

Development and Integration of IoT for Smart Systems and Sustainable Infrastructure

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Article Info

Article history:

Submission February 3, 2026

Revised March 17, 2026

Accepted April 8, 2026

Published May 29, 2026

Keywords:

IoT

Smart Systems

System Integration

Smart Infrastructure



ABSTRACT

The rapid growth of digital technology has accelerated the adoption of the Internet of Things (IoT) in the development of smart systems across multiple sectors. However, challenges related to system integration, scalability, and efficient data management remain significant barriers to optimal implementation. **This study aims** to design IoT-based intelligent systems that enable real-time monitoring, automation, and intelligent decision-making for various applications. The research employs a system development approach combining IoT devices, sensor networks, cloud platforms, and data analytics to create an interconnected smart environment. The proposed framework is implemented and evaluated through several application scenarios, including smart environment monitoring and smart infrastructure management. The **results** indicate that coordinated IoT deployment improves operational efficiency, enhances data accuracy, and supports adaptive system responses through continuous data processing. Furthermore, **the developed system contributes** to sustainable technological advancement aligned with the Sustainable Development Goals (SDGs) by promoting efficient resource utilization and smarter infrastructure management. In **conclusion**, the proposed architecture provides a scalable and flexible foundation supporting innovation, sustainability, and digital transformation across diverse application domains.

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1. INTRODUCTION

The rapid evolution of digital technologies has accelerated the transition toward intelligent and interconnected environments, giving rise to smart systems capable of autonomous operation and data-driven decision-making [1]. Among emerging technologies, the Internet of Things (IoT) plays a crucial role by enabling physical devices to sense, communicate, and exchange information through network infrastructures [2]. The widespread adoption of IoT has facilitated advancements in various domains, including smart cities, healthcare services, environmental monitoring, and industrial automation, where real-time data processing is essential for improving operational efficiency and system responsiveness.

Despite these advancements, the integration of IoT into smart systems remains a complex challenge [3]. Existing implementations often suffer from limited interoperability between heterogeneous devices, scal-

ability constraints, fragmented system architectures, and inefficient data management mechanisms [4]. Many current solutions are developed for specific applications, resulting in isolated systems that lack unified integration frameworks capable of supporting multiple services simultaneously [5]. Consequently, achieving seamless coordination among devices, platforms, and intelligent services continues to be a significant research issue.

Previous studies have proposed various IoT architectures and smart system models, gaps remain in establishing an integrated framework that effectively combines sensing technologies, cloud-based processing, and intelligent analytics within a scalable and sustainable architecture [6]. Addressing these limitations requires a holistic integration approach that emphasizes flexibility, efficiency, and adaptability in dynamic environments.

In addition to technical challenges, IoT-based smart systems are increasingly expected to support sustainable development goals through efficient resource management, smart infrastructure, and environmental responsiveness [7]. This study is aligned with several Sustainable Development Goals (SDGs), particularly SDG 9, SDG 11, SDG 12, and SDG 13. SDG 9 is reflected through the development of innovative digital infrastructure and intelligent system integration [8]. SDG 11 is supported through smart infrastructure management and real-time monitoring for more sustainable communities. SDG 12 is addressed through efficient resource utilization enabled by continuous data monitoring and operational optimization. Furthermore, SDG 13 is supported through environmental sensing, early detection, and adaptive decision-making related to climate and environmental conditions.

Therefore, this research aims to develop and integrate an IoT-based smart system framework designed to enable real-time monitoring, automated control, and intelligent decision-making across diverse application scenarios. The main contribution of this study is the design of an integrated architecture that enhances interoperability, improves resource utilization, and supports sustainable technological development aligned with global digital transformation and SDG-oriented initiatives [9, 10]. The proposed framework provides a scalable foundation for future smart system implementations across multiple domains while contributing to smarter, more efficient, and sustainable digital transformation.

2. LITERATURE REVIEW

2.1. Internet of Things (IoT) in Smart Systems

The Internet of Things (IoT) has emerged as a fundamental technology for enabling smart systems through interconnected devices capable of sensing, communication, data exchange, and autonomous operation [11]. IoT allows physical objects such as sensors, actuators, embedded devices, and monitoring tools to connect through network infrastructures and generate real-time data for further processing [12]. In smart system development, IoT plays an important role in transforming conventional environments into intelligent environments that can monitor conditions, analyze changes, and respond automatically based on collected data [13].

In general, IoT architectures consist of several main layers, including the sensing layer, communication layer, data processing layer, and application layer [14]. The sensing layer collects data from physical environments, while the communication layer transmits data through wireless or wired networks. The data processing layer manages, filters, and analyzes incoming data, often using cloud computing or edge computing platforms [15]. Meanwhile, the application layer presents information to users through dashboards, monitoring systems, and automated control services. These layers work together to support intelligent environments that require continuous monitoring and fast decision-making.

Recent studies emphasize that IoT is not only useful for device connectivity but also for supporting automation, operational efficiency, and data-driven decision-making. Through real-time data collection and analysis, IoT-based smart systems can help users identify system conditions more accurately and respond to problems more quickly [16]. This capability makes IoT highly relevant for various application domains, including smart cities, smart healthcare, environmental monitoring, industrial automation, and infrastructure management [17]. Therefore, IoT has become one of the key drivers of digital transformation because it connects physical systems with digital intelligence.

2.2. Smart System Architecture and Integration

Smart systems rely on the integration of heterogeneous components, including sensors, communication gateways, cloud computing platforms, edge devices, databases, dashboards, and intelligent analytics [18]. These components must be connected within a unified architecture so that data can flow smoothly from the physical environment to the digital processing system. A well-designed architecture is important because

smart systems require not only data collection but also data transmission, storage, analysis, visualization, and automated response.

Several layered architectures have been proposed to manage data flow and improve system interoperability. Cloud-based architectures provide scalable storage and processing capabilities, making them suitable for applications that require large-scale data management [19]. Cloud platforms also allow sensor data to be stored, processed, and accessed remotely through monitoring dashboards. On the other hand, edge computing improves system responsiveness by processing data closer to the source. This is useful for real-time applications that require low latency and fast automated responses.

However, integrating multiple technologies into one smart system remains challenging. Different IoT devices often use different communication protocols, data formats, hardware standards, and software platforms [20]. These differences can reduce interoperability and create fragmented system architectures [21]. In addition, scalability becomes a major issue when the number of connected devices increases. Without proper integration, the system may experience communication delays, data inconsistency, and inefficient processing [22]. Therefore, smart system architecture must be designed to support interoperability, scalability, flexibility, and reliable data management.

An integrated IoT architecture should connect sensing devices, communication networks, cloud analytics, and application services into a cohesive framework [23]. This type of integration enables the system to collect real-time data, process information continuously, and generate adaptive responses. In this context, architecture becomes a critical factor in determining system effectiveness [24]. The performance of a smart system depends not only on the quality of individual devices but also on how well these devices are coordinated within the overall system structure.

2.3. Applications of IoT-Based Smart Systems

IoT-enabled smart systems have been widely implemented in various application areas such as smart cities, smart healthcare, environmental monitoring, smart infrastructure, and industrial automation [25]. In smart city applications, IoT is commonly used for energy management, traffic monitoring, public facility control, waste management, and infrastructure optimization [26]. Real-time sensor data allows city managers to monitor urban conditions and improve public services through data-driven strategies.

In healthcare services, IoT supports remote patient monitoring, health data collection, and early detection of health conditions [27]. Wearable devices and medical sensors can collect patient data continuously and transmit it to healthcare platforms for analysis [28]. This enables healthcare providers to observe patient conditions remotely and make faster decisions. In industrial environments, IoT is used to monitor machines, detect operational anomalies, improve production efficiency, and reduce system downtime through predictive maintenance.

Environmental monitoring is also one of the important applications of IoT-based smart systems. Sensor networks can collect data related to air quality, temperature, humidity, water conditions, and other environmental indicators. These data can be processed to support sustainability management and environmental decision-making. Through continuous monitoring, IoT systems can help detect environmental changes earlier and support more adaptive responses to climate and ecological conditions [29].

Although these applications show significant benefits, many IoT implementations remain domain-specific [30]. Some systems are designed only for one particular purpose and are difficult to adapt to other application areas. This creates limitations in terms of scalability and generalization [31]. Therefore, there is a need for a more flexible IoT framework that can support multiple application scenarios while maintaining reliable performance, interoperability, and efficient resource utilization.

2.4. IoT-Based Smart Systems and Sustainability

The development of IoT-based smart systems is closely related to sustainability because IoT can support efficient resource monitoring, smarter infrastructure management, and environmental responsiveness [13]. Through real-time monitoring, IoT systems can help reduce unnecessary resource consumption and improve operational efficiency. For example, smart monitoring systems can detect changes in environmental or operational conditions and support automatic responses to optimize energy, water, or infrastructure usage [32].

IoT-based systems also support sustainable digital transformation by enabling organizations and communities to make decisions based on accurate and continuous data [33]. This is relevant to the Sustainable Development Goals (SDGs), particularly SDG 9, SDG 11, SDG 12, and SDG 13. SDG 9 is supported through

innovation, digital infrastructure, and smart system integration. SDG 11 is supported through smart infrastructure and sustainable community management. SDG 12 is reflected in efficient resource utilization and operational optimization. Meanwhile, SDG 13 is supported through environmental monitoring, early detection, and adaptive decision-making related to climate and environmental conditions [34].

Therefore, IoT-based smart systems should not only be evaluated from a technical perspective but also from their contribution to sustainability [35]. A smart system that integrates sensors, connectivity, cloud analytics, and automation can provide both operational and environmental value [36]. This makes IoT an important technological foundation for building intelligent, efficient, and sustainable systems in the future.

2.5. Research Gap and Contribution

Previous studies have successfully demonstrated the potential of IoT technologies in supporting smart systems across various sectors. However, limitations remain in achieving scalable and interoperable smart system integration. Many existing studies focus on individual components, such as sensors, cloud platforms, or application dashboards, rather than developing a holistic framework that integrates sensing, communication, data processing, analytics, and automated responses into one cohesive architecture.

Another gap is the limited ability of existing IoT implementations to support multiple application scenarios. Many systems are developed for specific domains and cannot easily be adapted to other environments. This limitation reduces flexibility and makes it difficult to implement IoT solutions at a broader scale. In addition, challenges related to data management, communication reliability, system scalability, and interoperability remain important issues that need to be addressed in smart system development.

Based on these gaps, this study proposes an integrated IoT-based smart system architecture designed to enhance interoperability, scalability, adaptive decision-making, and sustainable system development. The proposed framework combines sensing devices, communication networks, cloud-based processing, monitoring dashboards, and automated response mechanisms. By integrating these components, the study contributes to the development of a flexible and scalable smart system model that can be applied across various domains.

The contribution of this research is not limited to technical system development. This study also emphasizes the role of IoT architecture in supporting sustainable technological innovation. By enabling efficient resource monitoring, real-time data analysis, and adaptive responses, the proposed framework supports both digital transformation and sustainability-oriented smart system implementation.

3. RESEARCH METHODOLOGY

3.1. Research Approach

This research adopts a system development and integration approach to design an Internet of Things (IoT)-based smart system that supports real-time monitoring and intelligent decision-making. The study follows an engineering-oriented methodology aligned with Design Science Research principles, focusing on the development and evaluation of a technological artifact in the form of an integrated smart system framework. The research begins by identifying existing challenges in IoT implementation, including interoperability, scalability, and efficient data management. This approach ensures that the proposed system not only addresses practical technological problems but also contributes to scientific knowledge through systematic design and validation processes.

Table 1. Research Framework of IoT-Based Smart System Development

Research Phase	Description	Method/Technology	Output
Problem Analysis	Identify IoT integration challenges	Literature review	Research objectives
System Design	Develop smart system architecture	IoT layered architecture	System framework
Implementation	Integrate devices and platforms	IoT devices & cloud	System prototype
Data Processing	Process real-time sensor data	Cloud analytics	Monitoring data
Evaluation	Assess system performance	Experimental testing	Performance results
Analysis	Interpret evaluation outcomes	Data analysis	Research conclusions

Table 1 presents the research framework used in this study for developing and integrating an IoT-based smart system. The research follows a structured development process starting from problem analysis, system design, implementation, data processing, and performance evaluation. Each phase contributes to validating the effectiveness and scalability of the proposed smart system architecture.

3.2. System Design and Architecture

The system design phase focuses on developing a structured architecture that integrates sensing devices, communication networks, cloud-based processing platforms, and application services. The proposed architecture adopts a layered model in which IoT sensors continuously collect environmental and operational data and transmit it through network communication to processing platforms. Data processing is performed using cloud computing technologies to enable storage, filtering, and analytical operations. This architectural design supports interoperability between heterogeneous devices while maintaining scalability and flexibility required for diverse smart system applications.

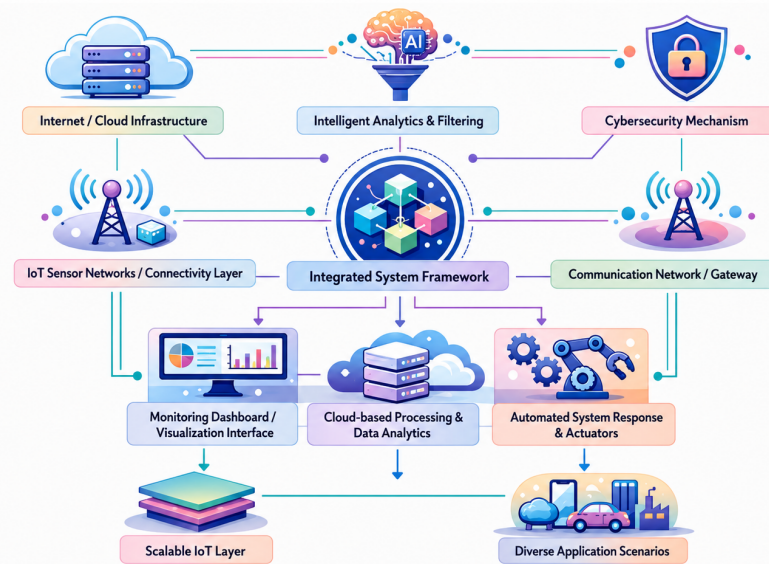


Figure 1. Integrated IoT System Architecture

As illustrated in Figure 1, the proposed architecture integrates IoT sensor networks, communication gateways, cloud-based analytics, and automated response mechanisms within an integrated system framework. Data collected from sensors are transmitted through communication networks to cloud processing layers, where intelligent analytics and filtering are performed. The results are visualized through monitoring dashboards and enable automated system responses across diverse application scenarios.

3.3. System Implementation and Integration

The implementation stage involves configuring IoT devices, establishing communication infrastructure, and integrating hardware and software components into a unified operational system. Real-time data transmission is established between sensing devices and cloud services to enable continuous monitoring and automated system responses. Integration ensures seamless interaction among system components, allowing intelligent services to operate efficiently. The developed application interface provides visualization and monitoring capabilities that assist users in observing system performance and supporting data-driven decision-making processes.

3.4. Evaluation Method

To validate the effectiveness of the proposed system, performance evaluation is conducted through prototype testing and scenario-based experimentation under continuous operational conditions. The evaluation analyzes system performance in terms of operational efficiency, data accuracy, responsiveness, and reliability of data transmission. Observations are performed to assess how well the system processes real-time data and maintains stable communication among devices. This evaluation process ensures systematic validation and reproducibility of the proposed smart system framework.

4. RESULT

4.1. System Implementation Results

The developed IoT-based smart system was successfully implemented through the integration of sensing devices, communication networks, cloud-based data processing, and application services. The implementation process focused on connecting physical sensing components with digital processing platforms to support continuous data acquisition, real-time monitoring, and automated decision-making. The sensing devices were configured to collect environmental and operational data, while the communication network functioned as the transmission layer that delivered sensor data to the cloud-based processing system.

The experimental deployment confirmed that the system was able to acquire environmental data continuously and transmit it in a stable manner. Data collected from sensors could be sent to the cloud platform for storage, filtering, and analytical processing. This shows that the proposed architecture can support a continuous data flow from the sensing layer to the processing layer without major disruption. The integration between hardware and software components also allowed the system to operate as a unified smart environment rather than as separated IoT devices.

The monitoring dashboard played an important role in presenting real-time visualization of system conditions. Through the dashboard, users were able to observe sensor data, monitor system performance, and identify changes in operational conditions more efficiently. This visualization feature improves user awareness because the collected data are displayed in a more understandable format. As a result, the system can support data-driven decision-making by providing updated information about the monitored environment.

Automated system operations were executed according to predefined parameters, demonstrating that the proposed architecture supports autonomous monitoring and control within smart environments. When specific conditions were detected, the system was able to provide responses based on the configured rules. This indicates that the integration of sensors, cloud analytics, and automation mechanisms can improve system responsiveness and reduce the need for manual observation. Therefore, the implementation results show that the proposed IoT-based smart system is capable of supporting real-time monitoring, automated control, and intelligent decision-making in diverse application scenarios.

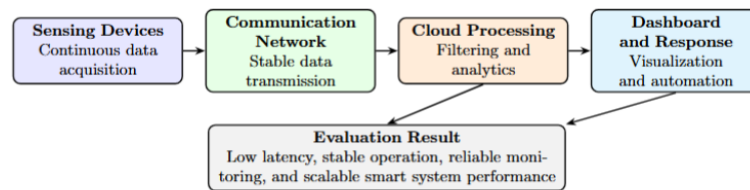


Figure 2. IoT System Evaluation Flow

Figure 2 illustrates the evaluation flow of the proposed IoT-based smart system. The process begins with sensing devices that collect data continuously, followed by communication networks that transmit data to the cloud processing layer. The processed data are then visualized through the monitoring dashboard and used to trigger automated responses. This flow supports the result that the proposed system can provide low-latency communication, stable operation, reliable monitoring, and scalable smart system performance.

In addition, the implementation results demonstrate that the proposed framework can be used as a scalable foundation for future smart system development. The layered structure allows sensing devices, communication gateways, cloud platforms, and application interfaces to work together in a flexible architecture. This flexibility is important because smart systems are often required to operate in different domains, such as smart infrastructure, environmental monitoring, healthcare, and industrial automation. Thus, the system implementation confirms that an integrated IoT architecture can enhance interoperability, support continuous data processing, and improve operational efficiency.

4.2. Performance Evaluation

System performance was evaluated based on transmission reliability, response time, operational stability, data accuracy, and system responsiveness. The evaluation was conducted through prototype testing and scenario-based experimentation under continuous operational conditions. This evaluation aimed to assess whether the proposed smart system could maintain stable communication among devices, process real-time data effectively, and support automated responses during system operation.

Testing results indicated low communication latency and consistent data delivery during continuous operation. The system was able to transmit sensor data to the cloud-based processing layer without significant delays. This result shows that the communication infrastructure used in the proposed architecture can support real-time monitoring activities. Low latency is important in IoT-based smart systems because delayed data transmission may reduce the effectiveness of monitoring, analysis, and automated response mechanisms.

The system also maintained stable functionality without significant interruptions throughout the experimental period. This operational stability indicates that the proposed integration framework can handle continuous data streams while maintaining reliable system performance. The stability of communication between sensing devices and cloud services confirms that the system architecture can support long-term monitoring processes. This is especially important for smart system applications that require continuous observation, such as environmental monitoring, infrastructure management, and industrial automation.

In terms of data processing, the cloud analytics layer allowed the collected sensor data to be stored, filtered, and analyzed effectively. This process helped transform raw data into useful information that can be accessed through the monitoring dashboard. The ability to process data continuously supports intelligent decision-making because users can monitor real-time conditions and respond to system changes based on updated information. Therefore, the performance evaluation confirms that cloud-based processing strengthens the overall capability of the proposed IoT system.

These results demonstrate that the integration framework maintains performance efficiency while handling continuous data streams, indicating its suitability for scalable smart system applications. The coordinated interaction between sensing devices, communication networks, cloud-based processing, and application dashboards improves system responsiveness and operational efficiency. In addition, the performance results show that the proposed architecture is not only technically effective but also relevant for sustainable smart system development. By enabling efficient monitoring and adaptive responses, the system supports smarter infrastructure management, efficient resource utilization, and data-driven digital transformation.

Table 2. IoT System Performance Evaluation

Evaluation Aspect	Observed Indicator	Result	Interpretation
Data Acquisition	Continuous sensor data collection from environmental and operational sources	Successfully achieved	The system was able to collect real-time data continuously from IoT sensing devices.
Data Transmission	Communication between sensing devices and cloud platform	Stable and consistent	The communication layer supported reliable data delivery with minimal disruption during testing.
Response Time	Time required for data transfer and system response	Low latency	The system showed fast responsiveness, supporting real-time monitoring and automated decision-making.
Monitoring Dashboard	Real-time visualization of sensor data and system conditions	Functional and accessible	The dashboard helped users observe system conditions efficiently and support data-driven decisions.
Automated Response	Execution of predefined control parameters	Successfully executed	The system was able to perform automated actions based on configured rules and detected conditions.
Operational Stability	System performance during continuous operation	Stable operation	The system maintained functionality without significant interruption throughout the experimental period.
Scalability Potential	Ability to support future smart system applications	Suitable for expansion	The integrated architecture provides a flexible foundation for broader smart system implementation.

Table 2 presents the supporting evaluation data of the proposed IoT-based smart system. The results show that the system performed effectively in continuous data acquisition, stable data transmission, real-time visualization, automated response, and operational stability. These findings indicate that the integration of sensing devices, communication networks, cloud-based processing, and monitoring dashboards can support

reliable smart system implementation. The evaluation also confirms that the proposed architecture is suitable for scalable applications because it maintains stable performance while handling continuous data streams.

Overall, the evaluation results confirm that the proposed IoT-based smart system provides a reliable foundation for integrated smart environments. The system performs effectively in terms of data transmission, response time, stability, and monitoring capability. These findings support the argument that an integrated architecture is essential for improving IoT implementation because system effectiveness depends not only on individual device capability but also on how sensing, communication, processing, and application layers work together within a unified framework.

5. DISCUSSION

The findings highlight that effective IoT implementation depends not only on the capability of individual devices but also on the strength of integrated system architecture. The coordinated interaction between sensing devices, communication networks, cloud-based processing, and application services enables the system to collect, transmit, analyze, and respond to real-time data more effectively. This integration improves interoperability among heterogeneous devices and reduces the fragmentation commonly found in conventional IoT implementations. Therefore, the proposed framework demonstrates that a unified architecture is essential for building smart systems that are scalable, adaptive, and reliable across various application scenarios.

The performance results also indicate that the proposed IoT-based smart system can support continuous monitoring and automated responses under operational conditions. Stable data transmission, low communication latency, and real-time visualization through the monitoring dashboard show that the system is capable of supporting data-driven decision-making. These findings suggest that IoT integration can improve operational efficiency by helping users monitor system conditions, identify changes, and respond to specific situations more quickly. In this context, the use of cloud analytics strengthens the system because it allows collected sensor data to be processed, filtered, and transformed into useful information for decision-making.

The proposed IoT-based smart system is closely aligned with several Sustainable Development Goals, particularly SDG 9, SDG 11, SDG 12, and SDG 13. The framework supports SDG 9 by strengthening digital infrastructure, innovation, and intelligent system integration through sensor networks, communication gateways, cloud-based analytics, and automated response mechanisms. It also contributes to SDG 11 by enabling smart infrastructure management, real-time environmental monitoring, and data-driven urban services that can improve the sustainability and resilience of smart cities. In addition, the system supports SDG 12 by promoting efficient resource utilization through continuous monitoring and optimization of operational processes. Furthermore, the use of IoT for environmental sensing and early detection supports SDG 13 by improving awareness, responsiveness, and adaptive decision-making related to climate and environmental conditions. Therefore, the proposed architecture is not only a technological solution but also a sustainability-oriented framework that contributes to smarter, more efficient, and resilient digital transformation. SDG 9 focuses on infrastructure, industrialization, and innovation, while SDG 11 emphasizes inclusive, safe, resilient, and sustainable cities; SDG 12 concerns responsible resource use, and SDG 13 focuses on climate action.

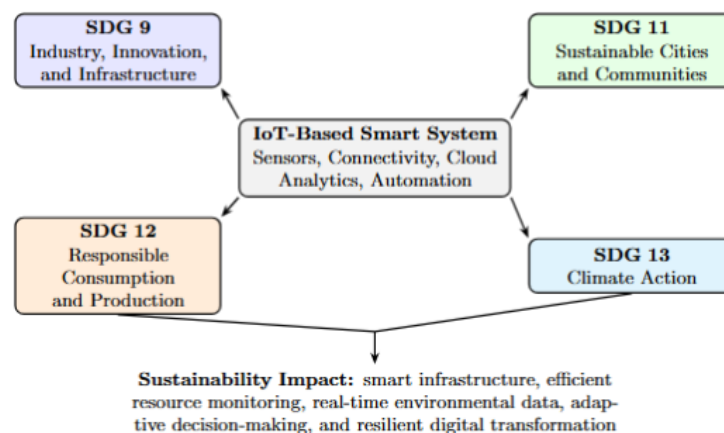


Figure 3. IoT Smart Systems Support SDGs

Figure 3 illustrates the relationship between the proposed IoT-based smart system and the Sustainable Development Goals. The central framework represents the integration of sensors, connectivity, cloud analytics, and automation, which collectively support intelligent monitoring and decision-making. This integration contributes to SDG 9 through technological innovation and smart infrastructure, SDG 11 through sustainable urban and infrastructure management, SDG 12 through efficient resource utilization, and SDG 13 through environmental monitoring and climate-responsive decision-making. Thus, the proposed system provides both technical and sustainability contributions for future smart system development.

Furthermore, the architecture supports sustainable smart system development by enabling efficient resource monitoring and facilitating digital transformation. The integration of IoT sensors and cloud analytics allows organizations or system users to monitor resource conditions continuously and make decisions based on real-time information. This capability is important because smart systems are expected not only to improve technical performance but also to support sustainability, efficiency, and long-term resilience. By connecting technical architecture with sustainability goals, this study shows that IoT-based smart systems can contribute to both operational improvement and broader social and environmental objectives.

Overall, the discussion confirms that the proposed IoT-based smart system provides both technical and sustainability contributions. From a technical perspective, the framework improves interoperability, scalability, automation, responsiveness, and real-time data utilization. From a sustainability perspective, it supports smarter infrastructure, efficient resource management, environmental monitoring, and data-driven awareness. Thus, the proposed architecture is not only useful as a technological framework but also as a strategic approach for developing sustainable smart systems in the future.

5.1. Research Implementation

This study demonstrates that integrated IoT architecture can enhance operational efficiency and support intelligent system development across multiple application domains. The proposed framework provides a practical reference for future smart system design by combining sensing devices, communication networks, cloud-based processing, monitoring dashboards, and automated response mechanisms into a unified architecture. This integration allows the system to collect environmental and operational data continuously, transmit the data through communication infrastructure, and process the information using cloud analytics.

The implementation of the proposed framework shows that IoT-based smart systems require more than the connection of individual devices. Effective implementation depends on the coordination between hardware components, software platforms, data processing mechanisms, and application interfaces. In this study, sensing devices function as the data acquisition layer, communication networks act as the data transmission layer, cloud platforms support data storage and analysis, while the monitoring dashboard presents real-time system conditions to users. Through this structure, the system can support continuous monitoring, data-driven decision-making, and automated control within smart environments.

From a practical perspective, the proposed architecture can be implemented in various smart system applications, including smart infrastructure management, environmental monitoring, healthcare monitoring, and industrial automation. The framework is flexible because each layer can be adjusted according to the needs of different application scenarios. For example, environmental monitoring can prioritize sensor accuracy and real-time alerts, while smart infrastructure management can focus on resource efficiency, operational stability, and automated responses. This flexibility makes the proposed framework suitable as a scalable model for future IoT-based smart system development.

The research implementation also contributes to sustainable technological innovation. By enabling real-time monitoring and efficient resource utilization, the proposed system supports smarter infrastructure management and more responsive decision-making. This contribution is aligned with the Sustainable Development Goals (SDGs), particularly SDG 9 on industry, innovation, and infrastructure, SDG 11 on sustainable cities and communities, SDG 12 on responsible consumption and production, and SDG 13 on climate action. Therefore, the implementation of the IoT-based smart system is not only relevant for improving technical performance but also for supporting sustainability-oriented digital transformation.

Overall, the research implementation confirms that the proposed integrated IoT framework can serve as a practical and conceptual foundation for developing intelligent, scalable, and sustainable smart systems. The system supports interoperability, operational efficiency, real-time visualization, automated response, and adaptive decision-making. These results indicate that the proposed architecture can reduce fragmentation in IoT implementation while providing a stronger basis for future smart system innovation.

6. MANAGERIAL IMPLICATIONS

The findings of this study provide important managerial implications for organizations that plan to implement IoT-based smart systems. Managers should recognize that successful IoT adoption does not only depend on the availability of sensors or devices, but also on the integration of sensing devices, communication networks, cloud-based processing, monitoring dashboards, and automated response mechanisms into a unified architecture. Through this framework, organizations can improve monitoring efficiency, support real-time visualization, reduce manual observation, and strengthen data-driven decision-making in areas such as smart infrastructure, environmental monitoring, healthcare services, and industrial automation. The proposed system also helps managers optimize resources, improve operational responsiveness, reduce system fragmentation, and maintain long-term performance stability. In addition, the implementation of IoT-based smart systems can support sustainability-oriented digital transformation by contributing to SDG 9, SDG 11, SDG 12, and SDG 13 through smart infrastructure management, efficient resource utilization, and environmental responsiveness.

7. CONCLUSION

The integration of Internet of Things (IoT) technologies within smart systems demonstrates significant potential for improving operational efficiency, supporting intelligent environment management, and enabling data-driven decision-making across multiple application domains. The implemented architecture confirms that coordinated interaction between sensing devices, communication networks, cloud-based processing, monitoring dashboards, and automated response mechanisms can establish a stable foundation for continuous data utilization. Through this integrated structure, the proposed system is able to collect environmental and operational data, transmit information reliably, process data through cloud analytics, and present real-time visualization to support smarter system monitoring.

The findings indicate that architectural coherence plays a more decisive role in system effectiveness than isolated device performance. A unified framework allows data to flow seamlessly across system layers, supporting adaptive operations and reducing fragmentation commonly encountered in conventional IoT deployments. The evaluation results show that the system can maintain stable data transmission, low communication latency, operational stability, and consistent performance during continuous operation. Beyond technical implementation, the proposed framework also supports sustainable digital transformation by contributing to SDG 9 through digital infrastructure and innovation, SDG 11 through smart infrastructure management, SDG 12 through efficient resource utilization, and SDG 13 through environmental monitoring and climate-responsive actions.

This study provides a practical and conceptual foundation for developing integrated IoT-based smart systems that are interoperable, scalable, responsive, and sustainability-oriented. The proposed framework can be adapted to various domains, including smart infrastructure, environmental monitoring, healthcare services, and industrial automation. Future research may expand this framework by integrating artificial intelligence, predictive analytics, adaptive learning models, and stronger cybersecurity mechanisms to improve system intelligence, resilience, and long-term reliability. Further testing in larger-scale and heterogeneous deployment environments is also recommended to validate the robustness, flexibility, and sustainability impact of the proposed architecture.

8. DECLARATIONS

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8.2. Author Contributions

Conceptualization: AA; Methodology: RS; Software: HA; Validation: NR and MM; Formal Analysis: AA and RS; Investigation: MM; Resources: AA; Data Curation: RS; Writing Original Draft Preparation: NR

and HA; Writing Review and Editing: HA and NR; Visualization: RS; All authors, AA, RS, HA, NR, and MM, have read and agreed to the published version of the manuscript.

8.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

8.4. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

8.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

- [1] T. Van Hoang *et al.*, “Impact of integrated artificial intelligence and internet of things technologies on smart city transformation,” *Journal of technical education science*, vol. 19, no. Special Issue 01, pp. 64–73, 2024.
- [2] M. A. Syari, U. Rahardja, T. Wellem, H. D. Purnomo, and R. Buaton, “Iot enabled smart farming system for optimizing crop management using sensors and machine learning,” in *2025 4th International Conference on Creative Communication and Innovative Technology (ICCIT)*. IEEE, 2025, pp. 1–7.
- [3] S. H. Abdulhussain, B. M. Mahmmod, A. Alwhelat, D. Shehada, Z. I. Shihab, H. J. Mohammed, T. H. Abdulameer, M. Alsabah, M. H. Fadel, S. K. Ali *et al.*, “A comprehensive review of sensor technologies in iot: Technical aspects, challenges, and future directions,” *Computers*, vol. 14, no. 8, p. 342, 2025.
- [4] K. Paraskevas, “Data integration and storage strategies in heterogeneous analytical systems: architectures, methods, and interoperability challenges,” *Information*, vol. 16, no. 11, p. 932, 2025.
- [5] A. Mehmood, M. Arif, and F. Mehmood, “Towards a unified digital ecosystem: The role of platform technology convergence,” *Electronics*, vol. 14, no. 24, p. 4787, 2025.
- [6] H. Rasheed, A. A. Salih, O. M. Ahmed, A. A. Yazdeen, R. Majeed, and T. Abdullah, “Consideration of cloud-web-concepts for standardization and interoperability: A comprehensive review for sustainable enterprise systems, ai, and iot integration,” *Journal of Information Technology and Informatics*, vol. 3, no. 2, pp. 1–12, 2024.
- [7] D. Hidayati, A. Andriyansah, G. P. Cesna, A. Y. Fauzi, D. Apriliasari, and U. Rahardja, “Building efficient iot systems with edge computing integration,” *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 4, no. 2, pp. 72–79, 2024.
- [8] United Nations Department of Economic and Social Affairs, “The 17 goals,” <https://sdgs.un.org/goals>, 2026, accessed: 2026-03-17.
- [9] G. Farhadian and M. Saeedi, “Sustainable digital transformation and the sdgs: a graph theoretic mapping of core is theories and societal impact,” *Frontiers in Sustainability*, vol. 7, p. 1793316, 2026.
- [10] P. A. Sunarya, T. Handra, S. Syahyono, K. A. Al-Farouqi, and S. V. Sihotang, “Governance frameworks for sustainable artificial intelligence in digital business practices,” *ADI Journal on Recent Innovation (AJRI)*, vol. 7, no. 2, pp. 173–184, 2026.
- [11] M. R. Anwar, S. N. Sari, S. Maesaroh, S. Widada *et al.*, “Implementation design in the creation of companies in the 4.0 technology era,” *Aptisi Transactions on Technopreneurship (ATT)*, vol. 4, no. 1, pp. 89–108, 2022, <https://doi.org/10.34306/att.v4i1.244>.
- [12] S. Pandey, M. Chaudhary, and Z. Tóth, “An investigation on real-time insights: enhancing process control with iot-enabled sensor networks,” *Discover Internet of Things*, vol. 5, no. 1, p. 29, 2025.
- [13] D. R. Ramani, B. B. Sujitha, and S. Tangade, “Smart environmental monitoring systems: Iot and sensor-based advancements,” *Environmental Monitoring Using Artificial Intelligence*, pp. 45–60, 2025.
- [14] F. A. Alaba, “Iot architecture layers,” in *Internet of Things: A Case Study in Africa*. Springer, 2024, pp. 65–85.
- [15] T. Shwe and M. Aritsugi, “Optimizing data processing: a comparative study of big data platforms in edge, fog, and cloud layers,” *Applied sciences*, vol. 14, no. 1, p. 452, 2024.

- [16] W. Villegas-Ch, J. García-Ortiz, and S. Sánchez-Viteri, "Toward intelligent monitoring in iot: Ai applications for real-time analysis and prediction," *IEEE access*, vol. 12, pp. 40 368–40 386, 2024.
- [17] R. Chataut, A. Phoummalayvane, and R. Akl, "Unleashing the power of iot: A comprehensive review of iot applications and future prospects in healthcare, agriculture, smart homes, smart cities, and industry 4.0," *Sensors*, vol. 23, no. 16, p. 7194, 2023.
- [18] I. Ficili, M. Giacobbe, G. Tricomi, and A. Puliafito, "From sensors to data intelligence: Leveraging iot, cloud, and edge computing with ai," *Sensors*, vol. 25, no. 6, p. 1763, 2025.
- [19] N. F. Akbar, N. Azizah, K. A. Al-Farouqi, I. A. Widjaya, and R. Supriati, "Designing educational information systems to optimize learning factory operations," *International Transactions on Education Technology (ITEE)*, vol. 4, no. 1, pp. 83–99, 2025.
- [20] D. M. K. Dave and B. K. Mittapally, "Data integration and interoperability in iot: challenges, strategies and future direction," *Int. J. Comput. Eng. Technol.(IJCET)*, vol. 15, pp. 45–60, 2024.
- [21] M. Sadeghi, A. Carenini, O. Corcho, M. Rossi, R. Santoro, and A. Vogelsang, "Interoperability of heterogeneous systems of systems: from requirements to a reference architecture: M. sadeghi et al." *The Journal of Supercomputing*, vol. 80, no. 7, pp. 8954–8987, 2024.
- [22] A. H. Adepoju, B. Austin-Gabriel, A. Eweje, and A. Collins, "Framework for automating multi-team workflows to maximize operational efficiency and minimize redundant data handling," *IRE Journals*, vol. 5, no. 9, pp. 663–664, 2022.
- [23] H. Kuchuk and E. Malokhvii, "Integration of iot with cloud, fog, and edge computing: a review," *Advanced Information Systems*, vol. 8, no. 2, pp. 65–78, 2024.
- [24] R. Aprianto, R. Haris, A. Williams, H. Agustian, and N. Aptwell, "Social influence on ai-driven air quality monitoring adoption: Smartpls analysis," *Sundara Advanced Research on Artificial Intelligence*, vol. 1, no. 1, pp. 28–36, 2025.
- [25] A. Hassebo and M. Tealab, "Global models of smart cities and potential iot applications: A review," *IoT*, vol. 4, no. 3, pp. 366–411, 2023.
- [26] D. Jonas, E. Maria, I. R. Widiyari, U. Rahardja, T. Wellem *et al.*, "Design of a tam framework with emotional variables in the acceptance of health-based iot in indonesia," *ADI Journal on Recent Innovation*, vol. 5, no. 2, pp. 146–154, 2024.
- [27] M. Alshamrani, "Iot and artificial intelligence implementations for remote healthcare monitoring systems: A survey," *Journal of King Saud University-Computer and Information Sciences*, vol. 34, no. 8, pp. 4687–4701, 2022.
- [28] Y. Du, J. Li, Y. Zhao, S. Tong, L. Wang, and J. Wang, "Health monitoring with earables: A survey," *ACM Transactions on Internet of Things*, vol. 7, no. 2, pp. 1–36, 2026.
- [29] B. Tjahjono, D. Hermawan, S. Millah, and R. Evans, "Bridging the skills gap curriculum transformation for automation industries and the role of digital technopreneurship," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 2, pp. 650–662, 2025, <https://doi.org/10.34306/att.v7i2.620>.
- [30] A. J. Salman, M. Al-Jawad, and W. A. Tameemi, "Domain-specific languages for iot: Challenges and opportunities," in *IOP Conference Series: Materials Science and Engineering*, vol. 1067, no. 1. IOP Publishing, 2021, p. 012133.
- [31] V. Gohil, S. Dev, G. Upasani, D. Lo, P. Ranganathan, and C. Delimitrou, "The importance of generalizability in machine learning for systems," *IEEE Computer Architecture Letters*, vol. 23, no. 1, pp. 95–98, 2024.
- [32] L. Sitoay, M. V. A. Sin, S. Riyadi, M. Daeli, and J. Parker, "Smart urban mental health mapping through iot sensor networks and ai analysis," *Journal of Orange Technology*, vol. 1, no. 1, pp. 19–28, 2024.
- [33] D. Mahmud, "An iot-enabled decision support system for circular economy business models: A review of economic efficiency and sustainability outcomes," *American Journal of Scholarly Research and Innovation*, vol. 4, no. 01, pp. 250–286, 2025.
- [34] M. Al-Raei, "Artificial intelligence for climate resilience: Advancing sustainable goals in sdgs 11 and 13 and its relationship to pandemics," *Discover Sustainability*, vol. 5, no. 1, p. 513, 2024.
- [35] M. F. Hilmi, H. Hamdan, A. Faturahman, B. N. Henry, and J. Wilson, "Ai in industry forecasting: The use of ai in predicting industry trends and demands," *Health, Empathy, and AI Learning (HEAL)*, vol. 1, no. 1, pp. 78–83, 2025.
- [36] R. Ajayi, "Integrating iot and cloud computing for continuous process optimization in real-time systems," *Int J Res Publ Rev*, vol. 6, no. 1, pp. 2540–2558, 2025.