

# A Novel Framework for E-Waste Inventory Based on IoT, Cloud Computing, and Machine Learning Technologies: The Case of Saudi Arabia\*

Hatim MADKHALI<sup>1,2</sup>, Haitham ASSIRI<sup>2</sup>, Linh NGUYEN<sup>3</sup> and  
Mukesh PRASAD<sup>1</sup>

<sup>1</sup> School of Computer Science, Faculty of Engineering & IT,  
University of Technology Sydney, Ultimo, Australia

<sup>2</sup> College of Engineering & Computer Science, Department of Computer Science,  
Jazan University, Jazan, Saudi Arabia

<sup>3</sup> Institute of Innovation, Science & Sustainability,  
Federation University, Churchill, Australia

Correspondence should be addressed to: Hatim MADKHAL, [hatimmadkhali@jazanu.edu.sa](mailto:hatimmadkhali@jazanu.edu.sa)

\* Presented at the 45<sup>th</sup> IBIMA International Conference, 25-26 June 2025, Cordoba, Spain

## Abstract

Electronic waste is rising rapidly worldwide, and Saudi Arabia currently produces the largest share within the Arab region. Existing studies focus on isolated technologies or regional snapshots; none combine cloud computing, Internet-of-Things (IoT) sensing, and machine-learning prediction in a single, traceable national inventory. To address this gap, this paper presents a hybrid cloud-IoT framework with an integrated machine-learning model for forecasting e-waste flows in Saudi Arabia. The architecture links stakeholders to scalable cloud services and IoT-equipped collection bins that assign unique identifiers and transmit real-time data, while the predictive model learns from historical records to estimate future volumes. Validation will draw on a secondary e-waste dataset, a structured stakeholder survey analyzed with standard statistical procedures, and simulation studies that test data movement from edge devices to the cloud under variable loads. Expected results include higher inventory accuracy, faster collection cycles, improved transparency for regulators, and closer alignment with Vision 2030 sustainability targets. Survey findings and model performance metrics will be compared with current collection practices to quantify gains in efficiency and resource recovery. These insights will provide evidence for policymakers and industrial partners planning large-scale deployment and will lay the groundwork for wider adoption of distributed digital solutions in the circular economy.

**Keywords:** E-waste inventory; Cloud-IoT framework; Machine-learning prediction; Saudi Arabia.

## Introduction

Electronic waste (E-waste) is the discarded electrical and electronic equipment that includes household appliances, office equipment, and entertainment devices, containing both valuable and hazardous materials requiring special handling (Gartner 2024). In 2022, the world produced around 62 million tons of unaccounted e-waste, an 82% increase from 2010, with only 22.3% being properly collected and processed (Global E-waste Monitor 2024). This unaccounted e-waste is projected to rise to 82 million tons by 2030, decreasing the processed quantity to

20%. Valuable materials worth billions of dollars are lost in unprocessed e-waste, while harmful emissions persist. According to Global E-waste Monitor (2024), in 2022, about 14 million tons of e-waste are used for landfills after processing, while around 31 million tons contained valuable metals like gold and an additional 14 million tons of minerals. The value of metals in e-waste is about 91 billion USD and that of gold is 15 billion USD, copper is 19 billion USD and iron is 16 billion USD. According to Global E-waste Statistics Partnership (2024), E-waste is also referred to as WEEE (Waste Electrical and Electronic Equipment). It includes a wide range of products – almost any household or business item with circuitry or electrical components with power or battery supply. E-waste can be classified into six distinct categories, which are temperature exchange equipment, Screens and monitors, Lamps, Large equipment, Small equipment and Small IT and telecommunication.

### ***E-waste in Saudi Scenario***

The amount of e-waste is increasing rapidly worldwide as well as in Saudi Arabia. Europe, Oceania, and the Americas lead in e-waste quantities and recycling rates, particularly for larger items. In the Arab region, Saudi Arabia is the largest generator of e-waste. Saudi Arabia produces approximately 595 kilotons (kt) annually, equating to about 13.2 kg per person. Despite this substantial quantity, much value from e-waste is lost due to illegal activities like scavenging and exporting valuable components. In Arab countries, 99.9% of e-waste is unmanaged or mismanaged, with only about 0.1% being collected for environmentally sound treatment across all Arab countries, and no specific data available for Saudi Arabia (Iattoni et al. 2021). According to Madkhali et al (2023), in 2022 Saudi Arabia introduced the National Transformation Program 2020 to reduce e-waste by 40%. Under Vision 2030's waste-to-energy and sustainability initiatives, the country aims for a 100% e-waste recycling rate. Factors driving these issues include increasing e-waste quantities, lack of e-waste legislation, limited management infrastructure, competition between formal and informal sectors, legal and illegal import/export of e-waste, and the recent availability of e-waste data, excluding Saudi Arabia. Valuable materials like copper and gold are found in e-waste, but harmful substances such as lead, cadmium, and mercury pose environmental risks. Only 10-15% of e-wastes is individually collected and ultimately disposed of in landfills, underscoring the prominence of the informal waste management system (Almulhim 2022). A survey by Almulhim (2022) found that 70% of Saudi people misclassified e-waste as ordinary refuse, 45% stored it at home, and 32% mixed it with regular waste as. Managing e-waste collection and disposal is critical issue worldwide. In this paper, our framework aims to provide better solution for e-waste inventory and management in Saudi Arabia. The framework as discussed below, integrates advanced and trending technologies such as cloud computing, IoT and machine learning. These technologies aim to automate the disposal and inventory practice, provide scalability, privacy, transparency and traceability. Additionally, the framework aims to predict the future amount of e-waste by utilizing machine learning technology. Our framework helps to ensure better solution for e-waste in Saudi and aligns with Saudi 2030 Vision.

### **The importance of E-waste inventory system**

With the prospect of rapidly increasing e-waste, a proactive and uniform national e-waste inventory system is necessary ensuring that all stakeholders participate in it (Kumar and Rawat 2013). E-waste management requires keeping track of the movement of electronic products to develop effective strategies, infrastructure, and a sustainable supply chain network. This involves considering economic, social, and environmental factors and requires a comprehensive database. This can be achieved through the creation of a detailed E-waste inventory, as demonstrated by a study conducted in India on households in Pune city (Bhat and Patil 2021). Similarly, a study in Pakistan by Sajid et al (2019) emphasized the importance of developing an inventory system in the country due to the fluctuating and increasing E-waste generation. E-waste inventory, encompassing discarded, recycled, or refurbished electronic items, requires a systematic approach for efficient management. According to the United Nations Environment Programme (UNEP), there are established guidelines for selecting and assessing e-waste inventory methodologies, including the time step method, market supply method, Carnegie Mellon method, and approximate formulas. The market supply method is preferred due to its minimal data requirements, illustrated through case studies in Cambodia and India. However, UNEP does not address digital technologies like cloud computing, IoT, and machine learning in their methods (UNEP 2007). Moreover, e-waste contains precious metals and useful raw materials, such as gold, silver, copper, and platinum. The total value of all these recoverable from discarded e-waste in 2019 was US\$57 billion (£45 billion). These gains from proper e-waste inventory management outweigh the harm caused by them (World Economic Forum 2020). All the above highlight the critical importance of e-waste inventory. Therefore, we propose a novel framework that utilizes advanced technology to optimize the e-waste collection and ensure sustainability.

## **Utilizing advanced technologies for e-waste inventory**

E-waste data in India often relies on electronics sales, but poor record-keeping leads to rough estimates. About 26% of electronics are sold online, while offline sales are inferred from GST data. A study Das et al. (2020) introduced a cloud-based framework to integrate these sources, aiding in the development of a national e-waste inventory. Likewise, Wang and Wang (2014) developed a cloud-based platform for e-waste recovery via remanufacturing, featuring QR code tracking and lifecycle assessment tools, validated through an LCD TV case study. Effective dismantling is crucial for e-waste treatment. The author in Xia et al. (2015) introduced a cloud-based disassembly planning method to boost material recovery and reduce environmental harm, while Pramanik et al. (2023) leveraged IoT devices and sensors for real-time data collection to enhance efficiency and sustainability. RFID tags and sensors ensure accountability and traceability throughout the e-waste supply chain. Integrating IoT with the Circular Economy (CE) provides sustainable opportunities, as demonstrated by Hatzivasilis et al. (2019) in a telecommunications company, extending equipment lifespans and aiding recycling companies in tracking supply chains and making informed investments, thereby mitigating electronic waste in developing countries. A study by Turkolmez et al. (2024) proposed a machine-learning algorithm to address pricing in the remanufacturing process of end-of-life laptops for third-party remanufacturers, incorporating an additive model, CART analysis, Random Forest, and Polynomial Regression. For estimating generated e-waste. The author in Khoshand et al. (2023) developed a modified adaptive neuro-fuzzy inference system (MANFIS) using five parameters related to legal and illegal imports and exports, focusing on e-waste accumulation in Teheran and Iran. The authors of Chattopadhyay et al. (2024) introduced a multidimensional cost-function-based EWM framework structured on environmental, economic, and social uncertainties as sustainability pillars in e-waste recycling plants. Their model includes a material recovery process from e-waste facilities employing chemical and mechanical recycling and ranks each module using Machine Learning protocols of Analytical Hierarchical Process (AHP) and combined AHP and Principal Component Analysis (PCA). Based on the review above, we conclude that hybrid cloud-IoT system integrated with machine learning show significant promise for enhancing e-waste collection in Saudi, and their selection for our framework is explained in the following section.

## **The benefits of integrating Cloud computing, IoT and Machine learning for e-waste inventory system**

Integrating advanced technologies such as cloud computing, IoT and machine learning significantly enhances e-waste management by optimizing processes and promoting sustainability. A study by Sharma et al. (2023) emphasized that these technologies facilitate tracking e-waste flow, optimizing collection routes, and improving management planning. Similarly, Khoshand et al. (2023) highlighted that cloud computing offers scalable, flexible, and energy-efficient IT infrastructures that support environmental initiatives through real-time data analytics, predictive maintenance, and automated controls. AI-driven systems further improve operational efficiency by detecting recyclable items and forecasting waste trends, reducing landfill contributions. The author of Omar (2024) reiterated that these technologies optimize resource usage, decrease waste, and minimize carbon emissions, providing unparalleled opportunities for environmental sustainability and effective e-waste management.

### ***The novelty in integrating cloud and IoT with ML for e-waste inventory***

A review by Yafeng et al. (2023) highlighted the usefulness of integrated cloud computing and IoT service platforms for e-waste collection, which can help in e-waste inventory management. A novel way of integrating the cloud with IoT and ML was described by Srivastav et al. (2023). However, their framework mainly focuses on automation and classification; they use the cloud only as storage without providing real-time data processing or unique identifiers and timestamped data for traceability. They also did not mention the validation strategy. The framework proposed by Srivastav et al. (2023) can identify and filter out reusable components, as well as extract valuable metals. However, it does not predict the future e-waste and does not ensure multiple stakeholders. These issues have been addressed in our framework by integrating real-time data processing, predictive analytics, multi-stakeholder collaboration, and rigorous validation, ensuring a more scalable and transparent solution.

### ***The novelty of such a system in Saudi Arabia***

Saudi Arabia, the largest country in the Middle East with a land area of 2,150,000 sq km and a population of about 34 million as of August 8, 2024, generated approximately 595 kt of e-waste in 2021 (Iattoni et al. 2021). The country faces significant challenges in e-waste management due to the lack of real-time data on e-waste flows,

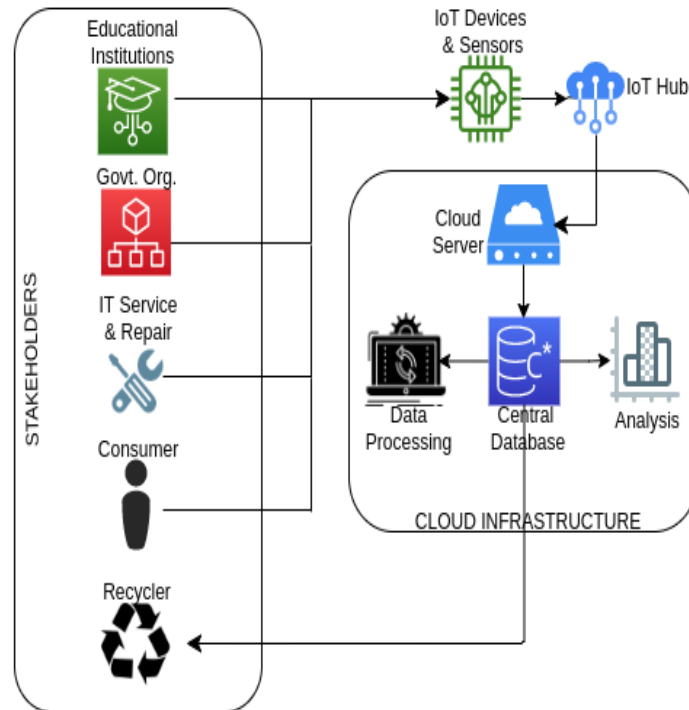
highlighting the need for an effective e-waste inventory system, which aligns with the sustainability goals of Saudi Vision 2030 (Kingdom of Saudi Arabia 2016) and smart city projects like Neom and The Line cities. Efficient e-waste inventory management requires digital technologies such as cloud computing, IoT, and machine learning for optimum effectiveness. A study by Filimban et al. (2019) noted that sustainable e-waste management models from the USA and Malaysia could be adapted for Saudi Arabia, though they originally lacked digital technologies. While smart vehicles, robotics, AI tools, real-time monitoring, and sensors improve e-waste management, further ecosystem development is needed to fully realize their potential in Saudi (Madkhali et al. 2023).

## **The proposed framework architecture**

Our proposed framework for e-waste in Saudi Arabia aims to integrate IoT, Cloud Computing, and Machine Learning to create a comprehensive e-waste inventory system. The framework is built on four main components: stakeholders, cloud infrastructure, IoT devices, and machine learning. This innovative framework with these components aims to create a scalable, transparent, and efficient e-waste inventory. The stakeholder in our framework involves educational institutions, government and private organizations, consumers, repair centers, and e-waste collector companies. The cloud serves as the backbone of the architecture, offering scalable storage, computational power, and real-time data processing to maintain e-waste inventory, historical data, and analytics. Additionally, IoT devices in collection bins capture real-time data and notify sectors when full, allowing machine learning models to predict future e-waste generation. Fig. 1 shows the framework component and the model data flow.

### ***Technical Aspects***

Our proposed framework for e-waste inventory in Saudi Arabia addresses various technical aspects. The cloud infrastructure ensures scalability which enable the system to deal with large amount of data. Another technical aspect is the real-time data processing where the IoT devices transmits data instantly. Furthermore, traceability and transparency are maintained through unique identifiers and timestamped data, ensuring accountability and responsible handling of e-waste throughout the management process. Additionally, the architecture incorporates privacy-preserving mechanisms to safeguard consumers' personal information while enabling data analysis and monitoring for regulatory compliance. The framework also aims to provide predictive analysis techniques by leveraging historical e-waste data set to anticipate the future e-waste trends. The proposed hybrid cloud-IoT framework with an ML predictive model for e-waste inventory management offers a comprehensive and efficient solution to tackle the challenges of e-waste. This novel approach presents a comprehensive solution for sustainable e-waste management, enhanced resource utilization, and a greener future for Saudi.



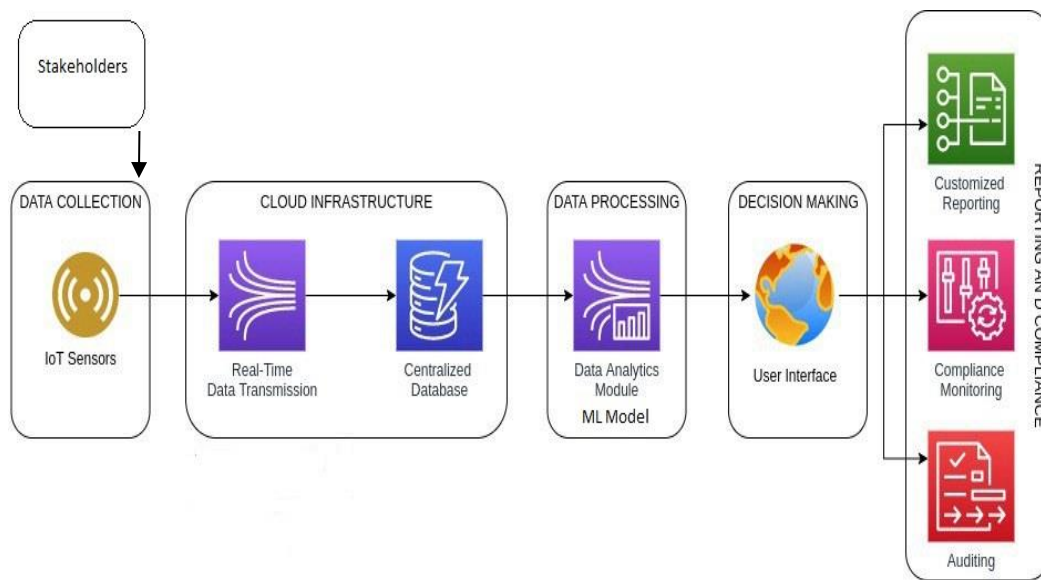
**Fig 1. Proposed Model Architecture**

### ***Data Flow***

Our proposed framework strengthens the process of the e-waste collection and monitoring starting from the initial point of e-waste generation through its eventual collection. This can be done through sequence of integrated steps that ensure data-driven coordination and efficiency across all stages. The data flow and operational logic of the framework are illustrated in Fig. 2.

1. *Real-Time Data Collection Mechanisms:* IoT devices constantly collect data, which is transmitted to the cloud via communication channels. The real-time data collection enables the system to provide up-to-date information on e-waste volumes and types, which is crucial for timely decision-making. For example, if a particular collection bin reaches capacity, the system can automatically trigger a notification to the relevant authorities to arrange for its collection and processing, thereby preventing overflow and ensuring efficient operations.
2. *Centralized Data Storage:* The cloud provides centralized storage for the bulk of the data, which ensure scalability for the framework. The feature is beneficial in scenarios where real-time processing is critical, such as identifying hazardous materials in e-waste or optimizing the routing of collection vehicles.
3. *Data Processing Methods:* Data processing within the framework is carried out using both batch and stream processing methods. Batch processing is used for analyzing historical data and generating reports on long-term trends in e-waste generation. In contrast, stream processing is employed for real-time analytics, allowing the system to generate immediate insights and trigger actions based on current data. The dual approach ensures that the system can provide both real-time operational support and in-depth analytical insights.
4. *Machine Learning for Predictive Analysis:* Machine Learning plays a crucial role in the framework by enabling predictive analysis of e-waste generation trends and optimizing the recycling process. ML algorithms going to be trained on historical data to predict future e-waste volumes, identify patterns in consumer behavior, and optimize the routing of collection vehicles. For example, time series forecasting models can predict seasonal fluctuations in e-waste generation, enabling the system to adjust collection schedules and recycling capacity accordingly. Regression analysis can be used to identify the factors that most significantly influence e-waste generation, providing insights that can inform policy decisions and public awareness campaigns.

5. *Data-Driven Decision-Making:* The insights generated by the ML models going to be used to make data-driven decisions that enhance the efficiency and sustainability of the e-waste management process. For instance, the system can ensure that collection and recycling resources are allocated efficiently, by predicting future e-waste volumes, reducing the likelihood of overflows and minimizing the environmental impact of e-waste. Such insights can also be used to inform regulatory reporting and compliance, ensuring that all relevant environmental standards are met.
6. *Tools for Regulatory Reporting and Compliance:* The framework includes tools for generating automated reports that ensure compliance with environmental regulations. Such reports provide detailed information on e-waste volumes, recycling rates, and the handling of hazardous materials, helping organizations to demonstrate their adherence to legal requirements and avoid penalties. The system reduces the administrative burden on organizations and ensures that all necessary data is accurately captured and reported, by automating the reporting process.



**Fig 2. Proposed Model Data Flow**

## Framework validation and future work

To validate and refine our proposed framework, we will first apply a machine learning model to a secondary e-waste dataset (not originating from Saudi Arabia) to evaluate its initial performance and make necessary improvements. Next, we will distribute questionnaires to various sectors in Saudi Arabia to gather insights on current challenges in e-waste collection and management, ensuring the framework's relevance to the local context. We will also assess the cloud infrastructure by simulating data flow from IoT devices to the cloud, testing the system's capacity, scalability, and data-processing efficiency under different loads. By executing these steps, we aim to refine our e-waste management framework and enable its successful deployment in Saudi Arabia, thereby fostering more effective and sustainable e-waste practices.

## Research Methodology

The research will adopt a qualitative technique for a comprehensive understanding of the challenges, benefits, and feasibility of implementing distributed systems for e-waste inventory and collection in Saudi Arabia. Data collection will involve distributing a structured survey across various sectors to assess e-waste generation and current disposal and collection practices. Additionally, semi-structured interviews with key experts in e-waste management, technology, and policy will offer in-depth insights into the challenges and potential benefits of these

systems. Statistical analysis tools will be employed to analyse the survey responses and thematic analysis will be done to transcribe and code the interview data.

## Conclusion

A novel framework based on IoT and Cloud integrated with machine learning for e-waste inventory systems in Saudi Arabia has been proposed in this paper. The model will be assessed and validated using secondary data and simulations. The usefulness of the system in real-time e-waste settings will be tested using qualitative research methods. The results of both validation and usefulness will be used to recommend further research and practice. The proposed framework facilitates the e-waste collection in Saudi Arabia by utilizing advanced technologies which will lead to sustainability in the country.

## References

- Almulhim, A. I. (2022) 'Household's awareness and participation in sustainable electronic waste management practices in Saudi Arabia,' *Ain Shams Engineering Journal*, 13 (4), 101729.
- Bhat, V. and Patil, Y. (2021) 'An integrated and sustainable model for e-waste management for Pune-city households,' *IOP Conference Series: Earth and Environmental Science*, 626, 062111.
- Chattopadhyay, A., Debnath, B. and Krishna Kumar, T. (2024) 'Optimization of a dynamic supply-chain network: Kinetic modelling of e-waste plants,' *Preprints*. [Online], [Accessed 8 August 2024], <https://doi.org/10.20944/preprints202405.0774.v1>
- Das, A., Debnath, B., Modak, N., Das, A. and De, D. (2020) 'E-waste inventorisation for sustainable smart cities in India: A cloud-based framework,' in *Proceedings of the 2020 IEEE International Women in Engineering Conference on Electrical and Computer Engineering (WIECON-ECE)*, IEEE, pp 332-335.
- Filimban, A. A. A., Al-Faraj, F. A. M. and Oti, A. H. (2019) 'Towards sustainable management of e-waste in the Kingdom of Saudi Arabia: A comparative study of three international models,' *Journal of Bioscience and Applied Research*, 5 (3), pp 325-339.
- Gartner (2024) 'Electronic waste (e-waste).' [Online]. Gartner. [Accessed 8 August 2024], <https://www.gartner.com/en/information-technology/glossary/electronic-e-waste>
- Global E-waste Monitor (2024) 'Global e-Waste Monitor 2024: Electronic waste rising five times faster than documented e-waste recycling.' [Online]. UNITAR. [Accessed 8 August 2024], <https://unitar.org/about/news-stories/press/global-e-waste-monitor-2024-electronic-waste-rising-five-times-faster-documented-e-waste-recycling>
- Global E-waste Statistics Partnership (2024) 'What is e-waste?' [Online]. Global E-waste Statistics Partnership. [Accessed 8 August 2024], <https://globalewaste.org/what-is-e-waste/>
- Hatzivasilis, G., Christodoulakis, N., Tzagkarakis, C., Ioannidis, S., Demetriou, G., Fysarakis, K. and Panayiotou, M. (2019) 'The CE-IoT framework for green ICT organisations: The interplay of CE-IoT as an enabler for green innovation and e-waste management in ICT,' in *Proceedings of the 15th International Conference on Distributed Computing in Sensor Systems (DCOSS)*, IEEE, pp. 436-442.
- Iattoni, G., Vermeersch, E., Baldé, C. P., Nnorom, I. C. and Kuehr, R. (2021) 'Regional e-waste monitor for the Arab States 2021,' United Nations Institute for Training and Research. [Online], [Accessed 8 August 2024], [https://ewastemonitor.info/wp-content/uploads/2021/12/REM\\_2021\\_ARAB\\_web\\_final\\_nov\\_30.pdf](https://ewastemonitor.info/wp-content/uploads/2021/12/REM_2021_ARAB_web_final_nov_30.pdf)
- Kingdom of Saudi Arabia (2016) *Vision 2030*. [Online]. Council of Economic and Development Affairs, Riyadh. [Accessed 8 August 2024], <https://www.vision2030.gov.sa>
- Khoshand, A., Karami, A., Rostami, G. and Emaminejad, N. (2023) 'Prediction of e-waste generation: Application of modified adaptive neuro-fuzzy inference system (MANFIS),' *Waste Management & Research*, 41 (2), pp 389-400.
- Kumar, S. and Rawat, S. (2013) 'E-inventory for proactive e-waste management,' in *Proceedings of the 2013 ACM International Conference on Sustainable Computing*, ACM, pp 112-115.
- Mallo, S. F. (2024) 'A review on feasibility of web technology and cloud computing for sustainable ES: Leveraging AI, IoT and security for green operations,' *Journal of Information Technology and Informatics*, 3 (2), pp 246-270.
- Madkhali, H., Duraib, S., Nguyen, L., Prasad, M., Sharma, M. and Joshi, S. (2023) 'A comprehensive review on e-waste management strategies and prediction methods: A Saudi Arabia perspective,' *Knowledge*, 3 (2), pp 163-179.

- Omar, H. Y. (2024) 'A review on upshots of cloud computing and web technology on future green transformation: AI, IoT and secure enterprise systems in fostering sustainable work practices,' *Journal of Information Technology and Informatics*, 3 (2), pp 271-296.
- Pramanik, A., Rajput, P. and Aluvala, S. (2023) 'IoT-based e-waste management: Towards a sustainable environment,' in *Proceedings of the 2023 IEEE International Conference on Smart Sustainable Technology (SUSTECH)*, IEEE, pp 226-230.
- Sajid, M., Syed, J. H., Iqbal, M., Abbas, Z., Hussain, I. and Baig, M. A. (2019) 'Assessing the generation, recycling and disposal practices of electronic/electrical waste from major cities in Pakistan,' *Waste Management*, 84, pp 394-401.
- Sharma, H., Kumar, H. and Mangla, S. K. (2023) 'Enablers to computer-vision technology for sustainable e-waste management,' *Journal of Cleaner Production*, 412, 137396.
- Srivastav, A. L., Markandeya, N., Patel, N., Pandey, M., Pandey, A. K., Dubey, A. K., Kumar, A., Bhardwaj, A. K. and Chaudhary, V. K. (2023) 'Concepts of circular economy for sustainable management of electronic wastes: Challenges and management options,' *Environmental Science and Pollution Research*, 30 (17), pp. 48654–48675.
- Turkolmez, G. B., El Hatham, Z., Subramanian, N., Kuppasamy, S. and Sreedharan, V. R. (2024) 'Machine-learning algorithms for pricing end-of-life remanufactured laptops,' *Information Systems Frontiers*, (in press).
- United Nations Environment Programme (UNEP) (2007) *E-waste Volume I: Inventory Assessment Manual*. [Online]. UNEP, Nairobi. [Accessed 8 August 2024], [https://wedocs.unep.org/bitstream/handle/20.500.11822/8828/e-waste\\_manual\\_15oct07.pdf](https://wedocs.unep.org/bitstream/handle/20.500.11822/8828/e-waste_manual_15oct07.pdf)
- Wang, X. V. and Wang, L. (2014) 'A cloud-based platform for waste electrical and electronic equipment (WEEE) recovery,' in *Proceedings of the 2014 International Manufacturing Science and Engineering Conference (MSEC 2014)*, ASME, pp 1-8.
- World Economic Forum (2020) *The future of jobs report 2020*. [Online]. World Economic Forum, Geneva. [Accessed 8 August 2024], <https://www.weforum.org/reports/the-future-of-jobs-report-2020>
- Xia, K., Gao, L., Chao, K.-M. and Wang, L. (2015) 'A cloud-based disassembly-planning approach towards sustainable management of WEEE,' in *Proceedings of the 2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, IEEE, pp 203-208.
- Yafeng, H., Shevchenko, T. and Rui, L. (2023) 'Research on urban e-waste management in China based on smart technologies,' *Bulletin of Sumy National Agrarian University*, 4 (96), pp 32-38.