TRANSFORMING RURAL AGRICULTURE USING INTERNET OF THINGS TECHNOLOGY SOLUTIONS FOR EFFICIENT AGRICULTURAL MANAGEMENT: SOME CASES FROM INDIA

Abstract

The article encapsulates the transformative impact of IoT technology on agriculture and economic development in rural areas, particularly in India. IoT solutions have emerged as a game-changer in the agricultural sector, revolutionizing traditional farming practices and driving efficiency. By integrating IoT devices and sensors into agricultural operations, farmers can gather real-time data on various factors like soil moisture, weather conditions, and crop health. This data enables informed decision-making and precise resource management, leading to enhanced productivity and sustainable farming practices. The inclusion of "Some Examples from India" emphasizes the practical implementation of IoT solutions in the Indian agricultural context, showcasing the success stories and highlighting the potential for widespread adoption in similar rural settings.This paper will delve into each of these IoT applications, offering insights into their implementation, benefits, and the potential they hold for shaping India's future across these critical sectors. Through a comprehensive exploration of these innovations, we aim to shed light on how IoT technology is revolutionizing India's approach to key challenges, ultimately contributing to the nation's growth, development, and overall well-being.

Keyword: Internet of Things, Agriculture, Rural Development, Healthcare, case studies

Authors

Dr. Sudhakar Madhavedi
Associate Professor & Head
Department of Business Management
Kshatriya College of Engineering
Armoor, Telangana India
reachfirst@gmail.com

Prof. (Dr.) R. K. Pandey
Managing Director
RDG Info Services
Lucknow, Uttar Pradesh, India

I. INTRODUCTION

The Internet of Things (IoT) has emerged as a transformative force, redefining how we interact with and leverage technology to tackle complex challenges. Its global impact spans various sectors, but within India, it has proven to be a potent catalyst for addressing critical issues in agriculture, healthcare, transportation, and beyond. India's diverse landscape, encompassing a burgeoning population, rapidly urbanizing cities, and vast rural expanses, provides a fertile ground for IoT to flourish and contribute significantly to sectors underpinning the nation's progress (Hafeez et.al, 2022). IoT technology has seamlessly connected devices, sensors, and systems through the internet, enabling real-time data collection, analysis, and decision-making, transcending traditional industry boundaries and opening new frontiers for innovation (Yadav et.al, 2018).

Remarkable applications of IoT technology in India have illuminated its invaluable role in tackling the country's most pressing challenges. IoT has empowered farmers with precise insights into soil health, weather patterns, and crop conditions, allowing them to optimize resource usage, reduce wastage, and boost yields in the agriculture sector. From precision farming techniques to smart irrigation systems, IoT is revolutionizing how Indian farmers cultivate and manage their crops. In healthcare, especially in bridging the urban-rural healthcare gap, IoT-based telemedicine and diagnostic technologies have emerged as lifelines (Holtschulte, 2022). These innovations connect patients in remote locations with specialist care, potentially saving countless lives (Gupta et.al 2020). Additionally, IoT's influence extends to transportation, addressing road safety and vehicle monitoring concerns, while in public utilities; it plays a pivotal role in resource optimization. Embracing IoT positions India to bolster agricultural productivity, improve healthcare access, enhance road safety, conserve vital resources, and pave the way for a more sustainable and technologically empowered future (Shruthi et.al, 2019).

II. METHODOLOGY

In conducting this research, a multifaceted methodology was employed to gather a rich array of data sources that would provide comprehensive insights into the impact and applications of IoT technology in India. The primary sources of data collection encompassed secondary data derived from reputable academic journals, industry-focused magazines, and reports. This secondary data was meticulously selected based on its relevance and credibility, ensuring that it formed a solid foundation for the research.Complementing the academic and industry-centric data, news clippings sourced from newspapers were scrutinized. This approach allowed for real-time updates and a dynamic perspective on IoT solutions in India, with data collection spanning from January to June 2023.

In addition to written sources, data was also gathered from exhibitions and industry events. These served as invaluable platforms for accessing firsthand information about emerging technologies, innovative IoT solutions, and industry trends. Furthermore, to gain a comprehensive understanding of the IoT landscape in India, a nationwide search for IoT solutions was conducted. This involved mining reports, government publications, and industry databases to identify and analyze IoT initiatives implemented on a national scale. The data collected from these diverse sources was subjected to meticulous analysis. Through a rigorous process, approximately 40 cases were initially gathered, representing a broad

spectrum of IoT solutions. These cases spanned agriculture, rural development, healthcare, and public utilities, reflecting the multifaceted applications of IoT in India.However, to present the most relevant and impactful findings, a stringent filtering process were employed. This involved a thorough evaluation of each case's significance and effectiveness in showcasing the potential and practicality of IoT solutions. Consequently, only the most pertinent cases were selected for inclusion in this research paper, ensuring that each case study offered valuable insights.

III. DATA ANALYSIS

The entirety of the collected data underwent a comprehensive analysis process and is presented in the form of compelling case studies.Each case was meticulously assessed for its relevance and ability to exemplify the practicality and potential of IoT solutions in India. Consequently, only the most significant cases were chosen for inclusion in this research and presented as follows

Case 1: IoT-Based Foot Mouth Disease Detection in Indian Cattle: A Breakthrough in Veterinary Science [Dutta et.al, 2022; Chatterjee et.al 2022;Kumari&Yadav, 2018;Rajendran, 2023;Vyas et.al, 2019]

In India, Foot Mouth Disease (FMD) and Mastitis are highly prevalent in domestic cattle, which can affect the health of cows or buffalos and cause fever and blisters that develop within weeks. FMD is a contagious viral disease, and Mastitis is a bacterial disease. These diseases result in an extreme reduction in milk yield and quality and can also cause infertility in cows, resulting in economic losses for farmers. According to the Indian Council for Agriculture Research, it is estimated that Rs. 1670 crore worth of milk is lost due to reduced yield caused by Mastitis. The disease can be detected at an early stage through cattle behavior. This process is simplified by using IoT technology, through which diseases can be easily identified. Rumination sensors, temperature sensors, and motion sensors are required, and these sensors are to be mounted on cows, with receivers also placed in suitable locations. Any abnormal behavior, such as a rise in temperature, decreased rumination, or abnormal movements, is tracked by sensors and sent to a Raspberry Pi processor before being sent to the cloud with the help of wireless LAN or Bluetooth. The data is then utilized to screen the diseased cow using ANN. By using IoT, the symptoms can be detected within 3 to 4 days, compared to 7 days when detected manually. Veterinary support is provided in time, and cattle health is preserved before the symptoms worsen. This is a breakthrough in the field of veterinary science, through which cattle disease identification and treatment is possible in a short time. This invention could be a commercial benefit to commercial dairy farming and marginal farmers.

Case 2: Saving Lives on Indian Roads: Real-Time Drowsiness Detection of Vehicle Drivers Using IoT [**Thulasimani**&Prithashasni, 2021;Pandey&Muppalaneni, 2021;Mittal et.al, 2016;Suryawanshi&Agrawal, 2020; Biswal et.al, 2021]

Indian roads are characterized by heavy traffic and congested roads, and road accidents are all too common, often resulting in the loss of precious lives. According to Indian government statistics, out of a total of 3,66,138 accidents in 2019-20, around 33% were fatal accidents that killed 131,714 people. Most commercial vehicles and passenger cars

cause accidents due to reckless driving that violates traffic rules, poor consciousness due to alcohol and drug consumption, drowsiness induced by fatigue, and early morning sleepiness. In this context, a valuable invention has emerged in the field of IoT that sends an alert to the driver and vehicle owners when the driver is in a state of drowsiness while the vehicle is moving out of the driver's control. The device requires a Pi Camera module, Raspberry Pi3 Model B Module, Speaker, Crash sensor, Force Sensitive resistor, and GPS module. The Pi camera module, connected to the Raspberry Pi3 model B Module, records the driver's facial movements continuously and processes them with the help of the controller's operating system. This IoT-based wireless sensor and GPS tracker will detect driver drowsiness and immediately send alerts to the driver and vehicle owners to prevent fatal accidents.

The researchers have clearly distinguished between drowsy and non-drowsy faces. Even in the event of an accident caused by drivers ignoring the alert, the GPS will locate the vehicle and the collision sensors will transmit the severity of the impact for immediate rescue and medical attention. The novelty of this device is that it is commercially feasible to install it in all types of light and heavy vehicles, which can prevent accidents and save thousands of lives. (Anil Kumar Biswal et.al)

Case 3: IoT-Based Highway and High Mast Lighting System: Minimizing Operational Losses and Conserving Resources[Solanki et.al, 2017; Manyake & Mathaba, 2022; Gowda et.al, 2023.]

Public authorities in India spend crores of funds on lighting and water supply in municipalities and panchayaths. However, the operational losses are heavy and challenging in Indian electricity distribution. These losses occur due to operational inefficiencies, staff negligence, and lack of supervision. It is estimated that a total of 20% is lost due to distribution inefficiencies at the grassroots level. Similarly, water is a precious resource that needs to be used judiciously to reduce excess usage, especially in cities where water is extremely scarce. To address these issues, researchers at Anna University have developed a conceptual framework to minimize electricity and water losses using IoT technology. They identified that in Lucknow city, electric lights are often left on unnecessarily due to the negligence of officials. To address this, an Advanced Highway and High Mast Lighting system was developed, which includes weather forecasting and traffic density. A LabVIEW platform is installed on a computer to control the lighting at the base station as per the requirement.

Onsite Highway/High Mast lamp and irrigation modules consist of a 30ft Rx Tx Weatherproof Communication Link Network (SPN2dp8) for a 5km radius communication range with no obstacles. An Arduino set is connected to the sensors and connected via a GSM link. This provides feedback to the base station regarding visibility on the road and traffic density, allowing trained engineers to light the high mast lamps as per the traffic density or visibility (all lights or alternative lights). The same information is also communicated to the irrigation base station regarding water level indication and soil moisture, and watering of plants is done using autonomous software controls accordingly. This breakthrough technology has the potential to reduce operational losses and conserve precious resources, ultimately benefiting the public.

Case 4: IoT-Based Tele-Radiography in Telemedicine: Bridging Healthcare Gaps in Rural India[Valsalan et.al, 2020; Singh, 2018; Gupta et.al 2020;Albahar et.al 2021; Abdellatif& Mohamed, 2020]

Approximately 75% of India's population resides in rural areas, while 70% of the doctors live in cities. Delivering healthcare to remote and rural areas is a challenging task for healthcare professionals. Patients face difficulty reaching district or secondary healthcare centers due to poor transport facilities, especially during episodes of illness. Moreover, secondary healthcare centers lack necessary infrastructure, making specialist care unattainable. However, the use of information communication technology (ICT) has helped minimize the gap between rural and urban healthcare services. Progress in communication technology has facilitated the exchange of clinical data from remote places to specialist care facilities.

Cardiovascular diseases (CVD) are prevalent in developing nations like India, and diagnostic and timely referral to higher/specialist centers are often not accessible. Studies reveal that 32% of reported deaths in India are due to CVD. By 2025, India is expected to have 70 million diabetic cases, with congenital heart disease also being more prevalent in rural areas. Lack of timely medical imaging facilities often leaves these cases untreated and unmonitored. However, IoT-based real-time tele-echocardiography has helped reduce the lag in delivering specialist care to remote areas. Doctors can use telemedicine methods to provide consultation to patients and offer better treatment and regular follow-up, resulting in effective disease management in remote areas. If necessary, emergency evacuation can also be done based on real-time telemedicine and tele-echocardiography outcomes, reducing fatalities.

In 2001, Care Hospital successfully launched telemedicine in Mahaboobnagar district in Telangana state under a private-public partnership. The government established CT, X-ray, tele-radiology, and tele-echocardiography units in Mahaboobnagar district hospital. From 2002 to 2020, around 3188 cases were diagnosed, with 1753 found to have abnormalities. Among these, 1402 were treated medically, and 143 were further diagnosed and treated medically, while 210 were given interventional procedures with support from Care's expert team of doctors, who were in regular contact with Mahaboobnagar district hospital. During the same period, tele-radiology was used to screen 40621 cases, delivering healthcare more effectively than private diagnostic centers. Patients were saved from time lag, travel costs, and received effective care from centers of medical excellence. The researchers observed that further miniaturization of medical devices with IoT can enhance health services to needy and remote populations in the future (Raju& Prasad, 2017).

Case 5: Fishing Boats Tracking Using IoT: Ensuring Safety and Preventing Losses [Amuthakkannan, 2023; Sriram et.al, 2023; Ramesh et.al, 2020; Tassetti et.al, 2022]

India has rich marine fisheries resources, and an average of 20-30 days of fish hunting during the fishing season can sufficiently feed families for an entire year. However, due to high currents and cyclones, commercial boats can float away from their actual planned locations, causing losses to their owners in many forms. In this particular condition, boat owners have to spend plenty of financial resources, time, and labor to locate the commercial boats by employing a few additional boats to trace the missed ones. In light of these observations, IoT has been giving promising results to make sufficient use of these marine

resources. Sensors mounted on boats will keep sending signals to their owners regarding their battery and engine condition and GPS location. This system provides useful support during cyclones, as commercial boats can become delinked from control stations, deviate from their set routes, and become untraceable to their owners due to extreme oceanic currents.

The system sensors mounted on commercial fishing boats to send real-time data to their owners. The sensors measure important parameters such as the boat's battery and engine condition, as well as its GPS location. This data is transmitted wirelessly to a central location where it can be monitored by the boat owner or other relevant stakeholders. During times of high currents and cyclones, when commercial boats can get delinked from control stations and deviate from their planned routes, this system becomes particularly useful. It enables boat owners to quickly locate and recover lost boats, potentially saving them from significant financial losses and the need to spend resources on additional boats and labor to search for the missing boats. By providing real-time data on the location and condition of boats, this system also promotes greater safety for the fishermen who operate them.

Case 6: Precision Farming: Optimizing Agriculture through IoT Technology [Shaikh et.al, 2022; Ardiansah et.al, 2020; Kumar et.al 2021; Fastellini&Schillaci, 2020]

It is also known as precision agriculture, is an approach that utilizes advanced technologies, including IoT, to optimize agricultural practices and improve productivity while minimizing resource waste. Precision farming involves the precise management of various agricultural factors, such as soil conditions, irrigation, fertilization, pest control, and harvesting. Precision farming involves the collection and analysis of detailed data on soil variability, topography, and other environmental factors within a field. This data is obtained using various technologies, including satellite imagery, drones, and ground-based sensors. By understanding the variations within a field, farmers can implement site-specific management strategies, tailoring inputs and practices to specific areas within the field based on their unique needs. Precision farming enables farmers to apply inputs such as fertilizers, pesticides, and water at variable rates based on the specific requirements of different parts of a field. By mapping the variations in soil fertility, nutrient levels, and moisture content, farmers can precisely determine the optimal application rates for each area. This approach minimizes input wastage, reduces environmental impact, and ensures that crops receive the necessary resources for optimal growth. Precision farming heavily relies on data collection, analysis, and interpretation to make informed decisions. IoT sensors, GPS technology, and remote sensing tools provide real-time and historical data on soil moisture, nutrient levels, plant health, and weather conditions. This data is processed and analyzed using advanced analytics and modeling techniques, enabling farmers to gain insights into crop performance, identify potential issues, and make timely decisions for improved yields and resource management.

IoT technology plays a significant role in precision farming by enabling remote monitoring and control of various agricultural operations. Farmers can access real-time data and insights through web-based platforms or mobile applications, allowing them to remotely monitor crop conditions, irrigation systems, and machinery performance. This remote accessibility facilitates prompt intervention and adjustment of farming practices, even from a distance. Precision farming leverages automation and robotics to streamline and optimize various farming tasks. Robotic devices, such as automated planters, harvesters, and weeding machines, are equipped with sensors and imaging systems to precisely perform operations

with minimal human intervention. Automation improves efficiency, reduces labor costs, and ensures accuracy in tasks such as planting, spraying, and harvesting. Precision farming integrates data from multiple sources, including sensors, weather stations, satellite imagery, and historical records. This integrated data is visualized through sophisticated software platforms that provide farmers with intuitive interfaces, maps, and charts for decision-making. Visualization tools help farmers interpret complex data sets and identify patterns, enabling them to take appropriate actions for improved crop management.By leveraging IoT technology and data-driven insights, farmers can make precise, site-specific decisions, enhancing productivity, sustainability, and profitability in agriculture.

Case 7: IoT-Based Soil Monitoring and Fertilizer Management: Enhancing Crop Productivity and Sustainability [Postolache, 2022; Pandey& Mukherjee,2022; Ananthi et.al 2017; Nagaraja et.al 2019.]

IoT technology plays a vital role in soil monitoring and fertilizer management. IoT sensors are deployed in agricultural fields to collect real-time data on crucial soil parameters such as pH levels, nutrient content, and moisture levels. These sensors continuously monitor and transmit the data to a centralized system for analysis and interpretation. The data collected by the IoT sensors provides farmers with valuable insights into the health and fertility of the soil. By understanding the current conditions of the soil, farmers can make informed decisions regarding fertilizer application. They can precisely determine the appropriate type and amount of fertilizers required for optimal nutrient management, avoiding both over-fertilization and under-fertilization.

The real-time data from IoT sensors enables farmers to monitor soil conditions on an ongoing basis, helping them detect any potential imbalances or deficiencies. With this information, farmers can take timely corrective actions to address nutrient deficiencies or adjust fertilizer application rates. By optimizing fertilizer usage based on accurate and up-to-date data, farmers can enhance nutrient availability to the crops, promote healthy growth, and maximize yields. The integration of IoT technology in soil monitoring and fertilizer management offers several advantages. It enables farmers to move away from traditional, generalized approaches to fertilizer application and adopt precision-based practices. This precision ensures that nutrients are provided to the crops exactly when and where they are needed, reducing wastage and minimizing environmental impact. It also helps in preventing excessive nutrient runoff, which can contaminate water bodies and harm ecosystems.

Moreover, the utilization of IoT sensors and data-driven insights in soil monitoring facilitates efficient resource management. By optimizing fertilizer application based on the specific needs of the soil and crops, farmers can reduce input costs and improve economic returns. Additionally, the continuous monitoring of soil parameters through IoT sensors enables early detection of soil health issues, allowing farmers to implement preventive measures and maintain long-term soil fertility. IoT-based soil monitoring and fertilizer management in precision agriculture provide farmers with real-time and accurate data on soil health and fertility. This data empowers farmers to make informed decisions regarding fertilizer application, leading to optimal nutrient management, improved crop productivity, and sustainable agricultural practices. The integration of IoT technology in this domain is instrumental in driving precision and efficiency in agricultural operations.

Case 8: Smart Irrigation Systems Powered by IoT: Efficient Water Usage in Agriculture [Krishnan, 2020; Obaideen et.al 2022; Nawandar&Satpute, 2019; Monicaet.al 2017.]

Smart irrigation systems utilize IoT technology to optimize water usage in agriculture. These systems incorporate sensors, weather monitoring devices, and data analysis to provide real-time information on soil moisture, weather conditions, and crop water requirements. IoT-enabled sensors are deployed in the agricultural fields to measure soil moisture levels at different depths. These sensors can be buried in the soil or placed at specific locations to collect data on soil moisture content. By continuously monitoring soil moisture, farmers can obtain accurate and up-to-date information on the water needs of their crops. Smart irrigation systems also integrate weather monitoring devices that collect data on temperature, humidity, wind speed, and rainfall. This information is crucial for understanding the environmental conditions and their impact on crop water requirements. By combining weather data with soil moisture data, farmers can assess how weather patterns affect the water needs of their crops.

The data collected by sensors and weather monitoring devices are processed and analyzed in real-time. Advanced algorithms and models consider factors such as crop type, growth stage, evapotranspiration rates, and historical weather patterns to determine the optimal irrigation schedule and water application rates. Farmers receive actionable insights and recommendations through user-friendly interfaces or mobile applications. Armed with real-time data and insights, farmers can implement precision irrigation techniques. Instead of applying a uniform amount of water across the entire field, they can precisely target water delivery based on the specific needs of different crop areas. This targeted approach helps to avoid over-irrigation, minimize water wastage, and reduce the risk of water stress or waterlogging for the crops.

Smart irrigation systems enable farmers to optimize water usage, leading to significant resource efficiency and cost savings. By avoiding excessive irrigation, farmers can reduce water consumption, conserve water resources, and minimize energy expenses associated with pumping and distribution. Moreover, efficient irrigation practices contribute to better crop health and productivity, resulting in improved yield and profitability. IoT technology allows farmers to remotely monitor and control their irrigation systems. Through mobile applications or web interfaces, farmers can access real-time data, receive alerts, and adjust irrigation settings from anywhere. This remote accessibility provides convenience, flexibility, and the ability to respond promptly to changing conditions or emergencies. Smart irrigation systems leverage IoT technology to enable precise, data-driven irrigation management. By optimizing water usage based on real-time data and crop requirements, these systems help farmers make informed decisions, conserve resources, enhance crop health, and increase agricultural productivity.

Case 9: IoT in Agriculture Supply Chain Management: Tracking and Ensuring Quality and Safety[Luthra et.al, 2018; Borah et.al, 2020;Yadav et.al 2020, Kaur et.al, 2022]

Supply chain management in agriculture involves the movement of agricultural products from farms to markets or consumers. IoT technology plays a crucial role in tracking and monitoring this process, leading to various benefits such as reduced wastage, improved logistics, and enhanced product quality and safety.IoT-enabled sensors and tracking devices

are used to monitor various parameters during transportation, such as temperature, humidity, and shock/vibration levels. For perishable agricultural products like fruits, vegetables, and dairy products, maintaining optimal storage conditions is crucial to prevent spoilage. IoT devices can send real-time data on environmental conditions, allowing stakeholders to take immediate action if any deviations occur. This helps in minimizing product wastage due to improper storage or transportation conditions. IoT technology enables real-time tracking and monitoring of agricultural products throughout the supply chain. Sensors attached to shipping containers, vehicles, or even individual product packages provide visibility into the location and status of the goods. This information is valuable for logistics planning, route optimization, and ensuring timely deliveries. It helps in streamlining operations, reducing delays, and improving overall efficiency in the supply chain.

IoT devices can monitor and collect data on various quality parameters such as temperature, humidity, and product integrity. For instance, temperature sensors can ensure that perishable goods are stored and transported within the desired temperature range, preserving their quality and extending their shelf life. Real-time monitoring enables proactive measures to maintain quality standards and prevents the distribution of compromised products.IoT technology allows for traceability and transparency in the supply chain. With the help of sensors, RFID tags, or QR codes, each agricultural product can be uniquely identified and tracked from farm to market. This traceability helps in ensuring food safety and enables quick recall or identification of the source in case of any quality or safety concerns. It also enhances consumer confidence by providing detailed information about the product's origin, production methods, and handling practices.By leveraging IoT technology in supply chain management, stakeholders in the agriculture industry can gain valuable insights into the movement and conditions of their products. This empowers them to make data-driven decisions, minimize losses, improve operational efficiency, and deliver high-quality, safe agricultural products to consumers.

IV. CONCLUSION

In the midst of India's dynamic and diverse landscape, the Internet of Things (IoT) has emerged as a powerful force for positive change, transcending the realm of mere technological innovation to become a driving force behind the nation's progress. In agriculture, IoT-driven precision farming techniques have fundamentally altered how farmers cultivate the land. Empowered with data-driven insights, farmers optimize resource usage, reduce waste, and enhance crop yields, thereby ushering in a sustainable approach to meet the nation's food requirements. The applications of IoT in precision agriculture, soil monitoring, and smart irrigation are revolutionizing farming practices by providing real-time data and insights.

In healthcare, IoT bridges the gap between rural and urban areas, ensuring access to critical medical care for remote populations. Telemedicine and diagnostic technologies exemplify IoT's transformation of healthcare, with the potential to save lives and improve public health. In transportation, IoT enhances road safety by detecting drowsy driving and reckless behavior, while marine fisheries benefit from tracking systems that reduce losses due to unpredictable oceanic conditions. In public utilities, IoT optimizes resource usage, contributing to economic efficiency and environmental sustainability. IoT's role extends beyond cost savings; it signifies a shift towards responsible resource management vital for

India's future. In conclusion, IoT is not merely a technological advancement; it is a catalyst for positive change, propelling India towards growth, sustainability, and prosperity. Harnessing IoT's potential will empower India to overcome unique challenges and embrace a brighter, more interconnected future.

REFERENCES

[1] Abdellatif, M. M., & Mohamed, W. (2020). Telemedicine: An IoT Based Remote Healthcare System. *International Journal of Online & Biomedical Engineering*, *16*(6).

[2] Albahri, A. S., Alwan, J. K., Taha, Z. K., Ismail, S. F., Hamid, R. A., Zaidan, A. A., ... &Alsalem, M. A. (2021). IoT-based telemedicine for disease prevention and health promotion: State-of-the-Art. *Journal of Network and Computer Applications*, *173*, 102873.

[3] Amuthakkannan, R., Vijayalakshmi, K., Al Araimi, S., & Ali Saud Al Tobi, M. (2023). A Review to do Fishermen Boat Automation with Artificial Intelligence for Sustainable Fishing Experience Ensuring Safety, Security, Navigation and Sharing Information for Omani Fishermen. *Journal of Marine Science and Engineering*, *11*(3), 630.

[4] Ananthi, N., Divya, J., Divya, M., &Janani, V. (2017, April). IoT based smart soil monitoring system for agricultural production. In *2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR)* (pp. 209-214). IEEE.

[5] Ardiansah, I., Bafdal, N., Suryadi, E., & Bono, A. (2020). Greenhouse monitoring and automation using Arduino: a review on precision farming and internet of things (IoT). *Int. J. Adv. Sci. Eng. Inf. Technol*, *10*(2), 703-709.

[6] Biswal, A. K., Singh, D., Pattanayak, B. K., Samanta, D., Chaudhry, S. A., &Irshad, A. (2021). Adaptive fault-tolerant system and optimal power allocation for smart vehicles in smart cities using controller area network. *Security and Communication Networks*, *2021*, 1-13.

[7] Borah, M. D., Naik, V. B., Patgiri, R., Bhargav, A., Phukan, B., &Basani, S. G. (2020). Supply chain management in agriculture using blockchain and IoT. *Advanced applications of blockchain technology*, 227-242.

[8] Chatterjee, P. S., Ray, N. K., &Mohanty, S. P. (2021). LiveCare: An IoT-based healthcare framework for livestock in smart agriculture. *IEEE Transactions on Consumer Electronics*, *67*(4), 257-265.

[9] Dutta, D., Natta, D., Mandal, S., &Ghosh, N. (2022). MOOnitor: An IoT based multi-sensory intelligent device for cattle activity monitoring. *Sensors and Actuators A: Physical*, *333*, 113271.

[10] Fastellini, G., &Schillaci, C. (2020). Precision farming and IoT case studies across the world. In *Agricultural internet of things and decision support for precision smart farming* (pp. 331-415). Academic Press.

[11] Gowda, V. D., Prasad, K. D. V., De, T., Srinivas, V., Kumar, N. A., &Moharekar, T. T. (2023, April). A Framework for Smart City Implementation using IoT-Cloud Based System Architecture. In *2023 International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE)* (pp. 1-6). IEEE.

[12] Gupta, N., Khosravy, M., Patel, N., Dey, N., Gupta, S., Darbari, H., &Crespo, R. G. (2020). Economic data analytic AI technique on IoT edge devices for health monitoring of agriculture machines. *Applied Intelligence*, *50*, 3990-4016.

[13] Gupta, S., Johnson, E. M., Peacock, J. G., Jiang, L., McBee, M. P., Sneider, M. B., &Krupinski, E. A. (2020). Radiology, mobile devices, and internet of things (IoT). *Journal of Digital Imaging*, *33*, 735-746.

[14] Hafeez, P. A., Singh, G., Singh, J., Prabha, C., &Verma, A. (2022, October). Iot in agriculture and healthcare: Applications and challenges. In *2022 3rd International Conference on Smart Electronics and Communication (ICOSEC)* (pp. 446-450). IEEE.

[15] Holtschulte, A. (2022). Use Cases for the Internet of Things. In *Digital Supply Chain and Logistics with IoT: Practical Guide, Methods, Tools and Use Cases for Industry* (pp. 171-219). Cham: Springer International Publishing.

[16] Kaur, A., Singh, G., Kukreja, V., Sharma, S., Singh, S., & Yoon, B. (2022). Adaptation of IoT with blockchain in Food Supply Chain Management: An analysis-based review in development, benefits and potential applications. *Sensors*, *22*(21), 8174.

[17] Krishnan, R. S., Julie, E. G., Robinson, Y. H., Raja, S., Kumar, R., & Thong, P. H. (2020). Fuzzy logic based smart irrigation system using internet of things. *Journal of Cleaner Production*, *252*, 119902.

[18] Kumar, L., Ahlawat, P., Rajput, P., Navsare, R. I., & Singh, P. K. (2021). Internet of things (IOT) for smart precision farming and agricultural systems productivity: A review. *IJEAST*, *5*, 141-146.

[19] Kumari, S., &Yadav, S. K. (2018). Development of iot based smart animal health monitoring system using raspberry pi. *International Journal of Advanced Studies of Scientific Research*, *3*(8).

[20] Luthra, S., Mangla, S. K., Garg, D., & Kumar, A. (2018). Internet of things (IoT) in agriculture supply chain management: a developing country perspective. *Emerging Markets from a Multidisciplinary Perspective: Challenges, Opportunities and Research Agenda*, 209-220.

[21] Manyake, M. K., &Mathaba, T. N. (2022, August). An Internet of Things Framework for Control and Monitoring of Smart Public Lighting Systems: A Review. In *2022 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD)* (pp. 1-9). IEEE.

[22] Mittal, A., Kumar, K., Dhamija, S., &Kaur, M. (2016, March). Head movement-based driver drowsiness detection: A review of state-of-art techniques. In *2016 IEEE international conference on engineering and technology (ICETECH)* (pp. 903-908). IEEE.

[23] Monica, M., Yeshika, B., Abhishek, G. S., Sanjay, H. A., &Dasiga, S. (2017, October). IoT based control and automation of smart irrigation system: An automated irrigation system using sensors, GSM, Bluetooth and cloud technology. In *2017 International Conference on recent innovations in signal processing and embedded systems (RISE)* (pp. 601-607). IEEE.

[24] Nagaraja, G. S., Soppimath, A. B., Soumya, T., &Abhinith, A. (2019, December). IoT based smart agriculture management system. In *2019 4th International Conference on Computational Systems and Information Technology for Sustainable Solution (CSITSS)* (pp. 1-5). IEEE.

[25] Nawandar, N. K., &Satpute, V. R. (2019). IoT based low cost and intelligent module for smart irrigation system. *Computers and electronics in agriculture*, *162*, 979-990.

[26] Obaideen, K., Yousef, B. A., AlMallahi, M. N., Tan, Y. C., Mahmoud, M., Jaber, H., & Ramadan, M. (2022). An overview of smart irrigation systems using IoT. *Energy Nexus*, 100124.

[27] Pandey, A. K., & Mukherjee, A. (2022). a review on advances in IoT-based technologies for smart agricultural system. *Internet of Things and Analytics for Agriculture, Volume 3*, 29-44.

[28] Pandey, N. N., &Muppalaneni, N. B. (2021, March). Real-time drowsiness identification based on eye state analysis. In *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)* (pp. 1182-1187). IEEE.

[29] Postolache, S., Sebastião, P., Viegas, V., Postolache, O., &Cercas, F. (2022). IoT-Based Systems for Soil Nutrients Assessment in Horticulture. *Sensors*, *23*(1), 403.

[30] Rajendran, J. G., Alagarsamy, M., Seva, V., Dinesh, P. M., Rajangam, B., &Suriyan, K. (2023). IoT based tracking cattle healthmonitoring system using wireless sensors. *Bulletin of Electrical Engineering and Informatics*, *12*(5), 3086-3094.

[31] Ramesh, M. V., Prabha, R., Thirugnanam, H., Devidas, A. R., Raj, D., Anand, S., &Pathinarupothi, R. K. (2020). Achieving sustainability through smart city applications: protocols, systems and solutions using IoT and wireless sensor network. *CSI Transactions on ICT*, *8*, 213-230.

[32] Shaikh, T. A., Mir, W. A., Rasool, T., &Sofi, S. (2022). Machine learning for smart agriculture and precision farming: towards making the fields talk. *Archives of Computational Methods in Engineering*, *29*(7), 4557-4597.

[33] Shruthi, B. S., Manasa, K. B., & Lakshmi, R. (2019). Survey on Challenges and Future Scope of IoT in Healthcare and Agriculture. *Int. J. Comput. Sci. Mob. Comput*, *8*(1), 21-26.

[34] Singh, P. (2018). Internet of things based health monitoring system: opportunities and challenges. *International Journal of Advanced Research in Computer Science*, *9*(1), 224-228.

[35] Solanki, V. K., Venkaesan, M., &Katiyar, S. (2017). Conceptual model for smart cities: Irrigation and highway lamps using IoT.

[36] Sriram, G. Y., MR, J., MR, G., NB, S. S., &Rao, S. (2022, August). MarineServe: An IoT-based AI-enabled Multi-Purpose Real-time Alerting System for Fishing Boats. In *Proceedings of the 2022 Fourteenth International Conference on Contemporary Computing* (pp. 591-596).

[37] Suryawanshi, Y., &Agrawal, S. (2020, October). Driver drowsiness detection system based on lbp and haar algorithm. In *2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)* (pp. 778-783). IEEE

[38] Tassetti, A. N., Galdelli, A., Pulcinella, J., Mancini, A., &Bolognini, L. (2022). Addressing gaps in small-scale fisheries: a low-cost tracking system. *Sensors*, *22*(3), 839.

[39] Thulasimani, L., &Prithashasni, S. (2021). Real time driver drowsiness detection using opencv and facial landmarks. *Int. J. of Aquatic Science*, *12*(2), 4297-4314.

[40] Valsalan, P., Baomar, T. A. B., &Baabood, A. H. O. (2020). IoT based health monitoring system. *Journal of critical reviews*, *7*(4), 739-743.
[41] Vyas, S., Shukla, V., &Doshi, N. (2019). FMD and mastitis disease detection in cows using Internet of Things (IOT). *Procedia computer science*, *160*, 728-733.
[42] Yadav, E. P., Mittal, E. A., &Yadav, H. (2018, February). IoT: Challenges and issues in indian perspective. In *2018 3rd International Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU)* (pp. 1-5). IEEE.
[43] Yadav, S., Garg, D., &Luthra, S. (2020). Analysing challenges for internet of things adoption in agriculture supply chain management. *International Journal of Industrial and Systems Engineering*, *36*(1), 73-97.

