ASIAN JOURNAL OF VOCATIONAL EDUCATION AND HUMANITIES VOL. 6 NO. 1 (2025) 21–27

AJVAH
e-ISSN: 2735-1165
DOI: https://doi.org/10.53797/ajvah.v6i1.3.2025

Smart Flood Warning System with ESP32-Based IoT Control

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Received 20 May 2025; Accepted 15 June 2025; Available online 21 June 2025

Abstract: This study details the development of an Internet of Things (IoT)-based egg incubator designed to automate the control and monitoring of temperature and humidity, addressing the inefficiencies of traditional hatching methods. The primary aim was to design and build a cost-effective and user-friendly incubator prototype for small-scale poultry farming, capable of maintaining stable environmental conditions to improve hatching success rates. The methodology involved a product development approach, starting with the design of an electronic system using an ESP32 microcontroller and a DHT22 sensor, and constructing a physical prototype. The system's functionality was tested over a 21-day incubation period with 10 chicken eggs, and its usability was evaluated through a survey of 11 poultry farmers. The findings demonstrated that the system effectively maintained temperatures between 37.1°C and 37.7°C and humidity between 41% and 73%, resulting in three successful hatches. User feedback was positive, with 72.7% of farmers expressing interest in the system, though 100% indicated a need for training. In conclusion, the project successfully produced a functional IoT incubator that meets the technical requirements for egg incubation and shows strong potential for adoption by its target users. Further enhancements are recommended, such as incorporating alternative power supplies and developing advanced automation features.

Keywords: Flood, Early Warning System, IoT, ESP32, Smart Community, Water Sensor

1. Introduction

Flooding is among the most frequent natural disasters in Malaysia, particularly affecting the eastern coastal states such as Kelantan, Terengganu, and Pahang. Contributing factors include heavy rainfall, river overflow, and inefficient drainage systems, all of which exacerbate flood occurrences, resulting in property damage and loss of life. Flash floods—such as the one that occurred in August 2021—highlight the critical need for a responsive and reliable early warning system. The Internet of Things (IoT) technology has shown significant potential in addressing this issue. Through the integration of smart sensors and real-time data processing, IoT-based systems can deliver early warnings to communities more effectively and inclusively (Ou et al., 2025; Raman & Iqbal, 2024).

The existing flood warning systems in Malaysia, managed by agencies such as the Department of Irrigation and Drainage (DID), are characterized by high implementation costs and limited coverage. Most of these systems rely on substantial government investment and conventional communication channels such as radio broadcasts or public announcements, which are often inadequate for low-income or rural communities. Previous studies, such as the project by Hadi et al. (2020), have demonstrated the successful use of ultrasonic sensors and IoT communication for early warning systems. Similarly, the system developed by Zainal & Po'ad (2024) for road water level detection achieved an accuracy rate of 96.65% using ultrasonic sensors. However, most of these systems remain centralized and are intended for use by public authorities rather than at the domestic level. What remains lacking is a smart flood warning system that is affordable, easily deployable, and tailored for individual households or small communities. Such a system should offer real-time alerts via mobile applications, be responsive, and feature a user-friendly interface. At present, existing solutions are predominantly large-scale systems or pilot projects, with minimal focus on functionality for small-scale community use. Systems like GridStix in the UK also emphasize edge processing capabilities, yet they have not been applied in domestic contexts in Malaysia. This study addresses this research gap by developing a low-cost, domestic IoT-based flood early warning system utilizing ultrasonic sensors and microcontrollers. The system is designed to send real-time notifications via a mobile application and provide visual alerts through an LED display. This innovation responds to the

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need for small-scale, affordable, and community-friendly flood detection solutions, as highlighted in recent works (Dong et al., 2021a; Zakaria et al., 2023). The proposed system leverages the ESP32 microcontroller and ultrasonic sensors to deliver timely flood alerts through a user-accessible and cost-effective platform.

Flooding in low-lying areas and regions with poor drainage infrastructure poses a serious threat to the safety and property of residents. The absence of easily accessible domestic flood detection devices hinders communities from making timely preparations. Existing warning systems are often expensive, complex, and lack direct communication channels with end users. Delayed communication of flood information can prevent timely evacuation, endangering lives and increasing flood-related losses. Moreover, unpredictable weather patterns caused by climate change complicate flood forecasting when using traditional methods. The lack of community-focused approaches—particularly for small communities and households—further limits the reach and effectiveness of current flood warning technologies. Research has highlighted the need for smart systems that are modular, adaptive, and tailored to the needs of small communities (Knight, 2025).This project aims to develop and evaluate a smart flood early warning system based on IoT technology. The main objectives of this study are to develop an IoT- and ESP32-based smart flood warning system capable of detecting water levels in real time and to evaluate the system's performance in terms of accuracy, efficiency of information transmission, and user functionality through flood simulation.

2. Methodology

This study employed an experimental research design, encompassing the development of a prototype and the functional evaluation of a Smart Flood Warning System. The research was conducted in several phases, beginning with initial planning, system development, technical testing, and concluding with user feedback collection to assess the effectiveness and usability of the developed system. Feedback was obtained from 10 respondents who are technology specialists in the electrical field, each with over 10 years of industry experience. In the preliminary stage, the researchers designed an initial system sketch to represent the core concept and basic functions. This sketch served as a technical communication tool and helped identify early constraints and design requirements that needed refinement prior to full-scale development.

Subsequently, the selection of systems and components was guided by a review of previous literature and consideration of current technological suitability. Based on this analysis, the ESP32 microcontroller was chosen due to its ability to connect to Wi-Fi networks and transmit real-time data to mobile applications such as Telegram. The system was further integrated with components including a float switch water level sensor, alarm buzzer, solar power panel, and protective equipment such as a waterproof enclosure and PVC piping. Component selection was justified by cost-effectiveness and suitability for operation in outdoor environments that are humid and exposed to weather conditions. The system development process was carried out in stages, involving technical activities such as cutting and assembling pipes, arranging components within the junction box, electrical wiring, applying protective paint, and programming the ESP32 microcontroller. Once the system was fully assembled and programmed, it underwent two main phases of testing: electrical testing and functional testing.

Electrical testing was conducted to ensure the overall safety and operability of the system, covering three main aspects: (i) continuity testing – to verify that all cable connections were intact and capable of transmitting current properly, (ii) insulation testing – to confirm there were no current leakages that could endanger users, and (iii) polarity testing – to ensure all terminal connections were made with the correct polarity. Once the system passed the electrical tests, it underwent functional testing to evaluate the accuracy of water level detection and the effectiveness of flood alerts. In addition to technical testing, this study also assessed user perceptions through questionnaires distributed to residents in flood-prone areas. Data collected from the questionnaires were used to evaluate the system's functionality, ease of use, and overall effectiveness from the perspective of end users. These findings also contributed to identifying areas for improvement to enhance the system's suitability for real-world deployment. The entire project implementation was organized systematically using a Gantt chart, which scheduled activities by week and month. This planning tool ensured that each task was completed on time, minimized delays, and maintained continuity in the system development process. The system was also tested for environmental durability and energy efficiency, in alignment with global recommendations for sustainable technology (Chen et al., 2023, Wiley). The schematic circuit of the project is shown in Figure 1, and the wiring circuit of the project is shown in Figure 2.

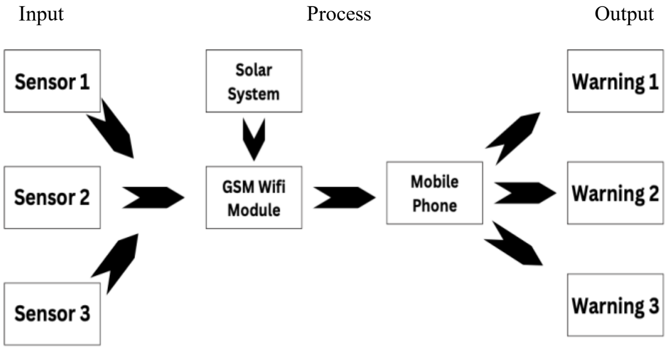

Figure 1. Schematic Circuit of the Smart Flood Warning System

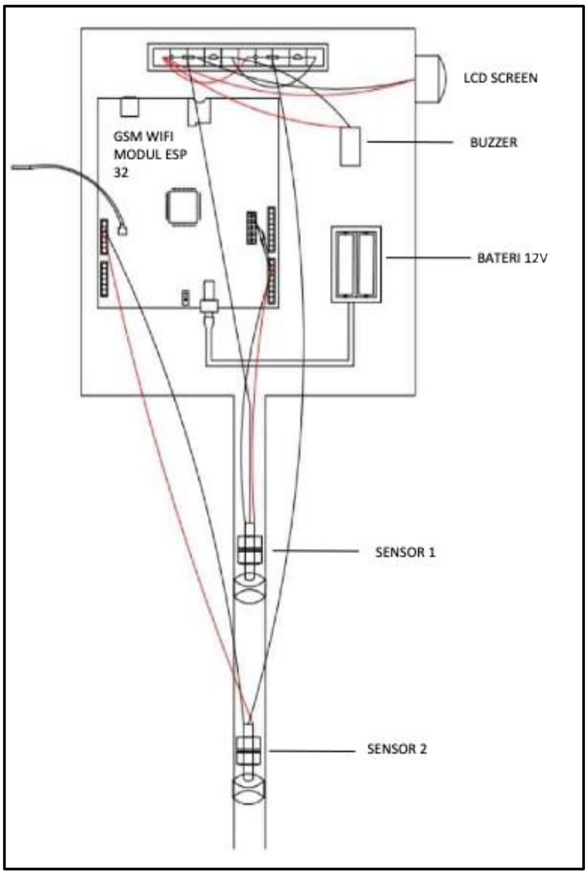

Figure 2. Project Wiring Circuit Diagram

3. Findings and Discussion

3.1 Electrical Safety and System Durability

The successful validation of the system's electrical safety and durability represents a cornerstone of this study's findings, forming the bedrock upon which its functional capabilities are built. Technical testing of the prototype yielded a continuity resistance of 0.5Ω and an insulation resistance of 1.2MΩ. These figures, while technical, are profoundly significant. The low continuity resistance, verified through specific testing procedures, provides critical assurance that all internal wiring and connections are sound, allowing electrical current to flow as intended without impediment. Conversely, the high insulation resistance of 1.2MΩ demonstrates that the system is exceptionally well-protected against current leakages. This is not a trivial matter; the system is expressly designed for deployment in challenging outdoor environments that are inherently humid and exposed to adverse weather conditions (Kiel et al., 2016; Pisano, 2019). An electrical leakage in such a setting could not only cause the device to fail during a critical flood event but could also pose a significant electrocution risk to users (Iwamoto & Krishnamoorthy, 2009; Möller et al., 2023). Therefore, these successful tests confirm the system's fundamental safety and operational integrity under its intended real-world conditions.

This finding correlates powerfully with the conclusions of existing research. For instance, Bukhari et al. (2025) and Jerrin Simla et al.(2024) emphasized that the long-term effectiveness of any IoT-based flood monitoring system is inextricably linked to its physical robustness, specifically requiring it to be waterproof and well-protected. The meticulous design choices made in this project—such as the use of a waterproof enclosure, protective PVC piping, and the application of protective paint —were deliberate measures to meet this very standard. The positive results of the electrical tests serve as empirical validation that these design choices were effective. The interpretation of this finding is that the prototype is more than just a proof-of-concept; it is a viable, robust, and safe apparatus ready for real-world application. It successfully navigates the critical challenge of creating a durable piece of hardware, a prerequisite for any meaningful community deployment, especially considering the project's goal to provide a sustainable solution for at-risk populations. This demonstrated durability, achieved within a low-cost framework, is a vital achievement that underpins the reliability of the entire system.

3.2 System Functionality and User Feedback

A pivotal and nuanced finding emerged from the user-centric evaluation of the system, revealing a clear distinction between its technical performance and its aesthetic reception. Interview responses from 10 experienced technology specialists in the electrical field revealed unanimous agreement on the system's core functionality. All respondents affirmed that the system operated effectively, particularly in detecting rising water levels in real-time and delivering timely alerts via a mobile application. One respondent stated, "From a technical standpoint, the system performs exactly as expected—it's reliable, and the alerts are prompt, which is essential for any flood warning mechanism." Another added, "The integration of IoT with ESP32 is well-executed, and the system meets the real-time communication needs that many larger systems overlook." . It successfully provides a direct communication channel to end-users, overcoming the limitations of existing systems that are often complex and lack such directness (Ciancia, 2013).

However, when discussing the system's physical design, feedback was more divided. Only five out of the ten respondents expressed satisfaction with its appearance and form. One noted, "While it works well, the external casing looks bulky and not very user-friendly for household settings." Another echoed this sentiment: "If we want people in rural or residential areas to adopt it, the design must be more compact and visually appealing."

This contrast highlights a critical issue: while the system fulfills its technical goals, its visual and physical design may hinder broader community adoption. As this project aims to empower individual households and small communities—beyond centralized government systems—its success will depend not just on functional excellence but also on user acceptance of its overall design.

In such a domestic context, aesthetics and user-friendliness are not secondary concerns; they are integral to the user's willingness to install and trust the device (Gulati et al., 2018; Harris et al., 2016). This finding aligns with broader discussions in technology implementation, where reports from bodies like Khare & Dhar (2021) & Mustafa et al. (2025) have consistently recommended that improving the user interface and physical design is essential for user engagement and adoption. The interpretation of this result is therefore twofold. First, it serves as a powerful validation of the system's underlying technology and its ability to solve the core problem. Second, it provides invaluable, actionable feedback: the prototype, while technically sound, must undergo a phase of user-centered design refinement to improve its physical form factor. To be truly "user-friendly", the system must not only work perfectly but also integrate seamlessly and appealingly into the community it is designed to protect.

3.3 Sensor Accuracy and Real-Time Response

The performance of the Smart Flood Warning System in terms of its accuracy and response speed constitutes a critical success, directly addressing the life-threatening issue of delayed flood warnings. Technical testing demonstrated that the system delivers notifications to the user's mobile application in less than 10 seconds and operates with a water level detection accuracy rate of 85–95%. The sub-10-second notification time is particularly significant. In the context of flash floods, which can occur with startling rapidity, this near-instantaneous alert can be the deciding factor that allows a family to evacuate safely. The system effectively mitigates the danger of "delayed communication of flood information," which has been identified as a major contributor to flood-related losses and fatalities. This rapid, direct-to-user communication channel stands in sharp contrast to more conventional and slower methods like public announcements (Geddes et al., 2025).

When benchmarked against other technologies, the system's performance is highly competitive. For example, its accuracy is comparable to a similar system for road water level detection that achieved 93.29% accuracy (Tambun et al., 2024). Furthermore, when compared to a highly advanced, hybrid deep learning model developed for predictive flood warning that achieved 97.8% accuracy (Dong et al., 2021b), this project's 85-95% accuracy is remarkable. The interpretation of this comparison is crucial: this project did not aim to create a complex, computationally intensive AI forecasting model. Instead, its objective was to develop a low-cost, affordable, and easily deployable system for domestic use. The system's architecture, built upon an affordable ESP32 microcontroller and ultrasonic sensors was estimated to cost only RM279.90. To achieve an accuracy rate that approaches that of a sophisticated deep learning model, but with accessible and inexpensive hardware, represents a triumphant trade-off between cost, complexity, and performance (Kim et al., 2022). This result validates the central hypothesis of the study: that an effective, reliable, and responsive early warning system can be made accessible to small communities and individual households, filling a critical gap not currently served by expensive, large-scale, centralized systems.

3.4 Sustainability and Environmental Friendliness

A key dimension of the project's success lies in its commitment to sustainability, a principle strongly validated by both the system's design and its reception by the target community. A significant 80% of respondents from user questionnaires expressed support for the use of solar energy to power the device. This high level of user endorsement confirms that sustainability is a valued feature and aligns perfectly with the project's goal of creating a sustainable, long-term solution for community-based early warning (Henao Salgado et al., 2025). This preference was anticipated in the design phase, which is why the integration of a solar power panel was a core part of the system's component list, alongside the ESP32 and sensors. The project methodology explicitly included an evaluation of the system's environmental friendliness and energy efficiency, underscoring its importance from the outset.

The practical implications of a solar-powered design are profound. Flood events are frequently accompanied by severe weather that can disrupt electrical grids, rendering any warning system dependent on mains power useless at the most critical moment (Lee et al., 2023). By incorporating solar power, the system achieves energy autonomy, ensuring it can remain operational during power outages and continue to protect residents. This is especially vital for the intended users in rural or low-income communities, which may have less reliable power infrastructure to begin with. This design choice also correlates with a larger, global trend in IoT development that emphasizes energy-efficient and sustainable systems, as highlighted in studies on rural LoRaWAN implementations by (Jabbar et al., 2024). The interpretation of this finding is that the use of solar power is not merely an environmental benefit; it is a strategic necessity that enhances the system's resilience, reliability, and user acceptance. It makes the system a self-sufficient and cost-effective tool that empowers communities without adding to their utility expenses or relying on fragile external infrastructure, thereby cementing its potential as a truly sustainable and community-friendly disaster risk reduction solution.

3.5 Design and Integration Challenges

While the project was successful in its primary technical objectives, the findings also brought to light significant challenges related to design and community integration, which are critical for the system's long-term impact. The user feedback indicating that the system's design needs improvement to enhance user engagement is a crucial finding. This points to the challenge of moving beyond a functional prototype to create a solution that users will readily adopt, trust, and integrate into their domestic environment. The problem statement itself highlights the need for community-focused approaches, and this finding reveals that "community-focused" must encompass aesthetics and usability, not just functionality (Knight, 2025). The current system, while technically proficient, risks being perceived as an alien piece of industrial equipment rather than a helpful home device, which could hinder its voluntary adoption by individual households.

This challenge is deeply rooted in the broader academic and practical discourse on disaster technology. Research from Hadi et al. (2020) supports the idea that for a warning system to be truly effective, it must be interactive and adaptable to its specific local context. A one-size-fits-all approach is insufficient. The system cannot simply be technically accurate; it must be socially integrated. Shafique et al.'s work on integrating IoT for disaster resilience emphasizes that technology is just one component of a larger socio-technical framework. Similarly, the mention of systems like GridStix in the UK, which have not been applied in a Malaysian domestic context, highlights the importance of cultural and contextual adaptation. The core interpretation of this challenge is that technical success is a necessary, but not sufficient, condition for mission success. The project has successfully addressed the *technological* gap for a low-cost domestic system; it must now address the *human-factor* gap. The path forward, as suggested by the study's conclusion, requires a shift in methodology toward more participatory and human-centered design, ensuring the system is not just deployed in a community, but is developed with it. This will be key to realizing the full potential of this promising technology.

4. Conclusion

This project successfully developed a cost-effective, user-friendly, and efficient smart flood warning system capable of delivering real-time information to communities. It addresses a research gap in small-scale domestic systems and contributes meaningfully to disaster risk reduction efforts. Future studies are recommended to explore the integration of artificial intelligence (AI) for flood forecasting analysis and to expand the system’s implementation in high-risk rural areas.

Acknowledgement

The authors would like to express their gratitude to the Vocational College Sungai Buloh for their support in providing both facilities and financial assistance for this research.

Conflict of Interest

The authors declare no conflicts of interest.

References

Bukhari, S. A. S., Shafi, I., Ahmad, J., Villar, S. G., Villena, E. G., Khurshaid, T., & Ashraf, I. (2025). Review of flood monitoring and prevention approaches: a data analytic perspective. *Natural Hazards*, *121*(5), 5103–5128. https://doi.org/10.1007/s11069-024-07050-w

Ciancia, M. (2013). Transmedia phenomena: New practices in participatory and experiential content production. *Proceedings of the 11th European Conference on Interactive Tv and Video Euroitv 2013*, 41–44. https://doi.org/10.1145/2465958.2465962

Dong, S., Yu, T., Farahmand, H., & Mostafavi, A. (2021a). A hybrid deep learning model for predictive flood warning and situation awareness using channel network sensors data. *Computer-Aided Civil and Infrastructure Engineering*, *36*(4), 402–420. https://doi.org/10.1111/MICE.12629

Dong, S., Yu, T., Farahmand, H., & Mostafavi, A. (2021b). A hybrid deep learning model for predictive flood warning and situation awareness using channel network sensors data. *Computer Aided Civil and Infrastructure Engineering*, *36*(4), 402–420. https://doi.org/10.1111/mice.12629

Geddes, A., Black, A. R., & Cranston, M. (2025). Integrating direct messaging with flood alerts and warnings: Insights into effectiveness from a registered public user population. *Journal of Flood Risk Management*, *18*(1). https://doi.org/10.1111/jfr3.12972

Gulati, S., Sousa, S., & Lamas, D. (2018). Modelling trust in human-like technologies. *ACM International Conference Proceeding Series*, 1–10. https://doi.org/10.1145/3297121.3297124

Hadi, M. I., Yakub, F., Fakhrurradzi, A., Hui, C. X., Najiha, A., Fakharulrazi, N. A., Harun, A. N., Rahim, Z. A., & Azizan, A. (2020). Designing Early Warning Flood Detection and Monitoring System via IoT. *IOP Conference Series: Earth and Environmental Science*, *479*(1), 012016. https://doi.org/10.1088/1755-1315/479/1/012016

Harris, M. A., Brookshire, R., & Chin, A. G. (2016). Identifying factors influencing consumers' intent to install mobile applications. *International Journal of Information Management*, *36*(3), 441–450. https://doi.org/10.1016/j.ijinfomgt.2016.02.004

Henao Salgado, M. J., Alfonso, L., & Vélez Upegui, J. J. (2025). Towards integrating community and institutional flood early warning systems: A framework applied to an Andean tropical case. *International Journal of Disaster Risk Reduction*, *116*. https://doi.org/10.1016/j.ijdrr.2024.105126

Iwamoto, N., & Krishnamoorthy, A. (2009). Understanding leakage current susceptibility in dielectrics using molecular modeling. *2009 10th International Conference on Thermal Mechanical and Multi Physics Simulation and Experiments in Microelectronics and Microsystems Eurosime 2009*. https://doi.org/10.1109/ESIME.2009.4938437

Jabbar, W. A., Mei Ting, T., I. Hamidun, M. F., Che Kamarudin, A. H., Wu, W., Sultan, J., Alsewari, A. A., & Ali, M. A. H. (2024). Development of LoRaWAN-based IoT system for water quality monitoring in rural areas. *Expert Systems with Applications*, *242*. https://doi.org/10.1016/j.eswa.2023.122862

Jerrin Simla, A., Aranganathan, A., Vedanarayanan, V., Gomathi, T., Sivasundarapandian, S., & Sakthi Prabha, R. (2024). Integrating IoT for Enhanced Flood Monitoring: A Raspberry Pi Pico-based System with Real-time Data Visualization and Early Warning Alerts. *Proceedings of the 2024 International Conference on Innovative Computing Intelligent Communication and Smart Electrical Systems Icses 2024*. https://doi.org/10.1109/ICSES63760.2024.10910728

Khare, A., & Dhar, D. (2021). Affecting Technology Consumption—Role of Designers in Ushering Behaviour Change. In *Smart Innovation Systems and Technologies* (Vol. 221). https://doi.org/10.1007/978-981-16-0041-8_43

Kiel, J., Petiet, P., Nieuwenhuis, A., Peters, T., & Van Ruiten, K. (2016). A Decision Support System for the Resilience of Critical Transport Infrastructure to Extreme Weather Events. *Transportation Research Procedia*, *14*, 68–77. https://doi.org/10.1016/j.trpro.2016.05.042

Kim, H.-N., Eun, H., Choi, J. H., & Kim, J.-H. (2022). SQNR-based Layer-wise Mixed-Precision Schemes with Computational Complexity Consideration. *Proceedings IEEE International Symposium on Circuits and Systems*, *2022-May*, 234–235. https://doi.org/10.1109/ISCAS48785.2022.9937948

Knight, A. (2025). COMMUNITY-LED DESIGN: Building Frameworks for Equity and Justice. In *Designing for Social Justice Community Engaged Approaches in Technical and Professional Communication*. https://doi.org/10.4324/9781003469995-3

Lee, S., Choi, J., Jung, G., Tabassum, A., Stenvig, N., & Chinthavali, S. (2023). Predicting Power Outage During Extreme Weather Events with EAGLE-I and NWS Datasets. *Proceedings 2023 IEEE 24th International Conference on Information Reuse and Integration for Data Science Iri 2023*, 211–212. https://doi.org/10.1109/IRI58017.2023.00042

Möller, F., Blanco, A. M., & Meyer, J. (2023). Characteristic leakage current of household devices and their impact on the tripping behaviour of residual current devices. *Electric Power Systems Research*, *214*. https://doi.org/10.1016/j.epsr.2022.108832

Mustafa, H. M., Alsbaihi, O., Jahameh, S., Sayed, A., & Othman, M. (2025). User interface, usability, and user experience: A bibliometric mapping for previous research and future research insight. *Information Design Journal*. https://doi.org/10.1075/idj.24006.mus

Ou, T.-H., Yang, T.-H., & Chang, P.-Z. (2025). Combination of Large Language Models and Portable Flood Sensors for Community Flood Response: A Preliminary Study. *Water Switzerland*, *17*(7). https://doi.org/10.3390/w17071055

Pisano, P. (2019). Are your roads weather savvy? *Public Roads*, *83*(1).

Raman, R., & Iqbal, S. M. U. (2024). IoT-based Flood Early Warning System for Effective Disaster Management. *International Conference on E Mobility Power Control and Smart Systems Futuristic Technologies for Sustainable Solutions Icemps 2024*. https://doi.org/10.1109/ICEMPS60684.2024.10559355

Tambun, I. P. T., Bumi, N. P., Ishak, Q. S., Paramesti, S. T., Pramudita, A. A., & Aziz, A. A. (2024). Water Levels Changes Detection Using Millimeter Wave FMCW Radar. *2nd International Symposium on Information Technology and Digital Innovation Creative Trends in Sustainable Information Technology Design and Innovation Isitdi 2024*, 5–10. https://doi.org/10.1109/ISITDI62380.2024.10795903

Zainal, Z. A., & Po'ad, F. A. (2024). Smart Flood Monitoring System via IoT Platform for Early Warning of Road Closures Against Flood Events. *Evolution in Electrical and Electronic Engineering*, *5*(1), 389–396. https://penerbit.uthm.edu.my/periodicals/index.php/eeee/article/view/15334

Zakaria, M. I., Jabbar, W. A., & Sulaiman, N. (2023). Development of a smart sensing unit for LoRaWAN-based IoT flood monitoring and warning system in catchment areas. *Internet of Things and Cyber-Physical Systems*, *3*, 249–261. https://doi.org/10.1016/J.IOTCPS.2023.04.005