

A Systematic Study of E-Governance Infrastructure for Smart Campus Development in CBSUA

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ABSTRACT

The integration of Information Technology and Management in smart campus settings is a big problem that needs to be addressed. The integration of Information Technology and Management in smart campus settings is a big problem that needs to be solved today. The institution to move forward, it is important to make sure that these areas are working together well. Conducted the systematic review in 2025 to trace the development, pinpoint the challenges, and map the possibilities still open to the e-governance backbone at Central Bicol State University of Agriculture (CBSUA), to sketch the path to the “University 4.0” goal. Using the PRISMA framework, gathering the findings from 14 journal articles to official reports published from 2020 to 2025. The evidence collected through the research indicates that the basic foundational CBSUA services have been established and integrated. There seems to be a lack of seamless integration and alignment between individual software systems, significant discrepancies in the digital infrastructure across the four campuses, and deficiencies in the faculty and staff in managing data. Artificial Intelligence, Big Data, and the Internet of Things (IoT) are used in the strategic planning of fostering personalized education, proactive advising, and responsive governance. The study contends that moving forward entails an executive strategy that integrates the basic services and infrastructural disparity and advances the development of digital and analytic competencies in a stepwise manner, rather than pouring resources into emergent technologies.

Keywords: *Smart Campus, E-Governance, Infrastructure, Artificial Intelligence (AI), Big Data Analytics, Internet of Things (IoT), Higher Education*

INTRODUCTION

Higher education systems globally are confronting the transformation driven by the acceleration of digital technologies and the parallel emergence of the smart campus architecture (Cavus et. al 2022). The core of this architecture lies the composition of three fundamental technology components: the Internet of Things (IoT), which deploys a framework of interconnected sensors and devices to produce real-time environmental and operational data across the campus; Big Data Analytics, process of examining large changing datasets that addresses the handling of the heterogeneous and huge volume of data in the system; and Artificial Intelligence (AI), which organized data to automatically that handle tasks both to the students and administrative task [1]. This programmatic framework increased operational efficiency and customized engagement of everyone [3]. The implementation of this e-governance infrastructure has shifted from distant concern to a compelling directive, witnessing this digital infrastructure as a prerequisite to enhanced operational effectiveness, more favorable outcomes from instruction, and improved global standards. [4]. The institutions persistently face the challenge of integrating digital technologies for academic and administrative life. The Central Bicol State University of Agriculture (CBSUA) has responded to this

challenge by declaring its intention to adopt the University 4.0 model by internalizing this aspiration through formal strategic documents.[13]. Signs of the transformation are observable across the university's multiple sites and consist of the operational rollout of core software architectures, namely, the Student Information and Accounting System (SIAS), an expansive Virtual Learning Environment (VLE), and an ensemble of digital platforms designed to facilitate interaction among faculty, students, and external collaborators. Furthermore, the systemic challenges hinder the transition from discrete module installation to a genuinely intelligent campus. CBSUA, such as the peer institutions, faces a suite of incompatible forces that disrupt both real-time coordination and sustainable scaling. The fragmented application programming interfaces that obstruct clear interservice data, persistent shortfalls in both physical and digital infrastructures most critically the absence of a pervasive IoT sensor fabric capable of continuously logging the real-time occupant levels in lecture the wide-ranging digital proficiency levels among faculty, administrative staff, and students and the data governance framework that is neither comprehensive in the stakeholder coverage [5,9,15]. The functional diagnostic exercise situates these inhibiting conditions alongside the university's inherited substantial economic resources, which are liable to reinforce the emergence of technically isolated, short-lived innovation pockets rather than accelerate the systemic, financially coherent, campus transformation that the university's master framework has projected [5].

II. E-Governance Infrastructure as the Foundation of Smart Campus Development

The Central Bicol State University of Agriculture (CBSUA) is undergoing a comprehensive development study transformation led by its ICT Office, which is already improving campus life with tools such as the Student Information and Accounting System (SIAS), a Virtual Learning Environment, and a digital library. The university aims to integrate these systems into a seamless e-governance framework, becoming a University 4.0 model [14]. This advanced smart campus will use Artificial Intelligence (AI) [19] and the Internet of Things (IoT) to create a more personalized, efficient, and innovative institution by tailoring academic and administrative support that optimize resource management, enhances campus safety, and serves as a living laboratory for new technologies. [2]

Feature	Integrated System	University 4.0 with E-Governance Infrastructure
Core Concept	The integration of existing digital systems for improved efficiency in administrative and academic tasks. [11]	Create a deeply interconnected and intelligent campus ecosystem that uses data-driven insights to enhance all aspects of university life.
Key Technologies	- Student Information and Accounting System (SIAS) - Biometric and Electronic document management system - Virtual Learning Environment (VLE)	IoT (Internet of Things), Big Data analytics, Artificial Intelligence (AI), E-governance platforms
Data & Analytics	Data is often siloed within different systems, and the analytics are primarily used for reporting for administrative tasks.	Emphasizes the analysis of vast amounts of data from various sources to gain deep insights that enable predictive analytics.
Governance	Administration focused on technology used to automate and improve existing processes.	The e-governance is organized on data-informed decision-making, transparency, and stakeholder engagement through digital platforms.
Infrastructure	To support integrated systems in both academic and administrative online environments.	Create an environment on the satellite campus that is responsive and interactive.

Focus of Development	Streamlining and automating existing processes to improve efficiency.	Transforming the university's operations through data-driven innovation and intelligent systems.
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Table 1. University 4.0 and Future Smart Campus

OBJECTIVES

The study addresses the critical integration of the development of e-governance infrastructure at Central Bicol State University of Agriculture (CBSUA) to guide its transformation into a University 4.0 [7]. The research is driven by three main objectives to systematically assess the current development and challenges of the university's e-governance backbone by reviewing relevant literature from 2020 to 2025; second, to identify key deficiencies, such as the lack of seamless software integration, infrastructural disparities across campuses, and gaps in the data management skills of faculty and staff; To propose a strategic roadmap that prioritizes integrating existing services and developing digital competencies before investing heavily in emergent technologies such as AI, Big Data, and IoT.

METHODS

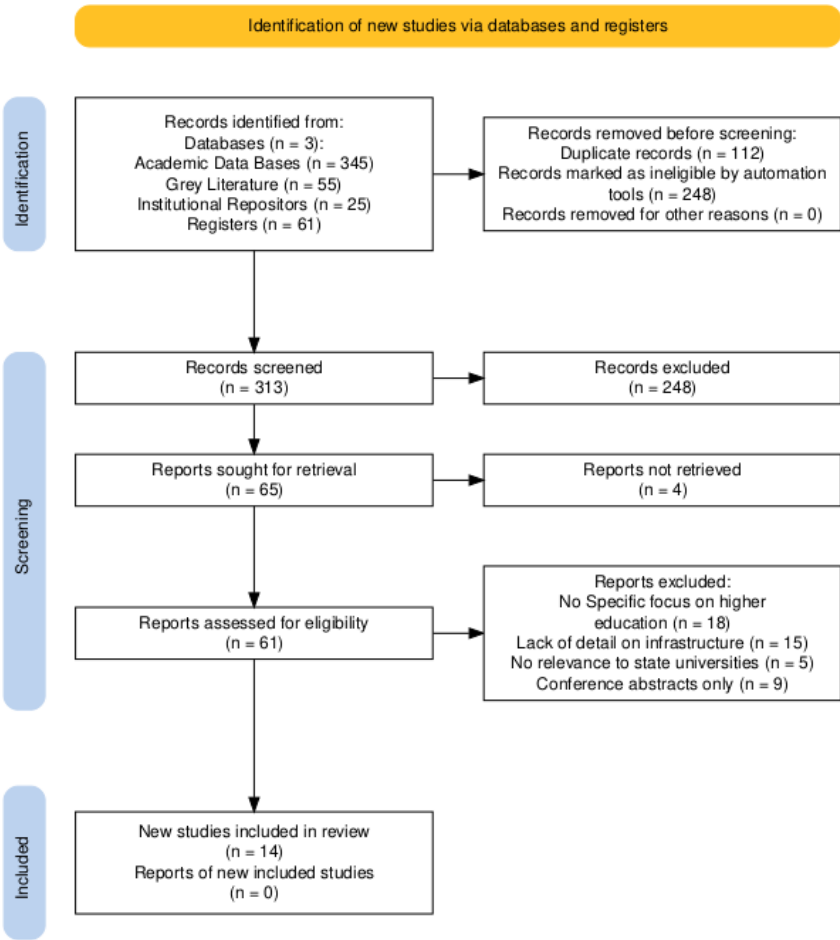


Figure 1. PRISMA 2020 Flow Diagram for a Systematic Study of E-Governance Infrastructure for Smart Campus Development in CBSUA (2020-2025)

This systematic review examined peer-reviewed journals, conference papers, institutional reports, and government publications from 2020 to 2025, focusing on e-governance infrastructure and smart campus technologies in higher education [16] within the Central Bicol State University of Agriculture (CBSUA). Literature was sourced from databases such as Academic Databases, Grey Literature, and Institutional Repositories archives using targeted keywords including e-governance, infrastructure, smart campus, artificial intelligence, Big Data analytics, and (IoT)

Internet of Things. The PRISMA framework systematically guided the study selection to promote methodological clarity and allow for future replication. The complete four-phase process is illustrated in Figure 1. That initiated our search by comprehensively querying the database. The study outlines the purpose for the transformation of Central Bicol State University of Agriculture (CBSUA), and the criteria for e-governance were developed using the PRISMA framework for systematic reviews. The process started with 425 records that were sorted to make sure they were studies that were relevant. The 112 duplicates and 248 articles based on irrelevant titles and abstracts, and 61 full-text documents were evaluated. The finding emerged as 47 of these were discarded for lacking concrete, actionable details and remaining purely conceptual. This method resulted in a curated collection of 14 high-quality studies, encompassing peer-reviewed journals, governmental frameworks, and institutional assessments, theoretical models with practical policy guidance, establishing the evidence-based foundation for CBSUA's strategic development.

The PRISMA flowchart (see Figure 1) visually outlines the review process, and the specific inclusion and exclusion criteria are detailed in Table 2.

Criteria Type	Inclusion Criteria	Exclusion Criteria
Time Frame	Publications released between January 1, 2020, and January 31, 2025.	Studies published before 2020.
Field	Emphasize on e-governance, intelligent campus technology, artificial intelligence, and Big Data analytics.	Literature not directly related to the specified keywords and themes.
Context	Research specifically situated within the higher education sector, with a strong preference for applicability to the university.	Studies lacking focus on the higher education environment or those whose findings do not apply to the Philippine context.
Publication Type	Peer-reviewed journal articles, conference papers, institutional reports, and official government publications.	Editorials, opinion pieces, book reviews, and literature where the full text was unretrievable.
Content Depth	Articles providing substantive detail on infrastructure, policy, and strategies related to the development of e-governance or a smart campus.	Publications discuss the concepts only in the abstract without providing practical, actionable details.
Uniqueness	Original records identified from the database search.	Duplicate records are identified across different databases within the same database search.
Language	Studies published in the English language.	Studies published in languages other than English.

Table 2. Outlines the review process in specific inclusion and exclusion criteria

The vision focuses on the application to the development of the campuses from 2020 to 2025 understood as a narrative rather than a linear account. The activities of the first two years felt less a sprint and transition to the next phase. The introduction of IoT, Big Data Analytics and AI would become the focus of this year's community [8] . To set out to develop what many referred to as the digital system. The deployment of hundreds of sensors, thermal cameras motion detectors on each quad was only a small part of the larger system, which stores data for later access by system administrators, researchers and students. A great deal of this activity felt such as basic configuration of the system for wiring, ducts, and standard displays. These initial activities were about foundation work that plan the foundation upon which advanced conceptual structures could be built. The achievements changed, reaching critical technological development by the start of 2023. Artificial Intelligence used to be a peripheral component of campus innovation [11]. The gap was defined by the departure from the period of change to the period of revolution, which

was characterized by a widely recognized breakthrough in machine intelligence. This accomplishment was rapidly disseminated to the other members of the campus community. The current expert consensus has it that the groundwork classified and refined data, as well as calibrated the system, which formed the basis of an AI system that could interpret as well as adapt to data changes of moderate scale [19].

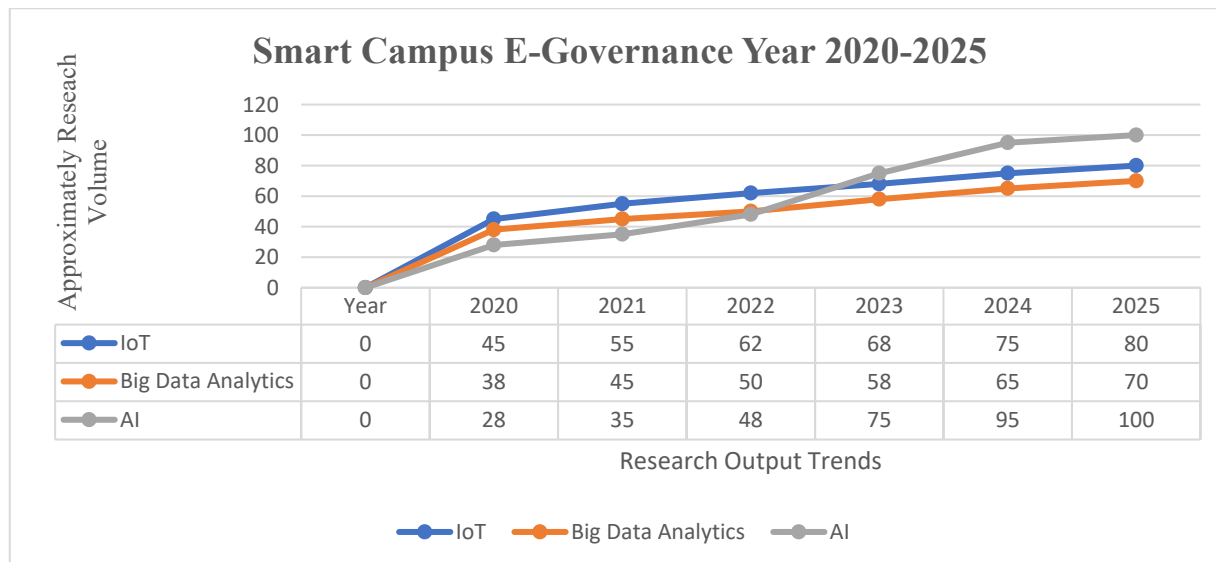


Figure 2. Smart Campus Technology Research Trends from 2020-2025

RESULTS AND DISCUSSION

The PRISMA framework narrowed down an initial set of 425 records to a final set of 14 studies that were very relevant and published between 2020 and 2025. This strict selection process makes sure that the results are based on relevant evidence. A thematic analysis of these 14 sources identified four principal themes that define the e-governance landscape for higher education. These themes include the current digital infrastructure, the main obstacles to progress, and the strategic opportunities. This the results of this thematic analysis discuss on how these results will directly affect the Central Bicol State University of Agriculture (CBSUA) and gives a clear, evidence-based path for the university to follow as it moves toward the University 4.0 vision.

Theme	Description	Key Evidence	Implication for CBSUA
The Smart Campus as an Urgent, Organizing Vision	The concept articulates the definitive purpose of organizing the digitization of CBSUA for global transformation in tertiary education.	The smart campus paradigm is progressively reshaping the administration of higher education.	The university's digital strategy framework serves as the rational foundation for resources and the evaluative criterion for all developments.
Foundational E-Governance Infrastructure	Identifies the core digital frameworks already established. The proposed frameworks are operational and adhere to national interoperability guidelines.	The suite of applications comprises the Student Information System (SIS), a Learning Management System (LMS), and a Digital Library System. Operate as discrete data silos for seamless data mobility.	The institution is a predominant tactical imperative for obtaining new architectures, linkage of the prevailing systems to establish a wide data ecosystem.
Strategic Opportunities in	The paradigm operation is realized only when integrated datasets are processed,	AI-Powered Personalization in Learning.	Anchored approach for CBSUA's future by reinforcing predictive credibility serves as a catalytic

Advanced Analytics	resulting in a more intelligent, responsive, and adjusted system to individual constituents.	Big Data Analytics for Institutional Effectiveness Intervention to a disposition of empirical, anticipatory strategy.	imperative to rectify and enhance streamlined operations.
Methodological Objective as a Basis for Action	This method shows how the research team followed a clear and careful path from question to recommendation. By using the PRISMA guide.	Use of PRISMA for reviews and meta-analyses. Across the report, every suggestion comes from the widest, sharpest grab of the literature.	The recommendations presented in the study are based on evidence synthesis of the available literature. This provides CBSUA's leadership with a defensible and reliable foundation for making critical strategic decisions.

Table 3 . Thematic Analysis of the Smart Campus of CBSUA

The findings of the systematic review are finalized in September 2025, which imperative shift from analysis to decisive action. The thematic analysis provides a clear diagnosis, but its value will be realized only through a structured implementation effort. The immediate next step for the CBSUA administration should be the formation of a dedicated, cross-functional Smart Campus Task Force. The member of the academic Council, ICT officer, the finance officers, and representatives from both the main and satellite campuses to ensure into holistic approach. Their primary mandate will be to translate the study's implications into a phased, budgeted, and time-bound action plan that prioritizes the integration of existing systems and the rectification of infrastructural disparities.

A. Synthesis of Foundational E-Governance Components

A review of the selected corpus substantiates that the infrastructural backbone overseeing e-governance at CBSUA mirrors the canonical framework observed across other Philippine State Universities and Colleges (SUCs). The present study uniformly characterizes a multifaceted array of applications as the fundamental framework of e-governance, encompassing a Student Information System (SIS), a Learning Management System (LMS) or Virtual Learning Environment (VLE), and a Digital Library System. CBSUA's architecture, consisting of the Student Information and Accounting System (SIAS), a purpose-built Virtual Learning Environment, and an automated library incorporating electronic resources, thus reaffirms its congruence with the national strategic model. The conclusion across multiple inquiries indicates that such platforms frequently function as isolated "data silos" [3], [4].

B. Systematic Analysis that Evolves the Challenges in Smart Campus Implementation (2020-2025)

This table outlines the major challenges that have shaped the development of AI, Big Data Analytics, and IoT in the context of higher education from 2020 to the present day in 2025. The focus evolves from foundational access to complex, integrated governance as the technologies mature [12].

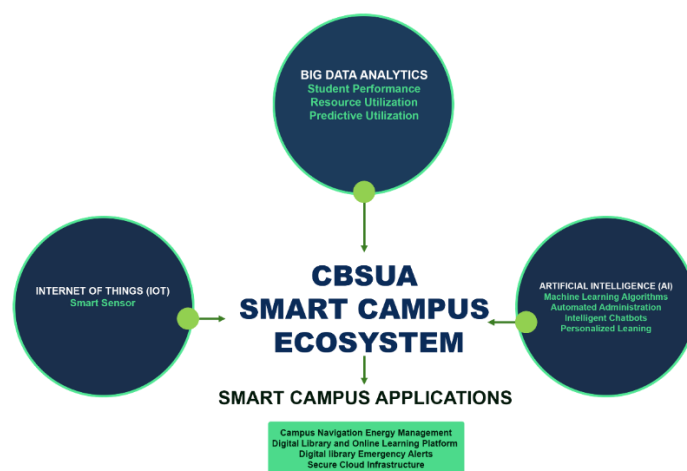
Year	Research Focus and Challenge	Impact on Technology (AI, Big Data, IoT)
2020	Emergency Connectivity and Access	The sudden shift to remote learning exposed severe infrastructural deficits and provided basic online access, making advanced IoT and Big Data projects a low priority.
2021	Bridging the Digital Literacy Gap	The struggle was training faculty and students to use the new digital tools effectively. AI adoption was stalled based to mastering foundational platforms.

2022	Confronting Data Silos	As digital systems became entrenched, the lack of interoperability emerged as a major bottleneck that hindered the student information systems from their learning platforms and Big Data Analytics initiatives.
2023	The Need for Good Data & Digital Divide	The persistence of data silos was now seen as the primary barrier to leveraging AI. The digital divide was redefined as not just a lack of internet, but a lack of quality data infrastructure.
2024	Establishing Data Governance & Security	With the real possibility of using AI on student data, the focus pivoted to data governance, privacy, and security. Research highlighted the urgent need for clear policies to manage data ethically and comply with regulations before deploying large-scale AI and Big Data projects.
2025	Integration for Strategic Planning	The goal is to unify a strategy that addresses infrastructure, interoperability, human skills, and data governance. The focus is on developing a comprehensive roadmap to finally make the fully integrated, AI-driven smart campus a reality.

Table 4. Impact in Smart Campus Implementation (2020-2025)

This identifies four main obstacles hindering the development of smart campuses [18]. The infrastructural deficits and the digital divide present a fundamental barrier, characterized by fragmented internet, limited bandwidth, and outdated hardware, especially in satellite campuses, which creates an intra-university digital divide. The lack of system interoperability and standardization results in isolated data silos due to progressive technology adoption, leading to heavy data reconciliation and preventing effective Big Data Analytics. The human-centric challenges, such as limited digital literacy among faculty, administrators, and students, alongside resistance to change, present the transformative potential of new platforms. [9] Inadequate data governance, privacy, and security frameworks pose significant risks, as institutions struggle to comply with data protection laws, underscoring the urgent need for clear policies on data stewardship and cybersecurity in an expanding data ecosystem.

C. The Proposed Ecosystem for Smart Campus of CBSUA

**Figure 3.** Ecosystem for Smart Campus of CBSUA

The evaluation of Central Bicol State University of Agriculture's (CBSUA) e-governance indicates that the infrastructure systems are not fully integrated. This results in several issues, including incompatible systems that generate data silos, technological disparities across campuses, and users lacking essential digital competencies. (Taruc et al., 2024). The University 4.0 model necessitates developing a comprehensive strategy to integrate these technologies into the Internet of Things (IoT) for real-time data collection, using Big Data Analytics for processing,

and utilizing Artificial Intelligence (AI) to customize learning and enhance management efficiency. This strategic integration will transform the campus from a digital environment into an intelligent, responsive, and interconnected area that utilizes data-driven insights to enhance the student experience and optimize operations. (Lytras et al., 2024)

CONCLUSION

This systematic review concluded in September 2025, determined that Central Bicol State University of Agriculture's e-governance system meets national standards. The advancement is blocked by four key obstacles: the lack of integration between different digital systems, infrastructural inequality among its Bicol campuses, inconsistent digital literacy skills among users, and the absence of a clear data governance policy. To progress, the university requires a unified strategy combining professional training with equitable technology access for all campuses. The study on existing literature, it recommends that CBSUA now conduct detailed on-site technical audits and stakeholder analyses to gather the specific, operational data needed to turn the smart campus blueprint into a tangible reality for the entire university community.

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