet owing to the IoT revolution where enormous amounts of data are continuously generated, to ensure the sustainability of the new smart cities.

The most precious asset for any cooperation, especially universities, is data, where proper data analysis enables decision-makers to optimize the utilization of university resources while also enhancing the quality of educational outcomes, in addition to continuously evaluating the decisions to reach to an optimum resource management scheme. However, the main concern in this area is that the sensors and integrated devices in smart universities generate an enormous amount of data, creating numerous challenges for big data storage and analysis. Due to the fact that traditional analysis techniques are not capable of handling the massive traffic, new sophisticated algorithms have been built to perform this task using "artificial-intelligence" (AI) and "machine-learning" (ML). Smart universities generate enormous quantity of data from the learning process and outcomes that needs to be refined and put in a meaningful context to improve the learning outcomes. In addition, big data generated to control the environment, such as heat, pressure, lights, and so on, also needs to be analyzed in a proper way to act in that regard. A university that accomplishes its goal by incorporating technological innovation into its design is called a smart university.

The smart university concept deal with two primary aspects: the first being a conceptual component of the smart-city concept by affording a smart-campus, including smart classrooms, libraries, parking lots, and lab, to enhance the quality of education, management, and environmental protection. In addition to the educational process, provision of smart citizens who can compete with the new community should also be emphasized in order to ensure the sustainability of smart universities. In this regard, a measurement tool is needed to ensure universities' compliance with all metrics of the framework designed for smart campuses. Recently, all universities are trying to keep up with the pace and move forward towards smart universities, especially after the pandemic of COVID-19, where all traditional universities shut their doors and only smart ones were still capable of continuing their missions through online and distance learning. This has created an alarming for almost all institutions throughout the world to transform into smarter ones.

2. LITERATURE REVIEW

One pillar of creating a smart city is creating a smart campus; to assure this goal, a smart campus dashboard was established by implementing policies, programs, activities, and events to build a smarter and more sustainable small city. The entire city may have a positive impact from indicator monitoring, bringing advantages to municipal operations and enhancing the quality of life for residents [1]. Only educated, smart citizens can make smart cities successful. For colleges, this entails teaching broad competences like problem-solving, creativity, flexibility, and critical analysis to all students. It is also essential to incorporate sustainability awareness into any effort for establishing/maintaining smart universities. The university must act with integrity by setting a good example in this regard [2].

Grimaldi and Fernandez in [3] demonstrated that there is a gap in students' preparation for the disciplines required for the smart city and that the university curricula do not align with the goals of smart cities. Therefore, they recommended changing the academic curriculum, especially at universities, to suit the demands of the next stage. These findings are based on a study conducted at universities in Barcelona.

Since the Internet-of-Things in postsecondary learning enables connectivity between sensors and the controllers of tangible items to convey information, the establishment of solutions based on such technologies is encouraged, a study provided an integrated model combining four technologies (IoT, AI, cloud computing, and big-data analysis) to fully grasp the idea of a smart-university [4]. The authors focused on major aspects to ensure sustainability, and through the paper, they conclude that whatever the kind of programs and technologies used or suggested, they must be fully consistent with the sustainability goals established by institutions and groups seeking to improve citizen wellbeing. Economic, social, and cultural sustainability metrics must be used to evaluate universities. Included in this is the power to increase recipients' capacity to offer the same service to others [4].

To assure the universities' effective participation on smart city projects, quality assurance in universities has been discussed in a professional and innovative manner that includes all the institutions' educational, research, and cooperation activities [5]. A crucial aspect of smart universities is a clean environment that reduces energy consumption in lighting, air conditioning, and all electric systems by using smart sensors, making the system more reliable and cost-effective by adopting a practical network design using proper protocols and numerous sensors and cameras that turn on the electrical device once movement is detected. The relevance of smart students as one of the primary aspects of the sustainability of the technological advent has been neglected in all recent studies, which focus on the technical element of smart universities and the need to guarantee that classrooms, campuses, and labs are all smart [6].

Smart universities perform several tasks spontaneously, such as monitoring incoming and leaving visitors, adhering to attendance, pathways lightning, using data input to enhance any needed area, preventing accidents by continuously monitoring traffic, and minimizing power usage expenses. It may be seen as a good approach to tackling ecology in smart universities. Several sensors that communicate with a central application, the main network, and the branches make up the standard smart university's design. Numerous pieces of work, including the integrator and gateway, radio-frequency identification (RFID), and wireless-sensor networks (WSN), among others, are included in this application offering reliable infrastructures for both teaching and learning as well as secure and efficient software and applications for research and development to accomplish the ultimate goal of building smart universities [7]. Building a smart online university requires the merging of such aspects as big-data, cellular technology, and cyber-physical systems inside the IoT culture, in addition to cloud technologies using service-oriented software platforms from major enterprises [8].

Alghamdi and Shetty [9] suggested that systems for businesses and building projects need at least one fast backbone network. Servers are necessary to manage the data collected by widely dispersed sensors; the process of building automation involves the use of a variety of sensors. Sensors that turn off services when a location is vacant, track carbon dioxide levels in workplaces and schools, control building temperatures, measuring humidity and pollutants in the environment and public areas, as well as sufficient deformation and vibration sensors for smart asset management [9].

In a recent article Shamsuddin *et al.* [10] divided the architectural structure of smart cities into four main components: the application layer, the computing layer, the transmission layer, and the sensor layer. Through its two main components, the sensing layer is essential for both object detection and information synthesis. Examples of sensors included RFID tags, reader-writers, cameras, infrared sensors, parking sensors, body sensors, sensor networks, and gateways. They managed services platform, interoperability platform, knowledge acquisition platform, and network security framework [10].

Adoption of the IoT will eventually lead to the generation of massive amounts of data from networked devices, necessitating the management and evaluation of big data. In order to keep up with the rapid pace of this technological race, researchers have become increasingly interested in smart universities. As a result, they have proposed several frameworks, most of which are not comprehensive enough to account for all aspects of smart universities, and some of which have not undergone adequate testing to yield reliable results. Rico-Bautista *et al.* [11] presented a somehow detailed literature review of many studies about the concept of smart universities, where most of these studies were found not to adequately address university innovation in addition to that IoT-related research dominates only in the field of IoT.

According to recent studies, there are several advantages to having a smart university, utilizing big data to grasp a great volume of information, improve the quality of research findings, and improve education, ranking, and performance. "Big data" is categorized by the 3Vs: volume, variety, and velocity. "Big data analysis" refers to a sizable collection of data that, owing to its volume and significance, has a significant influence on the technical and logical world and calls for incredibly complex and enormous information warehouses. Big data gives educators a lot of insightful data on their students. Owing to this vast amount of information, the benefits to educational institutions are substantial; for example, enabling careful evaluation of conveyance of educational and learning outcomes on both the collective and individual levels. It analyzes each student's development quickly, accurately, and intelligently by having correct data acquired once available. The institute may also spend less on infrastructure compared to other non- or less smart institutions. In present time it is necessary that conventional colleges move towards becoming smart ones (modern and intelligent). As discussed earlier, this was clearly demonstrated through the global pandemic where only fully or at least partially smart universities were able to provide their educational services to students [12]. Based on the examination of many technological models of technology adoption along with suggestion for big data-specific approach three factors were found to be of particular importance in this regard; personal perspective, privacy and risk, as well as management support [13].

Big data has been shown to be to be crucial in the idea of a "smart campus"; Nagarkar *et al.* [14] proposed a novel framework composed of four layers: a layer containing all required applications; a layer for

sensing devices attached to each application; a layer for interconnection, which is frequently wireless; and a layer for servers. With this framework, the researchers tried to compete with the advancements in networking technology, connectivity, sensors, and IoT, where the proposed framework could handle a variety of issues, including asset monitoring, providing access to information, enhancing planning, and generating and developing safer campus environments [14]. Dameri *et al.* [15] divided smart-cities into two three-element subgroups (universities, governmental agencies, and private businesses) (technological factors, human factors, and institutional elements). A top-down implementation strategy for smart-cities in which the government plays a significant, leading role is called the institutional factor. The technological component of smart universities entails designing and testing the use of innovative technology in metropolitan settings. Scholarly research also examines the benefits and drawbacks of advanced devices on citizen quality of life [15].

Viñán-Ludeña *et al.* [16], the setup of smart universities has been separated into several layers; in the suggested architecture, the authors utilized a three-layer model, but indicated that up to five layers may be incorporated into such model. Depending on the number of layers, the complexity of the system is determined, and any proposed solution should cover all the technological aspects of smart universities. These are outlined below:

- Capturing layer: the raw data obtained from sensors or other data collection devices will pass via an interface before being transformed into usable information and stored in the centralized database.
- Processing layer: data is cleaned up and put into a format that can be used in the analytical tier in this level, which is regarded of as one of cleansing.
- The analytics layer: this tier enables the creation of analysis, reports, and visualizations using processed data that has been pulled from a central repository.

Every piece of equipment on campus, including doors, windows, books, fans, as well as smart devices belonging to students, would be connected to the internet as part of the "smart university" to get input from various entities. Abdi [17] examined the idea of the IoT and its applicability on campuses by having a conceptual design covering whole aspects of smart university assets such as smart doors, smart gateways, and smart offices and investigated the level of support from IoT to all aspects of smart universities [17].

The use of numerous sensors and actuators on campus would be necessary for adopting IoT, which may be extremely labor-intensive if manual configuration is employed. Undoubtedly, new approaches to automating IoT device configuration must be thoroughly investigated for accurate and time-efficient transformation to smart universities. Due to its inexpensive price, easy fabrication, tiny size, and minimal maintenance needs, RFID is becoming increasingly common among identifying technologies. RFID is used to carry out a variety of tasks, including identification for authorized people, tracking both people and equipment, performing smart attendance, protecting valuable assets from theft, and doing some room automation for lights, fans and air conditioning among others. It is strongly advised to use RFID with the sensors currently in use; the authors also proposed a three-integrated module architecture for RFID use [18]:

- RFID reader: an RFID reader is composed of a microcontroller and an RFID module. When the person wearing the badge meets the reader, the tag is detected.
- Transmission takes place between the database server, control circuitry, and RFID reader.
- Control circuit: working with the database server, the control circuit gets translated IDs.

To track staff, faculty, and student attendance at a smart university, RFID is an important emerging technology, identifying goods with the aid of this affordable, secure wireless technology. Tracking and remote sensing make it simple to pinpoint the location; RFID uses radio waves to identify and communicate items, and a reader to collect data. RFID consists of two parts: a transceiver and a transponder. These sensors are crucial for connecting the offline and online worlds. These also keep an eye on environmental changes, such as managing room temperature, power leaks, air conditioning, ventilation, supply, and inventory tracking, while spontaneously alerting the user so that the relevant remedies/measures may be applied. The nodes that make up the wireless sensor network are equipped with sensors, memory cards, transceivers, microcontrollers, and batteries. The sensors are mostly utilized for data collection. Smart attendance systems track students' attendance using a basic smart ID card and send a short message service (SMS) to relevant personnel through smart phone applications upon arrival to and departure from the campus. Students are given ID cards with UHF RFID tags and antennae that track their movement during lectures, seminars, labs, libraries, and other activities. The IoT might help develop the Smart University in a safer and more energy-efficient way. To enable suitable high-performance IoT applications and provide us with a more environmentally and energy-conscious smart university infrastructure, RFID, wireless sensor networks, and robotics all play crucial roles.

Ananta *et al.* [19] proposed and tested a model for control circuitry that automates office equipment (lights, fans, and air conditioners) based on the specified profile of the label owner and compared to the legitimate tags. concluded that the use of smart cards is utilized to monitor instructor and student attendance, where less than four centimeters must separate the card from the reader for the reader to correctly read the

card's serial number; the reader successfully reads every card's serial number with a hundred percent success rate and where less than 0.2 seconds on average is needed to read the card's serial number. For movement detection, Al-Soufi [20] aimed at enhancing mobility on a smart campus. User placement was the main problem they concentrated on for mobility. A new demonstration technique based on indoor positioning systems based on existing WAP fingerprints without the need for any extra infrastructure was made available to application developers as a service on the smart university platform.

Many nations have adopted the concept of "smart universities". Bahrain is an excellent example of a country that has implemented all the pillars of a smart university, including virtual learning, management dashboards, green campuses, facility control, linked students, and productive analysis. Given that these elements generate massive amounts of data, the proposed framework partitioned the generated data into three main repositories to make big data analysis easier and more convenient [20]. A paradigm for developing an IoT-enabled smart campus university will be presented, embracing internet-based connectivity between controls and sensors embedded in a variety of products to ensure interaction between entities and data collection to create smart parking, classrooms, education, and, most importantly, smart students [21]. To reach the aspect of a smart university, all data generated from sensors must be delivered to the correct storage system to be analyzed at a later stage. A network linking the newest radios and IoT hotspots and universities is essential for providing effective communication, and a linked innovation tunnel should exist [22]. Hou *et al.* [23] conducted a four-stage experimental study about smart tools; in the first stage, no smart-tools were used; in the second stage, basic smart-tools were used; in the third stage, advanced smart-tools were used; and in the fourth stage, an innovative smart-tool was used, ending up with the result that even though each advanced stage costs more than the previous one, they still afford more beneficial information to organizations [23]. Prandi *et al.* [24] proposed a sensor infrastructure created and set up on a new department in the University of Bologna to collect information on various environmental conditions, including interior and outdoor occurrences. Chen provided a comprehensive system that controls all operations, including logical control of flow, knowledge, and energy efficiency, commencing with data collection, transmission, and analysis [25]. Building a framework to manage application systems and provide data that simplifies the process of choosing how much energy to spend in the computer room, presenting a website design on a green-campus, Sieck *et al.* [26] concentrated on one element of smart universities that has been discussed deeply, i.e., smart parking, where the proposed solution uses cameras with sensors to detect vacant spaces for database input and then sends data to a user-friendly application to spot the available parks; the same concept is used for other applications. Gaurkar *et al.* [27] employed Cisco packet tracer to create a model for smart universities; this configuration shows how data moved and interacted to ensure end-to-end connectivity by mapping each logically interacted element in separate virtual local area network (VLANs). The openness of the data that is available to everyone should serve as the foundation of a smart-campus.

Relaying on the views of respondents, the author divided them into four groups: repute and confidence, data evaluation, utilization of services and resources, and user participation, resulting in a variety of advantages for different stakeholders [28]. Consumption of energy is a particularly important concern that smart universities need to take into consideration. The adaptation of this concept, however, poses many challenges. The encountered challenges have been considered and a proposed solution was reached to maximize energy savings. The fundamental obstacles colleges must overcome in their quest to become and remain smart are not highlighted by the fact that they characterize themselves as smart environments [29].

When a university has its foundations throughout the comprehension and critical awareness of the fundamental information, in the identification of the more practical competences, and in the pursuit of high quality, it is said to be a "smart" university [30]. The transdisciplinary big data and open data ideas that are rapidly increasing and expanding have been critically explored in this work. As a result, conceptualizing big data required specifying and evaluating its sources and characteristics (7Vs) attributes [31].

A proposed design for waste management built on a prototype of a smart trash can, an inventive tool that can be used to autonomously recycle various objects utilizing a hybrid sensor and image-based classifier, The suggested method has an accuracy of above 97%, according to the results [32]. ML and AI algorithms will be applied to the available data to create unique applications that provide value to the institution and promote the development of cutting-edge technology spin-offs centered on smart cities. In addition to its economic and ecological impact this is likely to uplift the overall morale within the university community [33]. Purnomo *et al.* [34] emphasized that all universities should start taking serious steps towards implementing the smart campus concept as quickly as feasible. The authors have also provided several insights into how smart campuses can be implemented. Due to this availability of smart campuses, institutions now may be able to enhance the caliber of their operations and, consequently, their evaluation standards.

3. RESULTS AND DISCUSSION

Table 1 identifies the references that discussed each type of technology applied for reaching at the target of smart universities, including frameworks, IoT, sensors, and big data. In a smart university roadmap, many stages and technologies should be identified to come up with research reflecting high contribution in this field. Table 2 summarizes all the reviewed papers based on the seven defined comparison factors below, and identifies which papers were compliant and non-compliant with these factors (listed below).

- Proposed solution (PS)
- Smart university elements (SUE)
- IoT (IoT)
- Sensors (S)
- Big data (BD)
- Conceptual design (CD)

During this literature review, 34 references were summarized; Figure 1 shows the types of literature addressed. According to Figure 2, 27% of the papers reviewed did not propose any kind of framework or solution, 32% did so without providing any results or evaluating, and 41% proposed a framework that addressed either a specific technological aspect or smart universities supported by relevant data. Therefore, studies comprising this 41% were considered in the present research to contribute well toward reaching smart universities.

Table 1. Referencing for smart university technologies

Smart universities technologies		
No.	Technology	References
1	Smart universities and campus framework	[1]-[34]
2	IoT	[1], [2], [4], [5], [7], [9], [10], [13], [14], [18], [19], [23], [25]-[27], [29]-[33]
3	Sensors and RFID	[1], [2], [4], [5], [7], [9]-[11], [14]-[17], [19], [21], [23], [25]-[28], [30]-[34]
4	Big data	[3], [4], [7], [10], [13], [14], [23], [25], [31]

Table 2. Comparative between all studies targeting smart universities based on common factors

No.	Major theme	Comparison based on assessment factors						
		PS	SUE	IoT	S	BD	CD	R
[1]	Smart universities campus using IoT	✓	✓	✓	✓	×	✓	×
[2]	Smart campus	✓	✓	✓	✓	×	✓	✓
[3]	Smart universities	×	✓	×	×	×	×	×
[4]	The role of smart universities	×	✓	✓	✓	✓	×	✓
[5]	Smart university IoT model	✓	✓	✓	✓	✓	✓	×
[6]	Sustainable smart universities	×	✓	×	×	×	×	×
[7], [31]	Big data analysis for smart universities	✓	✓	✓	✓	✓	✓	×
[8]	Triple helix in smart cities	×	✓	×	×	×	×	×
[9]	Survey about smart campus	×	✓	✓	✓	×	×	×
[10]	smart universities architecture	✓	✓	✓	✓	✓	✓	×
[11]	Building A Smart University using RFID	✓	✓	×	✓	×	✓	✓
[12]	Smarter universities	✓	✓	×	×	×	✓	×
[13]	Smart universities	×	✓	✓	×	✓	×	×
[14]	Big data driven in Smart universities	×	✓	✓	✓	✓	✓	×
[15]	Smart university a new concept of IoT	✓	✓	×	✓	×	✓	×
[16]	Monitoring system at universities	✓	✓	×	✓	×	✓	✓
[17]	Smart university using IoT	✓	✓	✓	✓	×	✓	×
[18]	The challenges of smart universities	×	✓	×	×	×	×	×
[19]	Energy Aware IoT based Green Smart University	✓	✓	✓	✓	×	✓	✓
[20]	Enhance mobility in campus	✓	✓	×	×	×	✓	✓
[21]	Big data driven for smart universities	✓	✓	×	✓	×	✓	×
[22]	Smart campus features	×	✓	×	×	×	×	×
[23]	Smart universities, big data adoption model	✓	✓	✓	✓	✓	✓	×
[24]	Strategies of smart universities	×	✓	×	×	×	×	×
[25]	Smart university in IoT	×	✓	✓	✓	✓	×	×
[26]	Smart universities and IoT	✓	✓	✓	✓	×	×	×
[27]	Smart campus and IoT	✓	✓	✓	✓	×	✓	✓
[28]	Smart campus tools	✓	✓	×	✓	×	×	✓
[29]	Smart campus framework	×	✓	✓	×	×	✓	✓
[30]	Designing new campus using IoT	✓	✓	✓	✓	×	✓	×
[32]	IoT in smart campus	✓	✓	✓	✓	✓	✓	×
[33]	Smart campus based on wireless sensors	✓	✓	✓	✓	×	✓	✓
[34]	Smart parking in smart universities	✓	✓	✓	✓	×	✓	✓

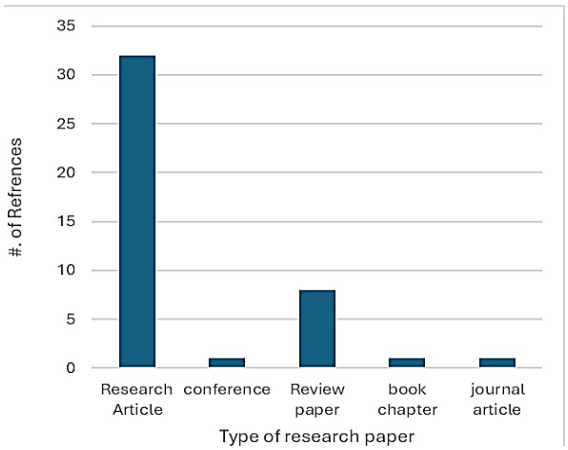

Figure 1. The types of research paper

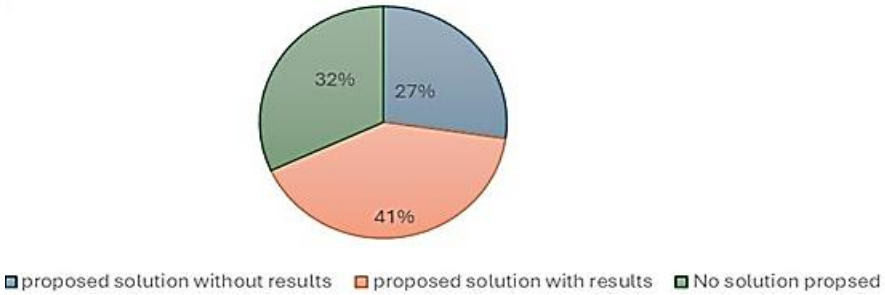

Figure 2. Measure the effectiveness of studies

4. CONCLUSION

To create a strict framework for smart colleges, these technologies IoT, sensors, RFID, and big data should all be handled from a collective perspective. Researchers became increasingly interested in this topic as smart universities emerged, and as a result, research in these subjects expanded by 1.5% annually. Forty-four research publications were examined during this review paper, of which 32 were research papers, 1 conference material, 1 book chapter, 1 journal article, and 8 review papers. As a result, 27% of the papers that were reviewed have not suggested any framework or solution; 32% of these studies provide a framework or solution but without offering any results or evaluations; and finally, 41% of the papers suggest a framework that addresses a particular technological aspect or smart universities that is backed up by data. In conclusion, only about 41% of these studies present significant contribution towards reaching to fully smart universities. Smart universities are an inevitable goal for any educational institution considering its sustainability as a long-term goal. As such, all universities with minimal futuristic vision should start (if haven't already started) adopting this approach. The "otherwise" option is simply not a "wise" one, if possible, at all. Having a rigid framework ensuring that all aspects of smart universities are included is a must. However, most of the conducted research focused on one aspect of technology, and it could be concluded that more insight research is needed to thoroughly cover other aspects that are not fully technological.

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