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Developing a Smart Campus Framework through System Dynamics Modeling

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Abstract

This study investigates the key components and challenges associated with the implementation of a smart campus at IPDN Campus Jatinangor. The aim was to identify critical infrastructural elements required for the successful transition to a smart campus, including internet infrastructure, smart classrooms, and smart security systems. A mixed-methods approach was employed, combining qualitative interviews with faculty, staff, and students, along with system dynamics modeling to explore the complex interactions among various components of the smart campus. The results show that increased internet speed, expanded smart classrooms, and integrated security systems are essential for improving the learning environment, enhancing campus safety, and supporting efficient administrative processes. Simulation results indicated that gradual infrastructure expansion, supported by sustainable funding models, would be the most effective strategy. The study contributes to the existing body of knowledge by applying system dynamics modeling to smart campus development, providing a framework for future research on the scalability and implementation of smart campuses across higher education institutions. The findings suggest that further research could explore funding strategies and examine the role of policy in driving smart campus development.

INTRODUCTION

The rapid advancement of digital technologies has fundamentally reshaped the landscape of higher education worldwide, prompting universities to transform their traditional campus environments into smart, technology-enabled ecosystems. A smart campus integrates digital infrastructure, data-driven systems, and intelligent services to enhance learning experiences, administrative efficiency, and campus sustainability (Alrashed & O'Connor, 2021; Mehmood, 2023; Mahariya et al., 2023; Elbertsen et al., 2025; Martins et al., 2021). This paradigm shift aligns with broader global trends emphasizing the strategic deployment of information and communication technologies (ICT) to improve institutional performance and competitiveness. As higher education institutions increasingly adopt cloud systems, data analytics, automated services, and blended learning environments, the smart campus concept has emerged as a critical framework for addressing contemporary academic and operational challenges. In Indonesia, despite significant progress in digital transformation, disparities in technological readiness and resource allocation continue to influence the pace and effectiveness of smart campus implementation across institutions (Hidayat & Sensuse, 2022; Aripradono et al., 2024; Hafel, 2023; Murfi & Hendarman, 2023).

International university rankings such as Times Higher Education (THE), the Academic Ranking of World Universities (ARWU), and Webometrics also reflect the growing importance of digital infrastructure and innovation capacity in determining institutional reputation. Universities that strategically integrate smart technologies tend to demonstrate stronger research productivity, improved student engagement, and more efficient governance systems, positioning themselves competitively on the global stage (Ferraris et al., 2020; Aithal & Maiya, 2023; Anttila & Jussila, 2018). Consequently, many universities—particularly in developing countries—are prioritizing investments in digital infrastructure, smart classrooms, automated administrative systems, and sustainable campus operations. However, the transition toward a fully functional smart campus remains complex, requiring a holistic understanding of technological components, human resources, institutional policies, and long-term planning. This complexity underscores the need for robust conceptual and operational frameworks to guide smart campus development (Polin et al., 2024; Dong et al., 2020).

Despite the acknowledged importance of smart campuses, many institutions face recurring challenges that inhibit comprehensive implementation. Common issues include limited internet bandwidth, insufficient digital infrastructure, lack of interoperability among existing systems, and inadequate staff competencies to operate advanced technologies (Sadeghi, 2022; Agbaje et al., 2022; Gambo et al., 2011). These challenges often lead to fragmented initiatives in which smart technologies are adopted in isolation rather than as part of an integrated ecosystem. The absence of standardized frameworks or models further complicates the process, resulting in inconsistent implementation strategies across universities. For institutions like the Institut Pemerintahan Dalam Negeri (IPDN), which plays a pivotal role in preparing future public administrators, addressing these systemic challenges is crucial for ensuring that campus digitalization supports broader goals of educational quality, governance efficiency, and public service innovation (Coronel & Trigos, 2024).

To address these challenges, several studies have proposed general solutions emphasizing strategic planning, investment in digital infrastructure, and capacity-building initiatives for faculty and administrative staff. Many scholars argue that successful smart campus implementation requires coordinated efforts to upgrade network infrastructure, enhance cybersecurity, expand smart learning facilities, and adopt integrated administrative platforms (Shtayyat & AlShaikh-Hasan, 2025; Ali et al., 2025; Evitha, 2024). Others highlight the importance of governance arrangements that align technology adoption with institutional missions and development plans. These general solutions provide valuable guidance, yet they often remain conceptual and fail to capture the dynamic interactions among technological, structural, and human factors that shape the evolution of smart campus systems over time.

In response to this gap, more specific solutions have emerged from recent scholarly work focusing on the operational mechanisms underlying smart campuses. For example, system-level approaches underscore the importance of modeling interdependencies among infrastructure components—such as internet capacity, digital classrooms, smart laboratories, and security systems—to assess how changes in one component influence others (Tasrif & Avianto, 2004). Studies employing technological ecosystem frameworks also emphasize the need for continuous feedback mechanisms to ensure system adaptability and long-term sustainability (Cope & Kalantzis, 2017). These perspectives highlight that smart campuses are not merely collections of digital tools but complex sociotechnical systems whose development must be managed strategically and holistically. Such insights provide a foundation for developing more comprehensive and operationally relevant models tailored to specific institutional contexts, particularly in Indonesia where empirical studies remain limited.

Within this growing body of literature, system dynamics has been increasingly recognized as a powerful methodological approach for examining the structural complexity of smart campus development. The method's capacity to model feedback loops, simulate policy interventions, and predict long-term outcomes makes it suitable for analyzing the nonlinear interactions that characterize smart campus ecosystems (Richardson, 2019). Prior studies applying system dynamics have demonstrated its utility in exploring digital infrastructure planning, resource allocation, and organizational change. However, its application in the domain of smart campuses—especially in Indonesian institutions—remains scarce. Moreover, existing studies often focus on isolated components such as smart classrooms or network infrastructure, rather than integrating multiple elements into a cohesive model capable of supporting strategic decision-making.

A review of the most relevant literature reveals a persistent gap in models that combine qualitative insights from stakeholders with dynamic system simulations to generate an empirically grounded smart campus framework. While frameworks exist for assessing readiness levels or identifying technological domains, few studies integrate stakeholder perspectives, institutional challenges, and system-level analysis into a single dynamic model. This gap is particularly evident in public sector educational institutions, where bureaucratic structures and regulatory constraints further influence digital transformation processes. Given the strategic importance of IPDN as a training center for future public administrators, developing a dynamic, institution-specific smart campus model offers unique value for both academic and policy audiences. Such a model can illuminate the causal relationships and feedback structures driving smart campus development, providing a foundation for scalable implementation in other government-affiliated institutions.

METHODS

The research design that has been used in this investigation is a mixed-methods research design, which combines qualitative questions with a system dynamics modeling to develop an elaborate smart campus model of IPDN Jatinangor. The methodology was structured into four progressive phases that were in line with the existing system dynamics procedures and traditional qualitative research principles. The selected methodological approach was meant to grapple with the inherent complexity of developing smart campuses which is a process whose dynamics is characterized by dynamic interactions of technological infrastructure, human resources, governance structures, and institutional procedures. According to Richardson (2019), system dynamics is specifically well suited to examine feedback loops and nonlinear interactions in sociotechnical systems, including the ones in intelligent campuses. The combinations and modeling of the qualitative data and dynamism were used to identify crucial elements of infrastructure, explain the views of the stakeholders, and simulate possible outcomes when various policy scenarios occurred. Each of the stages of the methodological process is outlined in detail in the following subsections.

The first step of the research was to identify the essence of issues and limitations related to the implementation of a smart campus at IPDN Jatinangor. This phase began with a careful evaluation of the current digital infrastructure and governance systems on campus along with the technological preparedness. Framed in line with Hidayat and Sensuse (2022) views of the importance of considering the institutional knowledge structure and technological capacity the research did pre-assessment and relied on campus documentation, network assessment reports, and institutional strategic plans. Such sources provided an initial insight into infrastructural limitations, such as the limited bandwidth, insufficient implementation of smart classes, and poor coverage of security measures, such as CCTV and smart lighting.

The identification of the problem also included a literature review of smart campus to place the local issues witnessed at IPDN in their global contexts. Most literature (including Sadeghi 2022) has examined the centrality of integrated infrastructure (and especially internet networks, smart learning spaces, and security systems) in maintaining a functional smart campus. It is this literature-based contextualization that guided the research processes that followed because it emphasized the importance of studying not just technological aspects but also interrelations between infrastructure, institutional policies, and stakeholder capacities. As a result, the initial phase resulted in the formulation of central research questions that would allow defining the fundamental infrastructural requirements, understanding movable associations between smart campus elements, and simulating future development initiatives.

The second phase entailed the qualitative data collection by use of an interview instrument based on the SOAR (Strengths, Opportunities, Aspirations, Results) strategic analysis framework. The SOAR framework developed by Stavros et al. (2013) is a continuation of the ideas of Appreciative Inquiry that Cooperrider (1995) presented, which is why it places significant emphasis on strengths-based exploration rather than a deficit-based evaluation. The use of the SOAR model made sure that the challenges were captured in data collection and at the same time, the enabling aspects, institutional aspirations, and the avenues that could be taken to achieve a vision of a smart campus were identified.

A purposive structured sampling method was used to recruit informants in order to have a representation of the major stakeholder groups that have experience in the operations of smart campuses. Ten informants were also interviewed and this included structural and functional officials, lecturers, students and one other functional technical officer. This piece of writing was aligned with such suggestions as Creswell and Poth (2016) suggested the significance of a variety of viewpoints when formulating a qualitative inquiry. The interviews were repeated until theoretical saturation was achieved, i.e. when any new themes were not revealed in the interviews, which is a common criterion in qualitative research of adequate sample size.

The interview questions delved into four main domains namely: (1) broad knowledge on smart campuses, (2) current application activities at IPDN Jatinangor, (3) facilitating and discouraging factors, and (4) recommendations to improve the situation. The data were logged, transcribed and coded. The SOAR-informed framework helped the participants to consider strategy opportunities and outcomes they want in addition to considering the operational constraints. This moderate stance was in line with the principles of system dynamics which entails identification of the reinforcing and balancing forces in a system (Forrester, 1994).

The third phase combined the qualitative data analysis with the creation of the system dynamics structures. The analysis of the interview transcripts was conducted with the help of NVivo software in order to create codes, themes, and conceptual categories. NVivo allowed conducting a systematic analysis that allowed finding patterns and making it possible to identify factors associated with digital infrastructure, human resources, governance, and institutional culture. As part and parcel of the thematic analysis method that Braun and Clarke (2006) use, the emergent themes were constantly sharpened, grouped and connected to the constructs pertinent to smart campus systems.

The study then moved on after the qualitative analysis to extract variables of both exogenous (independent) and endogenous (dependent) variables in the smart campus system. Microsoft Excel was used to organize these variables into a structured table which was a preparation step to causal loop diagramming. There is a need to determine the relationships between variables clearly before diagramming as it has been suggested by the scholars of the system dynamics like Sterman (2000) so as to be able to appropriately capture the system behaviour.

PowerSIM software was then used to develop the causal loop diagram (CLD). The CLD depicted the reinforcing (R) loops that enhance change within the system, and balancing (B) loops that stabilize the behaviour of the system. As an example, there was one positive feedback loop that demonstrated that the better the digital infrastructure is, the more satisfied users become, which leads to a higher level of demand towards technological improvement, which in turn causes an improvement in the smart campus building process. Another loop illustrated that a higher rate of the smart use of classrooms and laboratories enhanced academic achievement and operational performance, which enhanced the motivation of institutions to invest more in additional facilities. These illustrations were used to illustrate the interdependence of the variables including internet speed, number of smart classrooms, number of CCTVs, lighting systems and human resource capacity.

The initial CLD was tested by an expert faculty advisor in the field of systems thinking. Validation provided the consistency of concepts and also eliminated possible logical errors that could have happened in loop structures as encouraged in the literature of modelling (Barlas, 1996). The approved diagram was the basis of the second step, which was the construction and simulation of stock-flow diagrams.

The fourth stage involved constructing stock-flow diagrams to operationalize the causal structure identified in the CLD and to simulate potential policy interventions. Stock-flow modeling, a core component of system dynamics, provides a quantitative mechanism to trace how resource levels change over time due to flows influenced by feedback loops (Sterman, 2000). PowerSIM was again used to build stock-flow diagrams representing components such as internet capacity, number of smart classrooms, smart security devices, and laboratory facilities.

Several policy scenarios were simulated. One scenario tested increasing internet speed by 20 Mbps per year. The simulation demonstrated substantial improvements in the performance of smart campus systems that depended on connectivity. Another scenario explored incremental expansion of smart classrooms, revealing positive impacts on learning engagement and institutional performance but also highlighting the need for synchronized upgrades in bandwidth and maintenance capacity. A third scenario introduced enhanced security infrastructure through smart CCTVs and lighting systems, projecting reduced operational risks and improved campus safety metrics. Each scenario underwent final validation by the supervising faculty member to ensure coherence with system architecture, institutional realism, and methodological rigor. These simulations provided critical insights into leverage points and constraints for smart campus development and formed the basis for the study's policy recommendations.

To ensure the validity of the qualitative data, this study employed source triangulation and theory triangulation techniques. Source triangulation was conducted by comparing the patterns of findings from informants with different roles: structural and functional officials, lecturers, students, and technical officials. The recurrence of statement patterns among informants demonstrated consistent perceptions regarding the condition of the campus's digital infrastructure. Theory triangulation was conducted by comparing field findings with literature such as Sadeghi (2022) and Hidayat & Sensuse (2022), ensuring that conclusions were not based solely on informants' perceptions.

Furthermore, the reliability of the data analysis was maintained through an iterative coding process using the NVivo application. Coding was conducted in two cycles: open coding and axial coding to minimize interpretation bias. This process was then consulted with the supervisor as a peer debriefing step, thus increasing the reliability of the analysis results.

Interview results were analyzed to identify conceptual variables, which were then translated into operational variables in the system dynamics model. For example, informants' statements about bandwidth limitations were translated into the variables "internet speed" and "internet demand growth." Complaints about limited digital learning spaces were translated into the variable "number of smart classrooms," while security and efficiency needs were translated into "number of CCTV units" and "smart lighting coverage."

These variables were then mapped in a dependency table to show which variables served as stock, flow, and control variables. This process of reducing themes to variables ensured that the system dynamics model was not abstract but was truly based on empirical data from interviews with IPDN stakeholders.

RESULTS AND DISCUSSION

The results of this study provide comprehensive insights into the needs, challenges, and dynamics of smart campus infrastructure at IPDN Campus Jatinangor. This section outlines the key findings from both the qualitative data analysis and the system dynamics modeling, which explore the interconnectedness of various technological components critical for the development of a smart campus. The findings from the interviews with key informants, supported by the simulation results from the system dynamics model, shed light on the essential infrastructure, the relationships between these components, and the policy implications for further development.

Internet Bandwidth Improvement Scenario

Table 1. Internet Bandwidth Improvement Scenario (Three-Year Projection)

Scenario	Bandwidth Increase	Impact After Three Years
S0 (Baseline)	0 Mbps per year	Network congestion increases by 35%, service efficiency decreases by 18%
S1	+10 Mbps per year	Congestion decreases by 12%, digital services become stable but not yet optimal
S2	+20 Mbps per year	Congestion decreases by 31%, smart classroom and cloud-based services operate stably

A dynamic simulation was conducted to examine the impact of increasing internet bandwidth capacity on system performance. Three policy scenarios were simulated: baseline (no increase), a moderate increase, and an aggressive bandwidth expansion. The model projected system capacity, congestion, and overall service quality over a three-year period. The results showed a strong positive effect of bandwidth expansion, with the most significant improvements occurring under the scenario of 20 Mbps incremental growth per year. This scenario substantially reduced network congestion and ensured adequate capacity to support cloud-based learning platforms, administrative systems, and the growing demand from students and staff.

Smart Classroom Expansion Scenario

The second simulation examined the effects of increasing the number of smart classrooms on learning efficiency and digital engagement. Three policy alternatives were modeled based on different rates of classroom development. The results demonstrate that incremental but consistent expansion yields significant improvements in learning participation and overall instructional effectiveness.

Table 2. Simulation of Smart Classroom Expansion Scenarios (3-Year Projection)

Scenario	Rate of Classroom Development	Change in Digital Learning Participation	Change in Space Utilization Efficiency
SC0 (Baseline)	No expansion	+3%	+1%
SC1	2 new classrooms per year	+12%	+8%
SC2	4 new classrooms per year	+22%	+19%
SC3	6 new classrooms per year	+27%	+24%

The results indicate that Scenario SC2 achieves the most optimal balance between resource use and performance improvement, while SC3 offers additional benefits but at significantly higher operational cost.

Smart Security and Smart Lighting System Scenario

A third simulation evaluated increasing coverage of smart CCTVs and intelligent lighting systems. The dynamic model projected improvements in campus safety, blind-spot reduction, and energy consumption. Results demonstrated that gradual expansion of security devices leads to substantial improvements in operational safety and sustainability.

Table 3. Simulation Results for Smart Security and Lighting Expansion (3-Year Projection)

Variable	Baseline Condition	After Simulation	Percentage Change
Campus blind-spot areas	100% (reference)	72%	–28%
Energy consumption for lighting	100% (reference)	83%	–17%
Security monitoring efficiency	Moderate	High	—

These findings support the strategic importance of integrating safety and energy management systems into the smart campus framework. Reductions in blind spots and energy consumption demonstrate that automated systems deliver meaningful improvements in operational performance and long-term sustainability.

Smart Campus Infrastructure Needs

The first critical finding pertains to the essential components required for the successful implementation of a smart campus at IPDN Campus Jatinangor. Based on the qualitative interviews with administrators, faculty, and students, the following infrastructural elements emerged as key requirements for transforming the campus into a fully functional smart campus.

Internet Infrastructure

The internet infrastructure was identified as one of the primary needs at IPDN Campus Jatinangor. The current internet speed is 50 Mbps, which is insufficient given the growing number of students and faculty members relying on the internet for learning, research, and administrative purposes. This issue is exacerbated during peak hours when demand for bandwidth increases. According to Table 4, the current network speed is inadequate to support the necessary smart systems, such as online learning platforms, cloud-based applications, and smart classroom technologies, that require a higher bandwidth capacity.

Table 4. Current and Required Internet Speed for IPDN Jatinangor Campus (Based on data from IPDN, 2025)

Component	Current Speed	Required Speed	Gap
Internet Speed	50 Mbps	100 Mbps	50 Mbps
Number of Students	2,811 students	-	-
Number of Faculty	1,174 faculty	-	-

A robust and managed network infrastructure is foundational to a smart campus. As indicated by Hidayat & Sensuse (2022), without a strong and scalable network, the implementation of other smart campus solutions becomes challenging. The current internet infrastructure at IPDN limits the campus's ability to integrate advanced technologies that demand high-speed data transmission.

Smart Classrooms

The smart classrooms were another key component identified as necessary for creating an engaging and interactive learning environment. At the time of the study, IPDN had only one smart classroom, which was equipped with basic interactive technologies, such as projectors and smartboards. However, this classroom lacked advanced technologies such as integrated online learning platforms, adaptive learning systems, and real-time collaborative tools. The interviews indicated that an expansion of smart classrooms across the campus was critical to meeting the modern needs of both students and faculty. As Sadeghi (2022) emphasized, smart classrooms play a pivotal role in improving the quality of education by fostering interactive, personalized, and dynamic learning experiences.

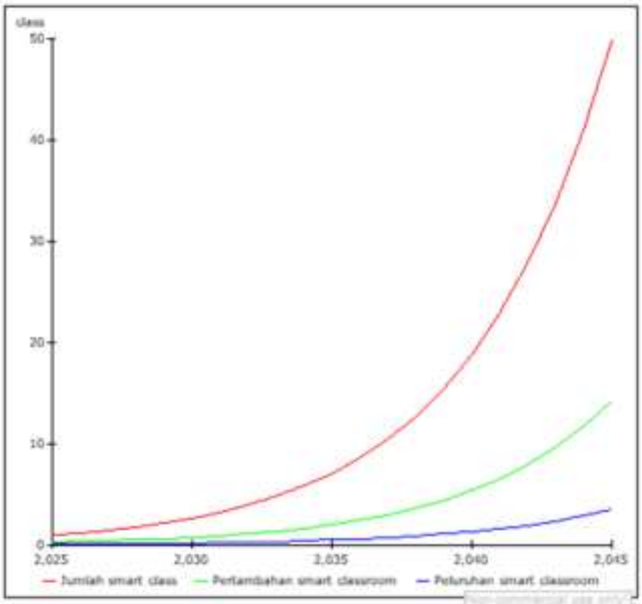

Figure 1. Time Graph of the Number of Smart Classrooms, Smart Classroom Growth, and Smart Classroom Decline

The need for smart classrooms was also emphasized due to the increasing demand for blended learning, where students engage both online and in-person. As indicated by Sadeghi (2022), the integration of smart classrooms with cloud technologies and adaptive learning tools would significantly enhance the learning experience and prepare students for the technological demands of the workforce.

Smart Lighting and CCTV Systems

The smart lighting system and CCTV systems were also identified as essential for enhancing the campus's security, energy efficiency, and overall functionality. The current security infrastructure, such as CCTV surveillance, was deemed inadequate as it only covered limited areas of the campus. This lack of comprehensive monitoring makes it difficult to assess real-time threats or manage security issues during large events. In the interviews, faculty members and administrative staff emphasized that a comprehensive, smart surveillance system would improve campus security by enabling real-time monitoring, automated threat detection, and better crowd management. As noted by Sadeghi (2022), an integrated security system would not only enhance safety but also create a secure learning environment for students and staff.

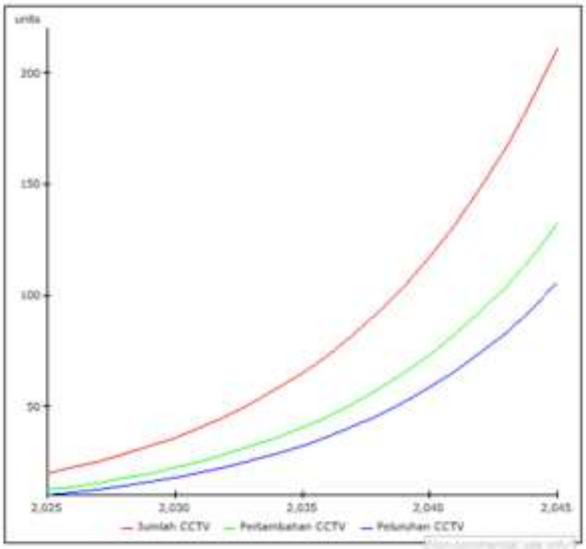

Figure 2. Time Graph of CCTV Number, CCTV Increase, and CCTV Decline

In addition, the smart lighting system, which automatically adjusts based on occupancy and environmental conditions, was identified as an important feature for reducing energy consumption and improving sustainability. The integration of smart lighting would contribute to the campus's environmental goals by minimizing energy waste, enhancing the overall campus experience, and lowering operational costs.

Smart Laboratories

The need for smart laboratories emerged as a critical component for supporting research and experimentation at IPDN. Currently, the campus lacks fully equipped smart laboratories that integrate automated systems, sensors, and data collection tools. Faculty members indicated that the existing laboratories were outdated and lacked the technological tools necessary for cutting-edge research. According to the interviews, upgrading these laboratories to smart laboratories would improve research capabilities, enhance the student experience, and support IPDN's academic focus on governance and public administration.

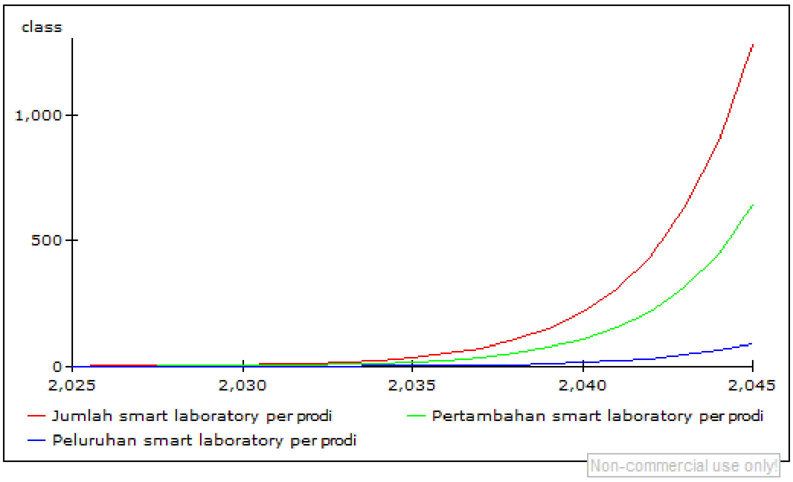

Figure 3. Time Graph of the Number of Smart Laboratories, Smart Laboratory Growth and Smart Laboratory Decline

Smart laboratories, as described by Sadeghi (2022), enable more efficient data collection, real-time monitoring, and analysis, which are essential for advanced research. Therefore, expanding and upgrading laboratory facilities was considered a priority to enhance the research and academic offerings of the institution.

Causal Relationships and System Dynamics Modeling

The findings from the qualitative data analysis were further examined using system dynamics modeling to understand the causal relationships between different components of the smart campus. System dynamics was used to capture the feedback loops and interdependencies among the key elements of the smart campus, such as internet infrastructure, smart classrooms, and security systems.

The causal loop diagram (CLD) developed for the IPDN Campus Jatinangor smart campus showed several reinforcing feedback loops that contribute to the development and sustainability of the campus's smart infrastructure. One critical loop identified was the relationship between the desire for a smart campus and the capacity to consult and develop skills among faculty and staff. As IPDN strives to implement smart technologies, the institution will need to invest in professional development programs to enhance the skillsets of its faculty and administrative staff. This investment, in turn, strengthens the institution's ability to adopt more smart technologies, which further contributes to the development of a smart campus. The dynamic feedback from this loop illustrates the importance of capacity-building as a driver for the smart campus transition.

Another reinforcing loop observed in the model pertains to the construction of smart buildings and performance evaluation systems. The integration of smart buildings, such as smart classrooms and laboratories, positively influences the performance of educational and administrative processes at IPDN. The model revealed that as these smart buildings are constructed and incorporated into the campus infrastructure, they help improve the evaluation systems by providing real-time data on the use and effectiveness of the space. This feedback loop emphasizes the interconnectedness between physical infrastructure and administrative efficiency, and how improvements in one can lead to enhancements in the other.

The results from the system dynamics simulations provided valuable insights into the potential impacts of different policy scenarios on the development of a smart campus at IPDN. One of the policy scenarios simulated was the impact of increasing internet speed to accommodate the growing demand for online learning and administrative services. The simulation results indicated that increasing internet speed by 20 Mbps per year would significantly improve the functionality of smart campus systems, such as smart classrooms, cloud-based applications, and online learning platforms. The model also showed that even with this increase in internet speed, the demand for bandwidth would continue to grow, emphasizing the need for continuous infrastructure upgrades to keep pace with technological advancements.

Another policy scenario simulated involved the expansion of smart classrooms across the campus. The simulation suggested that expanding the number of smart classrooms would lead to greater engagement and collaboration among students and faculty. The model indicated that an incremental expansion strategy, supported by adequate funding and maintenance capacity, would be the most effective approach for ensuring the long-term success of smart classroom initiatives.

Additionally, the policy scenario focusing on the integration of smart security systems and smart building technologies revealed the importance of comprehensive security measures and energy-efficient systems. The simulation predicted that implementing these technologies would lead to cost savings in operational expenses, improved campus safety, and better resource management. The integration of these technologies would also contribute to creating a sustainable campus that can adapt to future demands.

CONCLUSION

Modeling using a dynamic asset management system to support a smart campus at IPDN Jatinangor campus consists of elements or components that can be simulated. These elements or components are an analysis of the needs and desires of stakeholders implementing a smart campus at IPDN Jatinangor campus, consisting of physical and non-physical infrastructure. These elements or components are Wi-Fi internet speed, the number of smart classrooms, the number of smart lights, the number of CCTVs, the number of smart laboratories, the number of smart earthquake/fire alarms, and the number of smart boards. Therefore, these elements or components must be given serious attention in budget planning.

REFERENCES

Agbaje, P., Anjum, A., Mitra, A., Oseghale, E., Bloom, G., & Olufowobi, H. (2022). Survey of interoperability challenges in the internet of vehicles. *IEEE Transactions on Intelligent Transportation Systems*, *23*(12), 22838-22861. https://doi.org/10.1109/TITS.2022.3194413

Aithal, P. S., & Maiya, A. K. (2023). Innovations in higher education industry–Shaping the future. *International Journal of Case Studies in Business, IT, and Education (IJCSBE)*, *7*(4), 283-311. https://doi.org/10.2139/ssrn.4770797

Ali, G., Samuel, A., Mijwil, M. M., Al-Mahzoum, K., Sallam, M., Salau, A. O., ... & Melekoglu, E. (2025). Enhancing Cybersecurity in Smart Education with Deep Learning and Computer Vision: A Survey. *Mesopotamian Journal of Computer Science*, *2025*, 115-158. https://doi.org/10.58496/MJCSC/2025/008

Anttila, J., & Jussila, K. (2018). Universities and smart cities: the challenges to high quality. *Total Quality Management & Business Excellence*, *29*(9-10), 1058-1073. https://doi.org/10.1080/14783363.2018.1486552

Aripradono, H. W., Nursyamsi, I., Wahab, A., & Sultan, Z. (2024). Educational Technology for Digital Transformation of Higher Education Institutions into Entrepreneurial Universities. *Policy & Governance Review*, *8*(3), 303-322. https://doi.org/10.30589/pgr.v8i3.1019

Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. *System Dynamics Review: The Journal of the System Dynamics Society*, *12*(3), 183-210. https://doi.org/10.1002/(SICI)1099-1727(199623)12:3%3C183::AID-SDR103%3E3.0.CO;2-4

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Cooperrider, D. L. (1995). *Introduction to appreciative inquiry*. In W. French & C. Bell (Eds.), *Organization development* (5th ed.). Prentice Hall.

Coronel, R., & Trigos, F. (2024). Reframing Higher Education Management: A Transdisciplinary Digital Framework for University Administration. *Engineering For Social Change*, 947-956. https://doi.org/10.3233/ATDE240950

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Dong, Z. Y., Zhang, Y., Yip, C., Swift, S., & Beswick, K. (2020). Smart campus: definition, framework, technologies, and services. *IET Smart Cities*, *2*(1), 43-54. https://doi.org/10.1049/iet-smc.2019.0072

Elbertsen, M., Kok, H., & Salimi, N. (2025). Designing the future smart campus: integrating key elements to enhance user experience. *Journal of Science and Technology Policy Management*, *16*(10), 117-137. https://doi.org/10.1108/JSTPM-10-2024-0414

Evitha, Y. (2024). Leading Digital Transformation: Strategies for higher education leaders in navigating online platforms, Administrative Services, and Cybersecurity. *AL-ISHLAH: Jurnal Pendidikan*, *16*(2), 2645-2656.

Ferraris, A., Belyaeva, Z., & Bresciani, S. (2020). The role of universities in the Smart City innovation: Multistakeholder integration and engagement perspectives. *Journal of Business Research*, *119*, 163-171. https://doi.org/10.1016/j.jbusres.2018.12.010

Forrester, J. W. (1994). System dynamics, systems thinking, and soft OR. *System dynamics review*, *10*(2-3), 245-256. https://doi.org/10.1002/sdr.4260100211

Gambo, I., Oluwagbemi, O., & Achimugu, P. (2011). Lack of interoperable health information systems in developing countries: an impact analysis. *Journal of Health Informatics in Developing Countries*, *5*(1).

Hafel, M. (2023). Digital transformation in politics and governance in Indonesia: Opportunities and challenges in the era of technological disruption. *Society*, *11*(2), 742-757.

Hidayat, D. S., & Sensuse, D. I. (2022). Knowledge management model for smart campus in Indonesia. *Journal of Computer Science, Universitas Indonesia*. [Publication details missing]

IPDN. (2021). *Laporan assessment network dan rekomendasi smart campus IPDN tahun 2021*. Institut Pemerintahan Dalam Negeri.

Mahariya, S. K., Kumar, A., Singh, R., Gehlot, A., Akram, S. V., Twala, B., ... & Priyadarshi, N. (2023). Smart campus 4.0: Digitalization of university campus with assimilation of industry 4.0 for innovation and sustainability. *J. Adv. Res. Appl. Sci. Eng. Technol*, *32*(1), 120-138. https://doi.org/10.37934/araset.32.1.120138

Martins, P., Lopes, S. I., Rosado da Cruz, A. M., & Curado, A. (2021). Towards a smart & sustainable campus: An application-oriented architecture to streamline digitization and strengthen sustainability in academia. *Sustainability*, *13*(6), 3189. https://doi.org/10.3390/su13063189

Mehmood, N. (2023). Smart Campus Systems: Integrating IoT, AI, and Information Systems for Education 4.0. *Multidisciplinary Research in Computing Information Systems*, *3*(3), 156-168. https://doi.org/10.1109/ACCESS.2021.3109516

Murfi, M., & Hendarman, A. F. (2023). The Relationship between Human Capital Readiness in Digital Transformation Era 4.0 and Individual Performance Perception (The Case of Smart Campus in Indonesia Defense University). *American International Journal of Business Management*, *6*(3), 1-6.

Polin, K., Yigitcanlar, T., Washington, T., & Limb, M. (2024). Unpacking smart campus assessment: Developing a framework via narrative literature review. *Sustainability*, *16*(6), 2494. https://doi.org/10.3390/su16062494

Sadeghi, S. H. (2022). *Smart Campus E-Readiness: A Framework for Cyberspace Learning Strategic Management*. Routledge.

Shtayyat, A., & AlShaikh-Hasan, M. (2025). Enhancing Cybersecurity in E-Learning System Infrastructure: Analyzing Challenges and Implementing Solutions. In *Complexities and Challenges for Securing Digital Assets and Infrastructure* (pp. 157-174). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-1370-2.ch008

Stavros, J. M., Cooperrider, D., & Kelley, L. (2013). Strategic inquiry with appreciative intent: Inspiration to SOAR! *AI Practitioner: International Journal of Appreciative Inquiry*.

Sterman, M. B. (2000). Basic concepts and clinical findings in the treatment of seizure disorders with EEG operant conditioning. *Clinical electroencephalography*, *31*(1), 45-55. https://doi.org/10.1177/155005940003100111

Tasrif, M., & Avianto, T. W. (2004). *Kursus analisis kebijaksanaan menggunakan model system dynamics*. Kelompok Penelitian dan Pengembangan Energi, Institut Teknologi Bandung.

VOSviewer. (n.d.). *VOSviewer from Google Scholar database*. Retrieved from https://www.vosviewer.com/