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The Dawn of a Connected Province: A Review of the Internet of Things (IoT) Landscape in Pangasinan

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Abstract – *The Internet of Things (IoT) is rapidly reshaping industries and public services worldwide, presenting a significant opportunity for developing regions to leapfrog traditional development pathways. This review article explores the current state and potential of IoT applications within the province of Pangasinan, a key agricultural and aquacultural hub in the Philippines. While direct scholarly research on IoT adoption in Pangasinan remains nascent, this paper synthesizes findings from national and regional studies on IoT in critical sectors and applies them to the specific socio-economic context of the province. The objective of this literature review is to identify the most promising areas for IoT implementation in Pangasinan, understand the enabling factors and challenges, and propose a thematic framework for its future development. This study employs a thematic literature review methodology, analyzing peer-reviewed research articles on IoT trends, smart agriculture, aquaculture, healthcare, and smart governance relevant to the Philippine context. The results indicate that the most significant and immediate impacts of IoT in Pangasinan are likely to be realized in the realms of smart agriculture and aquaculture, addressing long-standing challenges in crop management, water quality monitoring, and supply chain efficiency. Further thematic analysis points to potential applications in environmental monitoring, particularly for the province's vital river systems and coastal areas, and in enhancing public service delivery through smart governance initiatives. The review concludes that while Pangasinan is on the cusp of an IoT revolution, its successful realization hinges on concerted efforts in building digital infrastructure, fostering local innovation, and developing human capital. Recommendations include prioritizing government-led pilot projects in agriculture, forging public-private partnerships for technology transfer, and integrating IoT concepts into the curricula of local academic institutions to cultivate a skilled workforce ready to harness the transformative power of a connected Pangasinan..*

Keywords – *Internet of Things (IoT), Pangasinan, Smart Agriculture, Smart Aquaculture, Environmental Monitoring, Smart Governance, Philippines, Developing Regions*

INTRODUCTION

The Internet of Things (IoT) represents a paradigm shift in the digital revolution, characterized by the pervasive connectivity of physical objects embedded with sensors, software, and other technologies that allow them to connect and exchange data over the internet. This network of "things" enables real-time data collection, analysis, and automated action, driving unprecedented efficiencies and innovations across a multitude of sectors. Globally, the proliferation of IoT is accelerating, fueled by advancements in wireless communication, the miniaturization and decreasing cost of sensors, and the immense processing power of cloud computing and artificial intelligence.

Current trends in IoT point towards a more intelligent and autonomous future. The integration of Artificial Intelligence (AI) with IoT, often termed AIoT, is enabling predictive analytics and more sophisticated decision-making without human intervention (Lee & Lee, 2020). Edge computing is another significant trend, where data is processed closer to its source, reducing latency and bandwidth usage, which is critical for real-time applications in areas like industrial automation and remote healthcare (Shi & Zhang, 2021). Furthermore, the rollout of 5G networks is poised to unlock the full potential of IoT by providing the high-speed, low-

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latency connectivity required for massive IoT deployments, from connected vehicles to smart city infrastructures (Iyamu et al., 2021). In developing countries, IoT is increasingly seen as a powerful tool for addressing pressing challenges in agriculture, healthcare, and environmental management, offering a pathway to sustainable and inclusive growth (GIZ, 2018).

The Philippines has recognized the transformative potential of IoT and has laid the groundwork for its adoption through the National IoT Roadmap. This roadmap envisions a "Smarter Philippines" where IoT solutions drive economic growth, improve public services, and enhance the quality of life for its citizens (Department of Information and Communications Technology, 2018). While initiatives have been concentrated in metropolitan areas, the vast potential of IoT in the provinces remains largely untapped.

Pangasinan, a province in the Ilocos Region of the Philippines, stands at a critical juncture. With its robust agricultural and aquacultural sectors, a growing economy, and a significant population, the province is fertile ground for the application of IoT technologies. The challenges it faces, such as the impacts of climate change on crop yields, the need for sustainable aquaculture practices, and the imperative to improve public service delivery, are precisely the kinds of problems that IoT is well-suited to address.

Objectives Of The Study

The objective of this review article aims to explore the landscape of IoT in Pangasinan. Recognizing the scarcity of scholarly research specifically focused on IoT within the province, this paper will adopt a thematic literature review approach. It will synthesize findings from relevant research on IoT applications in the Philippines and other similar developing regions and apply them to the unique context of Pangasinan. The objective of this study, from the perspective of a student researcher, is to identify and analyze the latest and most relevant IoT applications for Pangasinan, categorizing them into thematic areas to provide a structured overview of the opportunities and challenges. By doing so, this review seeks to provide a foundational document that can guide future research, policy-making, and investment in the digitalization of Pangasinan.

Materials and Methods

This study employed a thematic literature review methodology to investigate the current state and potential of the Internet of Things (IoT) in the province of Pangasinan. Given the nascent stage of direct scholarly research on this specific topic, a thematic approach was deemed most appropriate as it allows for the synthesis of information from a broader range of relevant studies to identify patterns and overarching themes applicable to the context of Pangasinan.

The literature search was conducted using a variety of academic databases, including Google Scholar, IEEE Xplore, and the Directory of Open Access Journals. Search terms included combinations of "Internet of Things Philippines," "smart agriculture Philippines," "smart aquaculture Philippines," "IoT environmental monitoring Philippines," "smart governance Philippines," and "IoT in developing countries." To ensure the contemporary relevance of the review, the search was primarily limited to research articles published between 2018 and 2025. News articles and general websites were excluded as primary references to maintain the academic rigor of the review.

The selection of articles for inclusion was based on their relevance to the research objectives. The abstracts and conclusions of the identified articles were first screened to determine their suitability. Full-text articles were then reviewed for in-depth analysis. The inclusion criteria prioritized peer-reviewed research papers that discussed the application, challenges, and impacts of IoT in sectors pertinent to Pangasinan's economy and development, such as agriculture, aquaculture, environmental management, and public administration.

The analysis of the selected literature was guided by a thematic framework. This involved identifying recurring concepts, technologies, and application areas across the different studies. These were then coded and categorized into distinct themes that form the structure of the Results and Discussion section. The main themes that emerged from the literature and were deemed most relevant to Pangasinan were: Smart Agriculture, Smart Aquaculture, Environmental Monitoring, and Smart Governance.

By synthesizing the findings from these thematic areas, this review constructs a comprehensive

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picture of the potential for IoT in Pangasinan. The discussion of each theme is grounded in the findings of the reviewed research, with logical inferences made to connect these broader findings to the specific conditions and needs of the province. This methodological approach allows for a robust and insightful analysis, despite the limited number of studies focusing directly on IoT in Pangasinan.

RESULTS AND DISCUSSION

The thematic analysis of the literature reveals several key areas where the Internet of Things (IoT) holds significant promise for the province of Pangasinan. While province-specific IoT research is sparse, the application of findings from national and regional studies to Pangasinan's socio-economic landscape provides a clear indication of potential pathways for development. The identified themes are Smart Agriculture, Smart Aquaculture, Environmental Monitoring, and Smart Governance.

Smart Agriculture: Cultivating a Data-Driven Future for Pangasinan's Farms

Pangasinan is one of the top agricultural provinces in the Philippines, with vast tracts of land dedicated to rice, corn, and high-value crops like mangoes. However, the agricultural sector faces numerous challenges, including the adverse effects of climate change, inefficient irrigation, pest infestations, and post-harvest losses. The literature strongly suggests that IoT-based smart agriculture can provide potent solutions to these issues.

Research on smart farming in the Philippines has highlighted the potential of IoT sensors for real-time monitoring of soil moisture, nutrient levels, and climatic conditions (Dela Cruz et al., 2021). For Pangasinan's farmers, this translates to the ability to make data-driven decisions on irrigation schedules, fertilizer application, and planting times. For instance, the deployment of soil moisture sensors can lead to significant water savings in a province that often experiences both drought and excessive rainfall. A study by Alipio et al. (2020) on an IoT-based irrigation system demonstrated the potential for optimizing water usage, a critical intervention for Pangasinan's rice paddies.

Pest and disease management is another area where IoT can be a game-changer. The use of IoT-enabled drones and image recognition technologies can facilitate the early detection of pest infestations and crop diseases, allowing for targeted interventions rather than broad-spectrum pesticide application (Gomez & Hernandez, 2022). This not only improves crop yields but also promotes more environmentally sustainable farming practices. For a province famed for its mangoes, which are susceptible to various pests and diseases, such technologies could be invaluable in protecting this high-value industry.

Furthermore, IoT can enhance supply chain management in the agricultural sector. The tracking of produce from farm to market using RFID and GPS technologies can reduce post-harvest losses, ensure food safety, and provide farmers with better access to markets (Reyes & Santos, 2021). In Pangasinan, where agricultural products are distributed to various parts of the country, an IoT-enabled logistics system could significantly improve efficiency and profitability for local farmers.

Smart Aquaculture: Enhancing the Productivity and Sustainability of Pangasinan's Waters

Pangasinan is renowned for its aquaculture, particularly the cultivation of bangus (milkfish) in coastal and inland fishponds. The industry, however, is vulnerable to environmental stressors such as water pollution, oxygen depletion, and harmful algal blooms. IoT offers a suite of tools to mitigate these risks and enhance the productivity and sustainability of aquaculture in the province.

The core of smart aquaculture lies in real-time water quality monitoring. Research has demonstrated the effectiveness of IoT-based systems that utilize sensors to continuously measure parameters like dissolved oxygen, pH, temperature, and ammonia levels (Yap et al., 2022). For the numerous fishponds in municipalities like Dagupan, Binmaley, and Bolinao, such systems can provide early warnings of deteriorating water conditions, allowing fish farmers to take corrective actions like activating aerators or adjusting feeding practices. This proactive approach can

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prevent mass fish kills, which have historically plagued the industry.

Automated feeding systems integrated with IoT are another promising application. These systems can dispense feed at optimal times and in precise quantities based on data on fish behavior and water conditions, reducing feed wastage and improving the feed conversion ratio (Salazar & Garcia, 2023). Given that feed constitutes a significant portion of operational costs in aquaculture, the potential for cost savings is substantial.

Moreover, IoT can aid in the traceability and quality assurance of aquacultural products. By tracking the conditions under which fish are raised and transported, producers can provide consumers with verifiable information about the quality and safety of their products. This can enhance the market value of Pangasinan's bangus and other seafood, both domestically and internationally.

Environmental Monitoring: Safeguarding Pangasinan's Natural Resources

The natural environment of Pangasinan, encompassing major river systems like the Agno River and a long coastline along the West Philippine Sea, is a vital asset that faces threats from pollution and climate change. IoT-based environmental monitoring systems can provide the data needed for effective resource management and disaster risk reduction.

Research on IoT for environmental applications in the Philippines has shown its utility in monitoring water quality in rivers and lakes (Corpuz & Reyes, 2021). Deploying a network of sensors along the Agno River and its tributaries could provide real-time data on pollutants from industrial, agricultural, and domestic sources. This information is crucial for environmental agencies to identify pollution hotspots, enforce regulations, and implement remediation measures.

In coastal areas, IoT sensors can monitor sea-level rise, coastal erosion, and the health of marine ecosystems like coral reefs and mangroves. For a province with a significant coastal population and a reliance on marine resources, this data is essential for developing climate change adaptation strategies and protecting coastal livelihoods. A study by Paringit et al. (2019) on coastal monitoring using remote sensing and in-situ sensors underscores the potential of such technologies for the Philippine setting.

IoT also plays a crucial role in early warning systems for natural disasters. The deployment of automated weather stations, rain gauges, and water level sensors in flood-prone areas of Pangasinan can provide timely alerts to communities at risk, enabling them to evacuate and take necessary precautions (Lagmay et al., 2020). This can significantly reduce the human and economic toll of typhoons and floods that frequent the region.

Smart Governance: Towards a More Responsive and Efficient Public Service

The principles of IoT can be extended to the realm of public administration to create a more responsive, efficient, and transparent government. For a province as large and populous as Pangasinan, smart governance initiatives can have a profound impact on the daily lives of its citizens.

The concept of a "smart city," or in this context, a "smart province," leverages IoT to improve various urban and rural services. While the Philippines is still in the early stages of smart city development, research has identified key areas for implementation (Serafica & De Vera, 2022). In Pangasinan, this could manifest in intelligent traffic management systems in urban centers like Dagupan and Urdaneta to alleviate congestion. Smart street lighting that adjusts to real-time conditions can lead to energy savings and enhanced public safety.

IoT can also improve the efficiency of public utilities. Smart meters for water and electricity can enable remote monitoring of consumption, reduce billing errors, and facilitate the early detection of leaks and outages. A study on the adoption of smart grid technologies in the Philippines points to the potential for improved energy efficiency and grid stability (Bautista & Del Mundo, 2021).

Furthermore, IoT can enhance the delivery of public health services. The use of wearable devices for remote patient monitoring, particularly for individuals with chronic illnesses or the elderly, can extend the reach of healthcare services to remote barangays in Pangasinan (Ramos & Gomez, 2022). During public

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health emergencies, IoT can aid in contact tracing and the monitoring of quarantine compliance.

The successful implementation of these IoT applications in Pangasinan is contingent on addressing several cross-cutting challenges identified in the literature. These include the need for robust and widespread internet connectivity, the high initial cost of investment in IoT infrastructure, the importance of data security and privacy, and the critical requirement for a skilled workforce capable of developing, deploying, and maintaining IoT systems (Department of Information and Communications Technology, 2018; GIZ, 2018). Addressing these challenges will require a multi-stakeholder approach involving the government, the private sector, academia, and civil society.

CONCLUSION AND RECOMMENDATION

This review of the potential for the Internet of Things (IoT) in Pangasinan, drawing upon a thematic analysis of relevant research in the Philippines and developing regions, illuminates a clear path toward a more connected and intelligent province. While direct, localized research is still in its infancy, the applicability of existing studies to Pangasinan's key sectors is undeniable. The findings indicate that IoT is not merely a technological novelty but a powerful enabler of sustainable development, with the potential to address some of the most pressing challenges faced by the province. The most promising and impactful applications are situated in smart agriculture and smart aquaculture, the twin pillars of Pangasinan's economy. The ability of IoT to optimize resource use, mitigate environmental risks, and enhance productivity in these sectors can lead to significant economic gains and improved livelihoods. Furthermore, the potential of IoT in environmental monitoring and smart governance points to a future where natural resources are better protected and public services are more efficient and responsive to the needs of the citizenry.

However, the journey toward a "Smarter Pangasinan" is not without its obstacles. The successful adoption of IoT is contingent upon the availability of reliable and affordable internet connectivity across the province, the willingness of stakeholders to invest in new technologies, and the assurance of data privacy and security. Perhaps the most critical success factor is the development of human capital. Without a skilled workforce to innovate, implement, and manage IoT solutions, the potential of this technology will remain unrealized.

Based on the findings of this review, the following recommendations are proposed:

For the Provincial Government of Pangasinan:

1. **Develop a Provincial IoT Roadmap:** In alignment with the national strategy, the provincial government should formulate a localized IoT roadmap that identifies priority areas for implementation, sets clear targets, and allocates necessary resources.
2. **Invest in Pilot Projects:** To demonstrate the value and viability of IoT, the government should initiate and fund pilot projects in high-impact areas, particularly in smart agriculture and aquaculture. These projects can serve as learning laboratories and showcases for wider adoption.
3. **Foster Public-Private Partnerships:** The government should actively seek partnerships with technology companies, research institutions, and private sector stakeholders to facilitate technology transfer, share costs, and leverage expertise.

For Academic Institutions in Pangasinan:

1. **Integrate IoT into Curricula:** Universities and colleges in the province should incorporate IoT concepts and skills into their engineering, information technology, and agriculture programs to build a future-ready workforce.
2. **Establish IoT Research and Development Centers:** Academic institutions can serve as hubs for research and innovation in IoT, developing solutions that are tailored to the specific needs and context of Pangasinan.
3. **Promote Extension Services:** Universities can play a crucial role in disseminating knowledge and providing technical assistance to farmers, fisherfolk, and local government units on the adoption of IoT technologies.

For Future Research:

1. **Conduct Baseline Studies:** There is a pressing need for empirical research to establish baseline data on the current state of digitalization and IoT readiness in Pangasinan's key sectors.
2. **Undertake Feasibility Studies:** In-depth feasibility studies are required to assess the economic, technical, and social viability of specific IoT applications in the province.
3. **Analyze Policy and Governance:** Research is needed to explore the policy and regulatory frameworks required to support the growth of IoT in Pangasinan, including data privacy, cybersecurity, and spectrum management.

1. In conclusion, the Internet of Things offers a transformative opportunity for Pangasinan. By taking a strategic, collaborative, and evidence-based approach, the province can harness the power of IoT to build a more prosperous, sustainable, and resilient future for all its people.

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