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Role of Artificial Intelligence in Municipal Solid Waste Management

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ABSTRACT: *Waste management incorporates technological, climatic, environmental, and demographic concerns. Socio economic, legal aspects. Traditional methodologies struggle to analyze, predict, and enhance such complex linear processes. Artificial intelligence (AI) tools can help tackle solid waste management (MSWM) concerns.AI solves obscure problems, learns from mistakes, and manages uncertainty and incomplete facts. Although much research has been done in this field, few review studies have evaluated AI's potential in MSWM. This research examines MSWM AI models and approaches, application areas, performance factors, and software platforms used to construct such models.AI uses in MSWM are also mentioned. This document offers AI models and ideas for organic waste management and deployment, as well as reporting output criteria for implementing these frameworks.*

KEYWORDS: -municipal solid waste management, Artificial Intelligence (AI), treatment, disposal, sustainable development.

INTRODUCTION

Municipal solid waste (MSW) is the term used to describe the solid and semisolid garbage generated in urban areas on a daily basis, including waste from construction and demolition projects as well as waste from businesses, organisations, and municipalities. Ecological assessment and management have made significant positive contributions to the modern economy and way of life. Due to the ongoing destruction of the environment, the scientific community is instructed to focus its efforts on investigating and evaluating new management options. Thus, the establishment of a logical evaluation system for monitoring and managing the environment is a critical element of sustainable development. The world has been rapidly advancing since the turn of the millennium, improving people's living conditions, extravagance, and comfort. Along with the

rapid development in population, solid waste generation has also risen. 2.01 billion tonnes of municipal solid waste were generated in 2016, according to the data. On average, 3.40 billion tonnes are projected to be produced by 2050.Unsafely handled and illegally dumped, most frequently in unregulated landfills, represents one-third of the entire amount of waste produced. Natural resource reserves are fast being consumed and being depleted at an accelerated rate as the population grows. Consequently, there is an increase in the rate of rubbish generation worldwide. Based on current generation rates, it is expected that the volume of municipal solid garbage would triple by 2025.Scientists and environmentalists are developing new study strategies to determine the negative consequences of urban trash on the ecology. Around the world, efficient municipal waste management systems are being built in order to use garbage as resources through material recovery in a sustainable manner. Additional waste kinds are created more frequently, in addition to municipal solid waste.

As a result of the technological boom, which has also increased rapid industrialization and led to the expansion of health care and medical services, the globe has seen a surge in the usage of electronic devices during the past 20 years. The disposal of the generated municipal waste is one of the main issues that both developed and rising nations must deal with. The many sorts of municipal rubbish must be systematically managed from the point of generation to collection, transportation, and proper disposal.It is used in collection bins, transportation machinery, and disposal procedures. Municipal garbage management is a significant problem since increasing population and increased consumer demand are directly contributing to rising solid waste creation each year. Poor solid waste management practices can have a significant impact on the environment by causing land degradation, contamination of surface and ground waters, health problems, and other issues. For the effective management of environmental concerns, the amount and kind of data that are available are essential. In the recent years, urbanization has accelerated significantly. Further reducing the problem through municipal waste management solutions would be extremely dangerous for developing nations. Most growing and developing cities are accustomed to seeing open dumping and overflowing trash bins. As a result, the local community's health is endangered in addition to the visual degradation. As a result of exposure to waste through various environmental components, numerous diseases impact diverse segments of the human population.

Consequently, it's essential to manage and trace trash. It is becoming more commonplace to handle municipal waste globally. Municipal waste management is significantly impacted by legal, environmental, political, technical, social, and economic aspects. These problems are complicated by a lack of information and ambiguity, necessitating the adoption of advanced modelling techniques for study and implementation. Numerous technical difficulties are present in municipal garbage management tasks. They also bring a variety of issues that need to be addressed and fixed on the political, economic, and social fronts. The concept of "smart cities" is becoming more and more popular worldwide thanks to modern technology and an operational strategy. Implementing

a comprehensive municipal solid waste management plan is a crucial component of the idea of a smart city. The scientific community has connected inadequate planning and poor operational strategies to poor waste management. The application of artificial intelligence has changed many industries. The application of artificial intelligence (AI) is well established in the automotive, electronics, and other industries; however, more recent developments have focused on the recycling and waste management sectors. The current waste management systems are unable to handle the enormous amounts of garbage that are produced every day.AI must be used to plan various municipal solid waste management tasks in order to control garbage, which is now a necessity. Reducing, reusing, recycling, and recovering are strategies to mitigate the damaging consequences of human activities on the environment. A number of institutional, professional, climatic, environmental, and financial restrictions frequently place restrictions on waste management practises. Providing computational solutions to problems with municipal solid waste management (MSWM), artificial intelligence (AI) technologies have recently become more significant.

Artificial Intelligence and Its Role in Environmental Conservation

With artificial intelligence (AI), machines can mimic human abilities such as learning from examples and skills, recognising patterns in data, and making decisions based on those patterns.Everyone in the world uses it to help them make better choices.It's because AI can process vast amounts of data at a far faster rate than humans.In order to solve problems such as waste detection, space garbage, and sustainability, artificial intelligence is supporting humans.Due to previously unimaginable uses, artificial intelligence (AI) has grown in prominence in a very short period of time.For example, you can use Siri, Alexa, etc. to communicate with your smartphone.Such firms have made a significant impact on the application of artificial intelligence (AI).Since this allowed renewable energy firms to run their facilities more efficiently, more renewable energy was produced and less carbon emissions were released. In order to better forecast energy consumption trends and adjust its operating system in order to dramatically boost efficiency, Xcel Energy, a coal-burning and nitrous oxide-emitting utility, has applied artificial intelligence. Carbon Trackers, a company that uses satellite data to track emissions from coal-fired power plants, has employed artificial intelligence to do so. With the help of satellite data, it can help investors focus on projects with a smaller environmental burden. Using an AI model, Google was able to reduce the energy load in its data centres by 40%, so saving money. A wide range of environmental engineering concerns, including water and wastewater treatment, air pollution mitigation, soil contamination and remediation, as well as municipal waste management planning methods, are being addressed using artificial intelligence (AI). Sustainable development goals such as eradicating hunger and achieving gender equality require the use of artificial intelligence (AI).As a result, AI offers UN parallel opportunities that, depending on the context in which they

are utilised, may or may not always provide favourable results. Artificial intelligence (AI) has the potential to accelerate global efforts to conserve resources and safeguard the environment. There is a pressing need for a constant search for methods and strategies that allow for the legitimate management of municipal solid waste in large urban areas while taking into account the unique characteristics of each section of a city. It can be difficult to understand how municipal solid waste management programmes are evolving. In order to have a successful arrangement, it is necessary to evaluate and anticipate municipal solid waste creation in advance. Artificial intelligence models can be effective in implementing municipal solid waste forecasting models since they are good at making predictions. In order to effectively deal with the tonnes of garbage produced every day, the current waste management system must be rethought and improved upon. Intelligent segregation, intelligent recycling, and the automation of garbage sorting and disposal are all predicted to benefit from the use of artificial intelligence (AI).

Applications in Municipal Waste management

AI-based models have been found to be used in a wide range of academic fields, including engineering, medicine, and more.It has been revealed that artificial intelligence technologies can be put to use in municipal trash management. In order to protect the environment and public health, waste must be properly regulated. The structure of the municipal waste management business has altered as a result of circular economy (CE) methods that generate value from trash produced.
Waste collection and categorization are among the most difficult aspects of moving toward a more circular economy. COVID era, on the other hand, sees most of the garbage that is emitted blended with ordinary waste.As a result of the outbreak, enormous amounts of infectious waste have been generated.As a result, healthcare institutions' municipal trash needs to be properly segregated at the source and stored, as well as transported, to protect resource efficiency and material recovery. In addition to preserving the efficiency of resources and the recovery of materials.In spite of the fact that waste minimization is frequently implemented on-site, one common example of how it's done at the source is the separation of hazardous waste from other trash.These goals can be achieved by integrating artificial intelligence into the waste management system.The use of artificial intelligence to manage municipal solid waste can be accomplished through a variety of these models.One of the most important functions of artificial intelligence is categorization and prediction.

To do a geographic analysis, an extra artificial neural network processes a large volume of data.
The adoption of AI aids in the improvement of garbage trucks' routes for collecting municipal rubbish by locating waste management facilities, calculating waste generation trends, and modelling waste conversion processes.Accurate forecasts of municipal solid waste quality allow for the proper collection, treatment, and disposal of garbage.There have been a number of research looking into how artificial intelligence could be utilised to manage municipal solid waste.Using small solar panels, the device is carbon-neutral, environmentally friendly, and safe for children to

use.Waste bin level detection, forecasting waste characteristics, estimating process outputs and parameters, vehicle routing, and MSWM planning are some of the applications of AI.Detection of garbage in the bin is related to monitoring how full waste bins are, whereas trash features prediction involves waste classification, waste compression ratio, and waste generation trends.

The waste heating value and temperature were two of the anticipated process parameters.The process output projection included simulation and optimization of leachate production and biogas generation.The optimization of garbage collection routes and frequency was one component of the difficulties in truck routing. Tripathi and his colleagues examined the use of a cloud-based waste monitoring system.This monitoring device eliminates the need for dust bin monitoring by hand. Using data sensing devices, Khan and his colleagues proposed a new type of network that could be used for smart detection, tracking, monitoring, and management.The clever bins will make sorting and carrying garbage a lot easier thanks to their automated operation.Bin sensors evaluate and compare the garbage collected with previous records to determine the appropriate course of action for the type of waste that was deposited.The waste is disposed of in accordance with the instructions of a sensor-based programme, such as a landfill or a recycling centre.The amount of municipal waste generated as a result of this can be drastically reduced.The carbon footprint of garbage management has also been reduced as a result of recent technological advancements.In the last several years, researchers have become increasingly interested in ways to conserve energy through the Internet of Things (IoT).It has become a major issue in both developed and developing countries when it comes to trash management.Automated waste sorting and disposal operations can be achieved through the use of artificial intelligence (AI) in smart recycling and trash management.

Segregation

When it comes to dealing with municipal solid waste, the segregation of trash plays a critical role.Garbage segregation is even more critical since it makes handling, transporting, and storing the waste much more efficient.Other academics are focusing on developing techniques and procedures to classify waste items using an automatic sorting sequence that eliminates the need for manual garbage separation.By using artificial neural networks (ANNs), the scientific community at large could distinguish between different types of trash.Different plastic types were identified in electronic waste by using multi-layer ANNs and hyperspectralphotography.The garbage segregation process was automated using deep Convolutional Neural Networks (CNNs).Deep convolutional neural networks were employed to discriminate between waste sorting and waste classification.Recyclable and non-recyclable rubbish were separated using a Convolutional Neural Network (CNN) &MultiLayer Perception (MLP) system.The maximum precision achieved by this hybrid technique was 98.2%, which was nearly 10% higher than the accuracy reached using only CNNs.C-LibSVM, Nu, and Random Forest (RF) all performed

exceptionally well in garbage categorization trials, with accuracy rates of over 90%, according to the researchers who looked at the effectiveness of a variety of machine learning algorithms (REF).Ysabel and his colleagues used data mining techniques like Cluster analysis and Decision Trees to link sociodemographic and behaviouralfactors to rubbish output (DT).With just 3.6 percent mistakes, the tree classifier was a great success.Using data mining techniques, another study determined how much rubbish is generated based on the type of house and the seasons.Using radio frequency identification tags (RFID) has completely changed how waste is separated and disposed of.South Korean city Songdo uses RFID tags to categorise its garbage.Finally, an automated garbage disposal unit scans and removes the tags from the waste.Thus, a central server, which stores all of this information, calculates the optimal method of disposing of the entire garbage generated.

Transportation

As a result, the amount of municipal waste generated may likewise be greatly reduced. The waste management industry's carbon footprint has been lowered as a result of recent technological breakthroughs. Energy efficiency using the Internet of Things (IoT) has grown increasingly popular among experts in recent years. It is becoming increasingly important for both industrialised and developing countries to deal with the abandoned electrical and electronic equipment. The use of artificial intelligence (AI) for smart recycling and trash management can lead to more sustainable recycling procedures. If transportation and collection services are to be trusted, waste must be collected promptly. Artificial Intelligence (AI) can help reduce waste transportation's carbon footprint by suggesting the most effective routes. An integrated MSWM strategy can only succeed if it has a well-planned garbage collection route, which accounts for 70 to 85 percent of the total cost of solid waste management. Trash that is infectious or otherwise dangerous should not be collected at the same time or in the same cart as regular trash, and should not be separated. Neither patients nor members of the general public should be able to access the storage facility. Good ventilation and the absence of vermin are essential. Another ground-breaking idea in urban waste management is the intelligent dumpster, which is equipped with IoT sensors and AI software. Data from the sensors in these dumpsters is sent to the main waste disposal system via intermediary servers, where it is processed .Overflowing containers can be emptied automatically when garbage trucks or vans get a signal. Numerous studies have optimised models for trash collection frequency and route planning based on Genetic Algorithm (GA) and hybrid forms of it. It was GA who made improvements to the route that Krol and his colleagues had taken to collect domestic electrical and electronic debris.To save money, GA reduced the number of collection vehicles, trucks, and workers. Users were encouraged to participate in the scheduling of waste pickup requests in order to build efficient routes. Garbage collection routes were optimised using GA and GIS by Amal et al. (2018).Research changed the Dijkstra algorithm

in GIS and then used GA findings to estimate the optimal route in order to locate the best possibilities. Fuel consumption was cut by 3 percent, operational distance was cut by 8 percent and travel time was decreased by 38% as a result of the suggested technique.

Collection

Garbage collection through permitted channels reduces contamination from dangerous substances derived from various constituents. In order to make garbage collection as convenient as possible for the inhabitants, the collection schedule must be clearly communicated, and the waste bins must be located in the most efficient manner. There are numerous methods for gathering trash. They include stationary waste collection at municipal garbage collection facilities, EEE stores, and mobile waste collection at curbside recycling stations and mobile terminals in high-traffic areas. Robotic waste sorting is now being implemented at landfills. Automated intelligence equipment is progressively taking the role of manual garbage sorting procedures. One day's work for these multitasking robots can sort tonnes of trash. Tin foil and paper are easily distinguishable by these robots' computer vision programmes, which allow them to operate autonomously. In a wide range of fields, such massive systems hold immense potential. No one else has employed regression models and ANN to route garbage collection. GIS route optimization and neural networks were used to study the impact of waste content and weight on optimal vehicle routes and emissions, as well as the best possible routes. Ferreira and coworkers used MLR and ANN models to predict the collection frequency needed at various sites. Empty bin locations were avoided, which reduced the impact on the environment and reduced the amount collected. According to the hauling truck capacity and the requirements for collection at various locations, an AIS model was created to optimise the trash collection time with vehicle workload.

Disposal

A research employing DTs to detect illegal trash disposal discovered over 500 trucks that may have been involved. Another study used rough sets to develop a cost-effective waste allocation strategy for already-existing processing and disposal facilities. Single-chamber, drum, and brick incinerators are designed to address the demand for public health protection when more advanced technologies are not viable to build and operate. AI-powered recycling technology is predicted to revolutionise trash management. This will have a huge impact on environmental protection and the development of a more prosperous and environmentally sound future for everyone concerned.

Future Perspectives

The majority of AI-based MSWM systems are still in the R&D phase.The commercialization of AI-based initiatives will aid in the achievement of long-term development goals and the preservation of the natural environment.A lot more research is needed on how to construct

affordable AI-based solutions before these technologies can fully realise their full potential.Future trash management will be more efficient and accurate if AI-based trash management is used. This will allow for more efficient and accurate sorting, cost-effective transportation, planned resource recovery, and rational waste disposal.AI-based systems that can be used in low-income countries to reduce waste and improve public health require careful planning.AI-based advancements will allow for improved environmental monitoring and management.

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