Review Article

Intelligent Technologies to Support Waste Management

Abstract

The fast growth of information and communication technology (ICT) has made it a necessary component of contemporary solid waste management (SWM) system planning and design. This paper offers a critical examination of the existing ICTs and their use in SWM systems in order to draw attention to the issues and challenges related to implementing integrated technology-based systems. ICTs are divided into four sections to assist in the planning, monitoring, collection, and management of solid waste: spatial technologies, identification technologies, data collecting technologies, and data transmission technologies. The basis of the ICT-based SWM systems categorized in this article is formed by the first three technologies, with the fourth technology being utilized by almost all systems. In order to assist with the development and design of a new, sustainable system, the reader may find this review helpful in learning the principles of contemporary ICTs and how they are employed in SWM. Waste, in all its formssolid, gaseous, and liquidincreases and affects the entire world as a result of population expansion, urbanization, and industry. Waste management includes reuse, recycling, reducing the amount of rubbish produced, and other strategies to mitigate the effects of waste generation brought on by increasing population growth and industrialization. In order to solve issues with trash creation, waste collection, waste transportation, waste treatment, and waste disposal methods, monitoring is one of the most crucial parts of waste management. The technology required to accomplish smart management was investigated in this study. Waste management artificial intelligence (AI) solutions were proposed, such as the application of convolutional neural networks and other AI technologies for efficient garbage recognition and sorting.

Keywords: Waste Management, Smart Management Technology, Smart cities, Internet of things

Introduction

A previously unheard-of chance exists to expedite waste management procedures and spark a paradigm change towards a circular economy, where waste is seen as a resource rather than a burden, thanks to the convergence of sustainability, data analysis, and smart technologies(Figueiredo*etal.*, 2019). Improved operational efficiency, trash generation patterns prediction, and collection route optimisation are all potential benefits of integrating advanced data analytics into solid waste management (Vu*etal.*,2019). Waste management organisations and municipalities may make more informed decisions, use resources more wisely, and lessen the environmental impact of trash disposal by utilising real-time data (Farooq*et., al* 2022). Furthermore, waste management is expanding into new areas thanks to the development of smart technologies like blockchain, artificial intelligence, and Internet of Things (IoT) sensors (Ramadoss*etal.*, 2018). Systems that are networked and capable of dynamic, intelligent waste management can be created thanks to these technologies (Vermesan*et al.*, 2022). In order to facilitate prompt and accurate waste collection and minimise fuel usage and greenhouse gas emissions, IoT sensors installed in waste containers may transmit critical information on fill levels (Abdallah*et al.,* 2019). Smart technologies not only improve operations but also enable increased public awareness and involvement. By enabling citizens to actively engage in waste reduction projects, mobile applications and online platforms can promote a sense of environmental stewardship and community duty (Poblet*etal.,* 2018) Through data analysis and smart technology, solid waste management is becoming more sustainable (Akram*etal.*,2021). This is not just a technological advancement it is also a crucial step in rethinking our connection with the environment. Through leveraging data and adopting cutting-edge technologies, we can build a future that is more robust, resource-efficient, and ecologically friendly. The intersection of data analytics, smart technologies, and sustainability appears as a ray of hope in this age of unprecedented problems, pointing the way towards a more regenerative and sustainable approach to solid waste management (Allioui& Mourdi 2023).

Intelligent Waste Management

The combination of cutting-edge technologies and clever solutions with trash management to maximise productivity, minimise environmental impact, and improve sustainability is known as intelligent waste management. This method enhances garbage collection, processing, recycling, and disposal procedures by utilising cutting-edge technology including artificial intelligence, sensors, data analytics, and the Internet of Things (IoT) (Marimuthu*et al.*,2021).

Internet of Things Sensors

Bin Sensors

Real-time fill level monitoring is possible with smart waste bins that have sensors installed. The central management system receives this data, which enables the scheduling and routing of garbage collection to be optimised (Pardini *etal.,* 2020).

Weight Sensors

Some systems employ weight sensors to precisely measure the quantity of waste in bins. The more effective planning of collecting routes is made possible by this knowledge (Al Mamun*et al.,* 2016).

Temperature sensors

Keeping an eye on the temperature within trash cans can assist spot any problems like fire hazards (Elmustafa& Mujtaba2019).

Monitoring in Real-Time and Data Analytics

Cloud-Based systems

Real-time monitoring and analysis of trash levels and collection patterns are made possible by the transmission of sensor data to cloud-based systems. (John, 2022).

Predictive analytics

By using advanced analytics to forecast when a garbage container will be filled, collection routes and timetables can be made more efficient.Predictive analyticsWaste management systems can forecast when trash cans will likely fill by examining past data and present patterns. This makes it possible to plan collection routes in advance, cutting down on pointless travel and maximising fuel efficiency (Medehal, 2023).

Performance Monitoring

Data analytics can be used to track how well waste management procedures are working, pinpoint problem areas, and put focused fixes in place (Van Der Aalst& van der Aalst2016).

Optimising Routes

Algorithms are used by intelligent waste management systems to optimise collection routes using data collected in real time. This decreases operating expenses, cuts carbon emissions, and uses less fuel (Hannan*etal.*,2020).

Remote Observation

Remote monitoring of waste management systems enables prompt detection and resolution of problems like equipment failures or overflows (Drenoyanis*et al.*,2019).

RFID Implementation

Trash cans with radio-frequency identification (RFID) tags allow for precise garbage control and tracking. In certain systems, RFID technology is employed for invoicing, making sure that trash generators are billed according to the amount of waste they produce (Iyer*et al.*,2021).

Conscientious Recycling and Sorting

Waste sorting facilities use advanced technologies to automate the separation of recyclable items. Machines with artificial intelligence (AI) and robotic systems can improve recycling processes' efficiency (Ahmed & Asadullah2020).

Public Participation

Public participation in intelligent waste management frequently takes place via online or mobile application platforms. Encouraging a sense of community involvement, citizens can receive alerts, report complaints, and obtain information about garbage disposal practises (Joshi& Ahmed2016).

Recovering Energy

Waste-to-energy plants are examples of waste management systems that use technologies for recovering energy from waste. This lessens the need for conventional energy sources and promotes sustainable practises (Kumar &Samadder 2017).

Fleet Administration

Route Optimisation

Fuel consumption, emissions, and operating expenses can all be decreased by optimising waste collection routes with the use of data analytics (Vu*et al.*,2019).

Mobile Programmes

User Engagement

By offering details about schedules and regulations for disposing of waste, as well as by promoting conscientious waste management practises, mobile apps can actively involve the public (Ramzan*et al.,* 2021).

Reporting

By using mobile apps, citizens may report problems like overflowing trash cans or unauthorised dumping, which speeds up the resolution process (Buntaine*et al.*,2021).

Sustainability of the Environment

Recycling Initiatives

By encouraging the separate collection of recyclables and offering information on recycling rates, smart waste management systems frequently place a strong emphasis on recycling (Zhou*et al.,* 2021).

Diminished Effect on the Environment

Fuel consumption and greenhouse gas emissions are decreased through the optimisation of waste collection routes and schedules (Hemidat*et al.*,2017).

GPS tracking

This real-time tracking of garbage collection vehicles guarantees effective routing and enables prompt problem-solving (Anjum*et al.,* 2022).

Blockchain Technology for Openness

Blockchain technology can be used to improve waste management procedures' traceability and transparency, particularly when it comes to monitoring material recycling and disposal (Centobelli*et al.,* 2022).

Reduction of Environmental Impact

Intelligent trash Management strives to lessen the environmental effect of trash disposal, encourage sustainable practises, and support a circular economy by streamlining waste collection and recycling procedures (Fatimah*et al.,* 2020).

Waste treatment, characterisation, and management

trash management includes both strategies to mitigate the consequences of trash creation brought on by industrialization and population expansion as well as methods to reduce waste generation, such as recycling and reuse (Gaur*et al.*,2020). Monitoring is a critical component of waste management, as it allows for the resolution of issues related to waste creation, collection, transportation, treatment, and disposal methods (Fatimah *et al.,* 2020). Trash classification is a vital initial step in efficient waste management, which aims for zero waste.

Condensed current research on smart ways to garbage management aims to achieve Zero waste, which is centered on protecting raw materials and resources and minimizing municipal waste problems in smart cities. (X. Chen, 2022). Among these issues include landfilling, which contaminates soil and spreads illness, as well as incineration, which emits air pollution and dangerous gasses. Among these issues include waste minimization, recycling, composing rubbish, and reuse (Silva*et al.*,2021). Research showed how important waste characterisation is to achieving zero waste routing and how important it is to consider the ratio of carbon to nitrogen content when creating composites from organic waste sources (Pakdel*etal.*, 2021). Another study confirmed the need for waste characterization and emphasized the significance of characterizing wastes derived from plastic in terms of the waste product life cycle, quality, application, and presence of impurities, which can take the form of distinct plastic colours, waste materials made of two or more polymers, plastic offsets, and polymer sets. identified and discovered that plastic, paper, and organic materials were among the trash detected in airplane cabins (Blanca Alcubilla, 2021).

Spatial technology

An important component of environmental modelling is spatial analysis, which is a prominent area of study in environmental studies. the collection, archiving, analysis, and mapping of spatial data. Topology, raster, attribute data, and features make up the majority of spatial data (Reddy, 2018).

a) Information systems related to geography (GIS)
b) location-based tracking (GPS) and
c) remote sensing (RS)

An information system called a geographic information system (GIS) may gather, store, analyse, integrate, manipulate, and display data, among other things. Using four categories, the GIS operation process which includes data collection, management, analysis, and cartography was classified (Zhu, 2016). GPS is a worldwide positioning and navigation system that uses a network of strategically placed satellites and ground stations to determine a location. Remote sensing is the use of satellite sensing technology to identify and categorise objects from a distance using signal propagation. Sensors, image processing tools, and data communication tools make up the majority of its components (Bailey, 2023).

Conclusion

One of the most important steps towards building a cleaner, more effective, and environmentally conscious future is the advancement of sustainability through data analysis and the incorporation of smart technologies in solid waste management. We must utilise data analytics and smart technology to address the urgent issues brought on by growing trash quantities and their environmental impact, as we stand at the nexus of technological innovation and environmental guardianship. The health of our world and its people is significantly impacted by the efficient management of solid waste. We can better understand the complex dynamics of trash generation, composition, and disposal trends by adopting data-driven insights. This knowledge is essential for developing focused plans to improve waste management procedures, lessen pollution to the environment, and preserve important resources. Waste management systems can be made more effective and efficient with the help of smart technologies. Municipalities and organisations are empowered to adapt proactively to changing waste circumstances through the integration of Internet of Things (IoT) devices, sensors, and real-time monitoring solutions. Better logistical planning is made possible by this, and it also makes it easier to design dynamic waste collection routes, which minimises fuel use and lowers the waste management operations' carbon footprint. Moreover, the utilisation of smart technologies promotes a waste management approach that is more inclusive and participative. Through the use of social media, mobile applications, and community-based sensors, citizen participation is increased and people can actively participate in trash reduction initiatives. Data democratisation guarantees that all parties involvedfrom local communities to policymakershave access to the information they need to make wise decisions and promote long-lasting change. The convergence of data analytics, smart technologies, and sustainability creates new opportunities for waste-to-resource projects. We can turn garbage into valuable commodities and renewable energy sources by using smart data analysis to find opportunities for recycling, composting, and energy recovery. In addition to lessening the load on landfills, this helps to create a circular economya closed-loop system that conserves, reuses, and recycles resources. Governments, business, academia, and the general public must prioritise collaboration as we set out to advance sustainability in solid waste management. Multidisciplinary collaborations will make it easier to share information, resources, and best practises, which will promote creativity and hasten the global adoption of sustainable waste management techniques. In conclusion, the combination of data analytics, smart technology, and sustainability in solid waste management represents a commitment to the health of our planet as well as a technological advancement. We can paves the way for a time when garbage is managed sensibly, sustainably, and environmentally friendly by using information, adopting cutting-edge technologies, and encouraging teamwork. We can create a cleaner, greener, and more sustainable environment for future generations by acting now, when the time is right.

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