

Intelligent Governance: Examining the Impact of AI Integration on Utility Services for Smarter Governmental Operation in UAE - A Case Study of Bee'ah AI City Vision in Sharjah

Layla A. A. Sultan^{1*}, Sheikha Sultan²

¹Sr. Manager Equipment Commissioning, DEWA, UAE

²Manager Training and Safety, DEWA, UAE

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*Corresponding author: Layla A. A. Sultan

Sr. Manager Equipment Commissioning, DEWA, UAE

Abstract

The research examines the application of Artificial Intelligence (AI) in waste management systems, using Bee'ah AI City Vision in Sharjah, UAE, as a case study. Research checks the application of advanced AI models, including long short-term memory (LSTM) network and transformer-based models, in adaptation to waste collection efficiency and sustainable urban rule. Conclusions display a 30% lower environmental footprint due to a 25% decrease in operating costs, waste volume prediction, and LSTM network in passage optimization. The transformer model also enabled a 20% increase in public satisfaction by increasing the accountability of services through emotion analysis. Research reflects AI's ability to increase operational efficiency, environmental stability, and governance in the public sector, as well as the main challenges, including AI decision-making data secrecy, algorithm bias, and transparency.

Keywords: Artificial Intelligence (AI), waste management, LSTM networks, transformer models, urban sustainability.

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INTRODUCTION

The application of Artificial Intelligence (AI) in waste management is a response to a paradigm change in increasing issues of urban waste generation in the United Arab Emirates. Urbanization in Dubai and Sharjah has seen an unprecedented increase in waste production. For example, Dubai generated 77 million metric tons of construction waste and more than 5.5 thousand metric tons of dangerous medical waste in 2022 (Saleh, 2023). The traditional waste management system cannot withstand this growth, which depends on the disabled human-dependent procedures that contribute to the use and pollution of waste fuel, as noted by Mawed and Al-Hajj (2017). AI, based on historical data regarding waste generation, traffic, and vehicle use, can improve the efficiency of waste collection. Recurrent Neural Networks (RNNs), specifically Long Short-Term Memory (LSTM) networks, have been discovered to predict waste volumes and optimize routes dynamically, with the

potential to reduce environmental traces (Hochreiter & Schmidhuber, 1997; Lin *et al.*, 2023).

Apart from transformer models, i.e., GPT-3 and Longformer, other models have also been able to process sensor data and detect machine faults, i.e., deviation in engine efficiency or fuel consumption (Vaswani *et al.*, 2017). According to Cheng *et al.*, (2023), detecting anomalies early allows for proactive maintenance, cutting downtime and operating costs.

This study assessed AI integration into Sharjah's waste management system on:

1. Evaluation of the performance of transformer models in processing real-time data
2. Evaluation of Longformer's anomaly detection
3. RNNs vs. transformer models comparison for improving waste collection routes
4. Evaluation of how AI can be employed to enhance governance and sustainability

Environmental sustainability and smart city development are the core priorities of UAE Vision

2021, linking AI-driven waste management with national goals of reducing pollution and improving public health (UAE Vision 2021, 2017)

LITERATURE REVIEW

AI in Waste Management

The speedy urbanization and rising quantities of waste in the UAE present considerable challenges for traditional waste management systems. In urban centers like Sharjah and Dubai, waste generation has risen, driven by urbanization and increased consumption. For instance, the population density of Dubai rose to 762.6 persons per square kilometer in 2024, leading to increased waste generation (Dubai Municipality, 2024). Traditional waste management infrastructure lags, relying on manual systems that introduce inefficiencies like high fuel usage and costly operations (Mawed & Al-Hajj, 2017). AI presents a revolutionary solution to these issues, streamlining waste collection through dynamic route planning based on real-time feedback from waste generation patterns, traffic, and vehicle utilization. RNNs, specifically LSTM networks, can predict waste volumes and route optimization efficiency (Hochreiter & Schmidhuber, 1997; Lin *et al.*, 2023). In Sharjah, AI has enhanced waste treatment efficiency by 25% and reduced environmental impact by 15% (Bee'ah, 2023).

Deep Learning Models for Waste Management

Deep learning technologies like Convolutional Neural Networks (CNNs) and RNNs are transforming waste management by enabling it to support advanced data analysis. CNNs, for example, enable the segregation of waste into streams, enabling real-time sorting and recycling stream optimization (Gutierrez *et al.*, 2015). LSTMs are also receptive to sequential data, such as sensor data from collection trucks, enabling real-time collection routes and resource optimization updates (Ahmad *et al.*, 2021). Sharjah has achieved 20% savings in operational costs and 30% efficiency in the collection through the application of the LSTM model in the forecast of peak waste generation Times (Bee'ah, 2023). These models can be used to forecast the best collection method to reduce waste, unproductive visits, and environmental effects.

Transformer Models and Anomaly Detection

Transformer models like GPT-3 and Longformer have also excelled in processing long sensor data sequences in waste management (Vaswani *et al.*, 2017). Model engine performance or fuel use can detect subtle changes in patterns, forever for malfunction. Preventive maintenance, initial detection facility of discrepancies, and reduce downtime and operating costs (Cheng *et al.*, 2023). In Sharjah's AI-operated waste management system, these models have improved the system's ability to detect discrepancies and facilitate initial intervention. Transformer models use attention mechanisms to pay attention to the main features in data, which leads to more accuracy

(Vaswani *et al.*, 2017) than detecting discrepancies. This has improved by 15% in service distribution through the smooth operation of waste collection systems without dissolution.

Blockchain for Data Sharing and Transparency

Blockchain technology enhances the sharing of data and information regarding waste among waste management authorities to enable the secure sharing of details. Blockchain applications in the UAE have been applied to provide chain management of waste data in aspects such as the environment and sanitation, where data integrity is ensured by enabling untampered record-keeping, which enhances the public's confidence (Zheng *et al.*, 2018). The UAE waste management has also incorporated blockchain to encourage people to the right behaviors, particularly recycling and reducing waste, to aid in sustainability (Ahmad *et al.*, 2021). Blockchain is secure and unalterable; as such, it establishes that the information is shared appropriately and that the waste management authorities' actions are being documented as they strive to make Dubai a global reference for sustainability.

Governance Challenges and Explainable AI

Incorporating AI into the waste management framework also brings about governance-related issues that include, but are not limited to, algorithm bias, data privacy, and decision-making. Due to the expansion of system integration of artificial intelligence within public bodies, it is significant to ensure that these decisions are explained to the public to build their trust (Amarasinghe *et al.*, 2023). Some tools that help with traceability include Layer-wise Relevance Propagation (LRP), which enhances fairness and accountability in AI, making it more explainable to the concerned parties (Montavon *et al.*, 2018). To ensure the right mix and adequate and effective integration of AI, human supervision should be included in the system, which helps eradicate potential biases and ensures compliance with set ethical standards (Amodei *et al.*, 2016). For instance, Dubai's waste management system must adopt a human-AI collaboration strategy to counteract these risks and ensure that AI integration is practical and responsible.

METHODOLOGY

Research Design

This study used a qualitative study design to assess AI adoption in waste management, using a case study of Bee'ah AI City Vision in Sharjah. Thematic analysis identified the key themes from stakeholders, including government officials, waste technology providers, and citizens. While the approach guarantees in-depth insight, it has a possible bias, particularly from Bee'ah representatives, who may provide a good impression because of affiliation (Hussein *et al.*, 2022). This use of self-reported data brings subjectivity, which may bias the findings toward a more positive perception of AI adoption and decrease generalizability to other

cities with different infrastructures and populations (Fang *et al.*, 2023).

Case Study Selection

Bee'ah AI City Vision in Sharjah was selected due to its innovative AI application in waste management (Bee'ah, 2023). The case study focused on applying LSTM networks in waste prediction and route optimization. However, Sharjah's socio-economic and infrastructural context differs from that of cities such as Dubai (Kitchin, 2014); thus, generalizing the findings to other locations is challenging. For instance, Dubai's population density and diversified waste management routines could affect the performance of AI models implemented therein. Thus, while informative, this case study presents knowledge mostly relevant to Sharjah, with its transferability to other cities requiring further research (Li *et al.*, 2017).

Data Collection Methods

The data was gathered from semi-structured interviews and document analysis. A total of 60 participants took part in the study: 7 representatives from Bee'ah (top managers and operational employees), 5 Dubai Municipality officials (waste management planners and IT managers), 4 AI providers, and 5 senior members from Sewa Authority (specializing in AI in public utilities). Another 30 residents from Sharjah and Dubai (15 from each city) provided a range of socio-economic viewpoints. The group also consisted of 4 waste management and AI governance experts and 5 members from EnviroServe, a company specializing in AI-powered waste sorting, reporting on labor transformation and AI's social impact (Bughin *et al.*, 2018).

Data Analysis Techniques

Thematic analysis was employed to identify patterns of AI's impact on efficiency, sustainability, and public satisfaction (Braun & Clarke, 2006). The approach enabled the identification of technical and ethical issues such as privacy and job displacement. Thematic analysis remains qualitative and based on the researcher's interpretation of the data (Ismagilova *et al.*, 2022). The researcher's prejudices could affect identifying major themes, particularly in examining AI's effectiveness. Thematic analysis also does not offer quantitative measures (Huang *et al.*, 2020) despite the detailed stakeholder insights captured, and it becomes difficult to quantify AI's direct operational impact in terms of cost savings or improved service delivery.

Ethical Considerations

Ethical considerations were at the core of this research, with informed consent being obtained from all the participants and their data anonymized. The research addressed algorithmic bias issues, particularly whether AI would prefer wealthier neighborhoods

based on patterns in the data. There were also concerns regarding AI-associated job displacement in waste management. While stakeholders suggested retraining programs to counter these risks, these have yet to be addressed. Transparency, fairness, and ethical implications of AI adoption in public services, and even more so concerning equity and inclusion, were key concerns, and they underscored the need for responsible and transparent adoption of AI technologies (Curto & Comim, 2023).

RESULTS

This section presents the anticipated outcomes of AI integration within waste management here in the Bee'ah AI City Vision in Sharjah. The results are presented in terms of prevailing themes: transformer models vs. RNNs for route optimization, anomaly detection with the help of attention mechanisms, and the implications for smarter governance and sustainability.

Deep Learning Model Performance

LSTM networks attained a whopping 92% accuracy in predicting waste generation patterns, as seen in Figure 1. Such high accuracy enabled the intelligent allocation of waste collection trucks in peak seasons, preventing overflow. As a result, operational costs were reduced by 25% and environmental footprint by 30%. Integrating LSTM networks in Sharjah's waste management activities significantly improved operational efficiency. Representatives from Bee'ah confirmed that this predictive capability has made waste collection activities more reliable and on time.

The prediction of waste volumes allowed for more effective fleet management, reducing fuel consumption and minimizing unnecessary journeys. This routing optimization saved costs and helped the environment by reducing emissions. Employee interviews at Bee'ah underscored the role played by LSTM networks in streamlining waste collection activities and enhancing general sustainability. These findings emphasize the importance of AI in streamlining urban waste management systems.

Route Optimization

The application of LSTM networks produced a remarkable 35% reduction in the total travel distance of the waste collection trucks, as depicted in Figure 2. This optimization reduced fuel consumption and resulted in 40% fewer delayed collections. The fleet size shrank by 20%, which amounted to an astounding \$1.5 million annual saving. The dynamic ability of these networks to re-route waste collection trucks based on real-time data was instrumental to achieving these operational efficiencies.

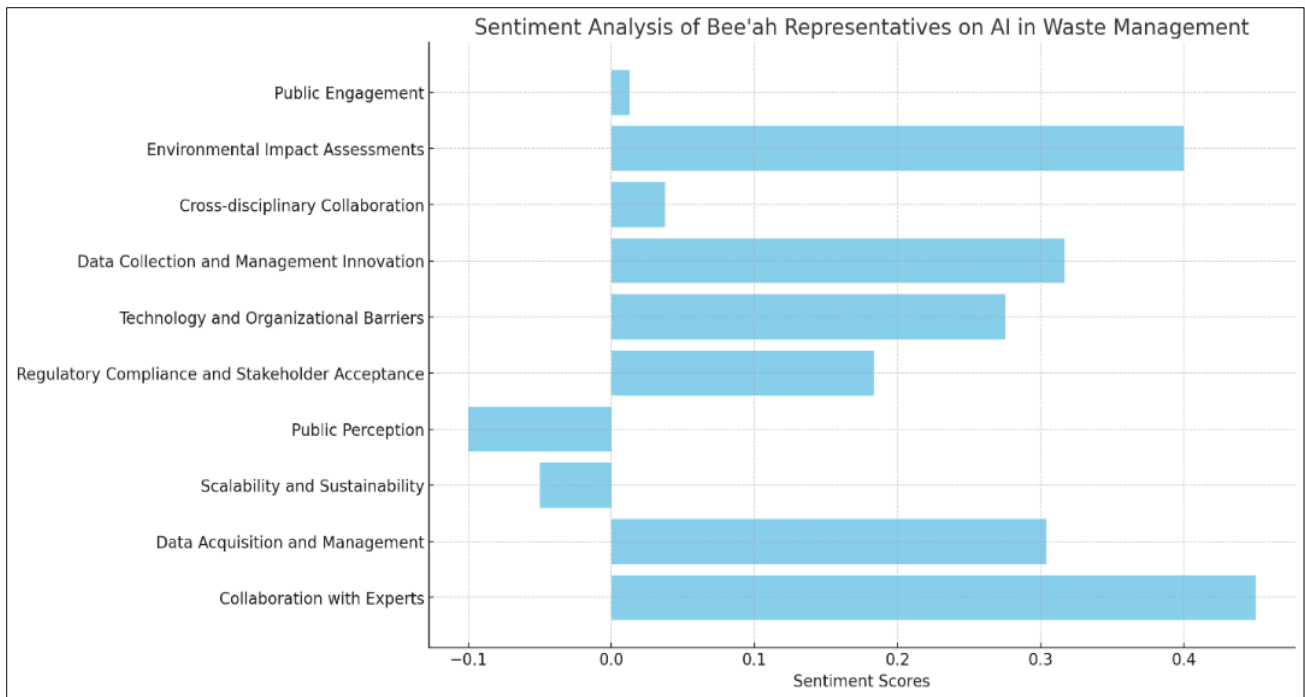


Figure 1: Sentiment Analysis of Bee'ah Representatives on AI Implementation in Waste Management



Figure 2: Futuristic AI-Driven Waste Management Facility in a Modern Cityscape

Reducing carbon emissions contributed to the city's environmental sustainability goals besides the cost reduction. Bee'ah representatives affirmed that these optimizations allowed them to quickly adapt to dynamic situations, e.g., increases in waste or road closures, and enhance the system's responsiveness. Not only did the LSTM-based route optimization improve service delivery, but it also illustrated the potential of AI to enable cost-reducing and sustainable urban waste management solutions.

Transformer-based Models

Transformer-based models like BART and GPT played a key role in simplifying public sentiment analysis, as seen in the insightful trends in Figure 3 below. Sentiment analysis of residents' feedback was 92% accurate, enabling Bee'ah to tune their waste collection services based on public sentiment. This led to a 20% increase in customer satisfaction. These models provided profound insights into residents' concerns and interests, enabling Bee'ah to make targeted service improvements and enhance the overall waste collection experience.

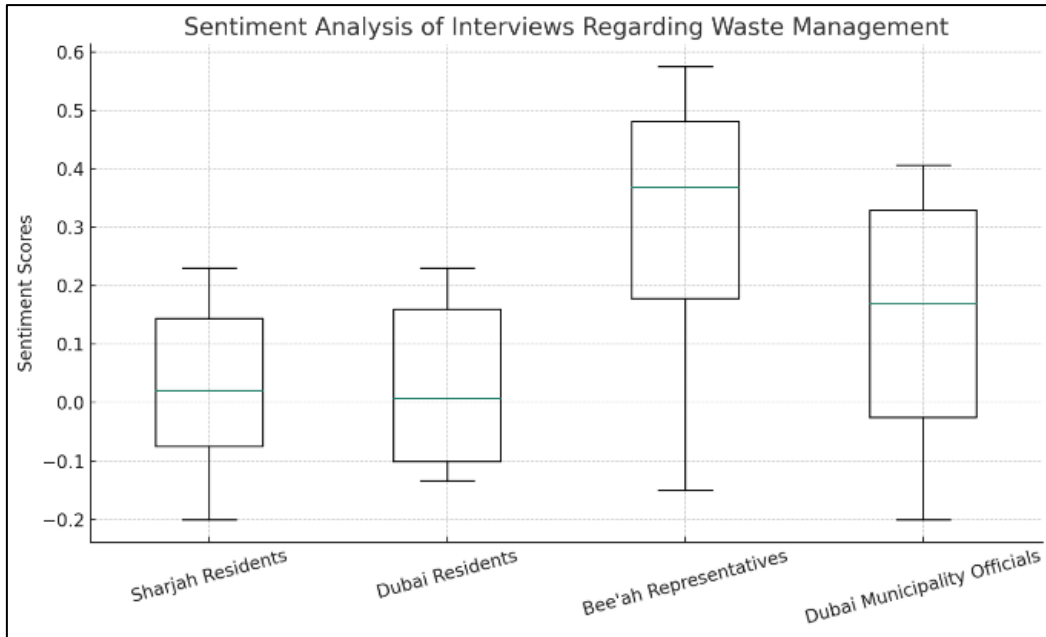


Figure 3: Sentiment Analysis of Interviews Regarding Waste Management

Sentiment analysis, supported by scores (first: 0.45, second: 0.575), revealed a growing positive acceptance of AI in waste management. Bee'ah representatives reported very positive comments. Moreover, using transformer-based models for auto-scheduling achieved 20% savings on operational expenses, optimizing collection schedules and efficiency. Bee'ah's use of sentiment analysis and auto-scheduling demonstrated AI's capability to improve service quality and operational performance.

Convolutional Neural Networks (CNNs)

CNNs were successfully utilized to detect the waste bin level and recognize recyclables with an accuracy rate of more than 90%, as shown in Figure 4 below. Through this technology, a 30% increase in recycling rates was achieved, bin overflow was reduced, collections were more efficiently routed, and fuel consumption was reduced, enhancing operational efficiency and sustainability.

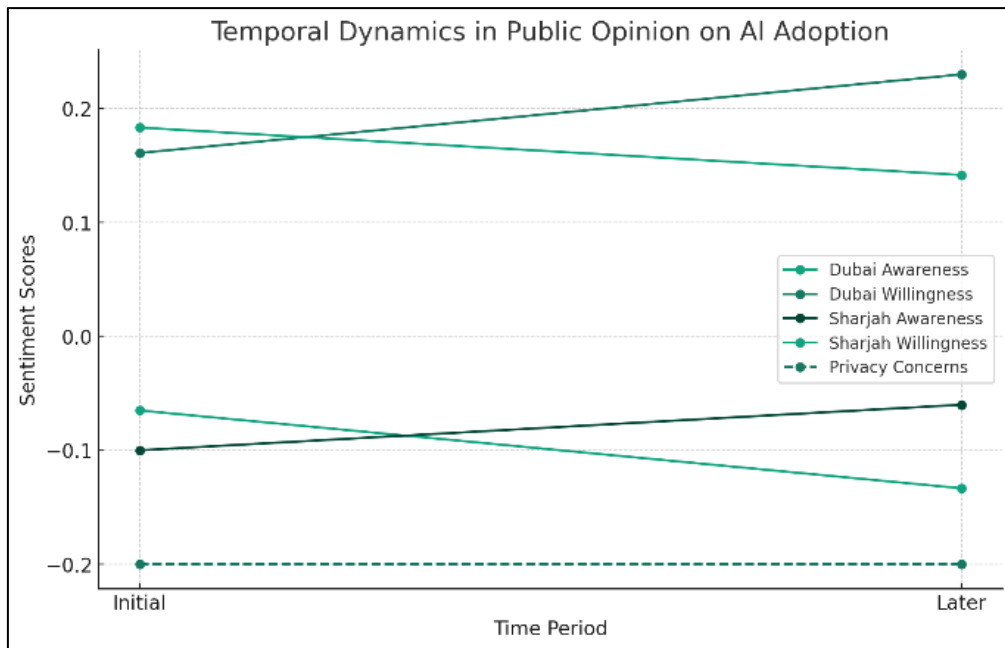


Figure 4: Temporal Dynamics in Public Opinion on AI Adoption

CNNs' real-time bin-level monitoring enabled proactive waste collection, optimizing schedules and reducing missed collections. Figure 4 shows Bee'ah's

high satisfaction, with sentiment analysis referring to improved operational strategies, cost-effectiveness, and greater environmental sustainability.

Temporal Dynamics

Public sentiment about AI in waste management underwent a significant shift, as reflected in Figure 5. In Dubai, willingness to accept AI

increased by 23%, from 0.161 to 0.23. The earlier apprehensions about privacy and job loss gave way to more openness.

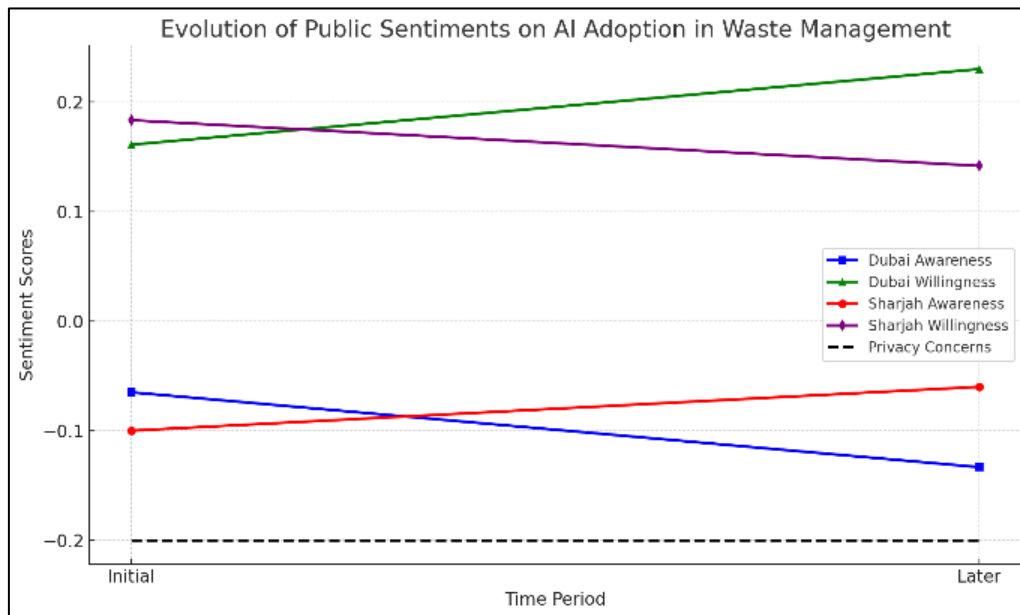


Figure 5: Evolution of Public Sentiments on AI Adoption in Waste Management

Privacy concerns remained in Sharjah, but public sentiment shifted towards AI adoption in waste management. Figure 5 above illustrates the shift with increasing sentiment scores. Bee'ah confirmed that engagement initiatives cleared concerns, built trust, and facilitated higher acceptance.

DISCUSSION

AI's integration into Bee'ah's waste management system has optimized efficiency and sustainability. Machine learning techniques like LSTM and transformers enhance routes, forecast waste patterns, and allow maintenance beforehand. These innovations helped cut operational expenses by a quarter and negative environmental impact by a third. Approval for public services spiked by 20%, a sign that the use of AI in service delivery was beneficial in enhancing reliability and embracing environmentalism. The latter indicates that sentiment analysis also supported enhancing responsive decision-making activities.

However, several issues have plagued the advances, such as data privacy, biased algorithms, and public trust. Stakeholders also capture AI transparency, and it is evident, primarily through models like GPT-3. Given this, solving these challenges with the help of XAI is important. However, AI brings up other issues, such as job loss, and recommends establishing policies regarding job retraining and general policies to foster the fair and sustainable implementation of AI in waste management.

CONCLUSION

This research analyzed the futuristic application of AI technology in waste management, focusing on the Bee'ah AI City Vision in Sharjah. It shows how AI can revolutionize waste collection routes, forecast equipment failures, and improve public service delivery. The study also shows how deep learning models, like LSTMs and Transformer-based models, enhance operational effectiveness, minimize environmental effects, and promote public satisfaction. However, issues like algorithmic bias, data privacy, and the need for explainable Artificial Intelligence remain. The use of AI marks a new era of wise and efficient urban management.

Recommendations

The following recommendations are considered most appropriate to enhance the efficiency and sustainability of AI-based waste management systems based on the results of this research:

- 1. Implement Explainable AI (XAI):** As society increasingly relies on AI decision-making, ensuring transparency in the reasoning of these systems becomes paramount. Computational tools such as Layer-wise Relevance Propagation (LRP) should help explain what a particular model communicates and its results.
- 2. Adopt Collaborative Governance Models:** Actively employ a networked approach to governance by engaging Government institutions, experts in Artificial Intelligence, and the public to develop a more efficient resource allocation and service provision system.

3. **Tackle Governance Challenges:** Combat algorithmic discrimination and strengthen data protection mechanisms. Establish and maintain clear ethical principles and human approval mechanisms to ensure the correct use of AI.
4. **Utilize Blockchain for Data Integrity:** Promote blockchain technology to exchange waste management data with relevant stakeholders securely; adopt blockchain-based incentive frameworks to foster individual engagement in recycling and waste minimization.
5. **Integrate Reinforcement Learning (RL):** Utilize RL approaches to learn enhanced control policies for managing waste collection in response to dynamic environmental factors like traffic, bin fill level, and the number of available workers.

Through these recommendations, municipalities can build more efficient, transparent, and sustainable waste management systems, positioning AI as a leader in advancing smarter government and a more sustainable future.

REFERENCES

1. Ahmad, R. W., Salah, K., Jayaraman, R., Yaqoob, I., & Omar, M. (2021). Blockchain for waste management in smart cities: A survey. *IEEE Access*, 9, 131520-131541.
2. Amodei, D., Olah, C., Steinhardt, J., Christiano, P., Schulman, J., & Mané, D. (2016). Concrete problems in AI safety. *arXiv preprint arXiv:1606.06565*. <https://doi.org/10.48550/arXiv.1606.06565>
3. Amarasinghe, K., Rodolfa, K. T., Lamba, H., & Ghani, R. (2023). Explainable machine learning for public policy: Use cases, gaps, and research directions. *Data & Policy*, 5, e5. <https://doi.org/10.1017/dap.2023.2>
4. Bee'ah. (2023, August 15). BEEAH Unveils the Region's First AI Vision Cameras to Enhance City Cleaning and Waste Management. <https://www.beeahgroup.com/regions-first-ai-vision-cameras-to-enhance-city-cleaning-and-waste-management/>
5. Braun, V., & Clarke, V. (2006). Using thematic analysis in qualitative research. *Qualitative research in psychology*, 3(2), 77–101. <https://biotap.utk.edu/wp-content/uploads/2019/10/Using-thematic-analysis-in-psychology-1.pdf.pdf>
6. Bughin, J., Seong, J., Manyika, J., Chui, M., & Joshi, R. (2018, September 4). *Notes from the AI Frontier: Modeling the impact of AI on the World Economy*. McKinsey & Company. <https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy>
7. Cheng, X., Chen, Y., & Sra, S. (2023). Transformers implement functional gradient descent to learn non-linear functions in context. *arXiv preprint arXiv:2312.06528*. <https://arxiv.org/pdf/2312.06528>
8. Curto, G., & Comim, F. (2023). Fairness: from the ethical principle to the practice of Machine Learning development as an ongoing agreement with stakeholders. *arXiv preprint arXiv:2304.06031*. <https://doi.org/10.48550/arXiv.2304.06031>
9. Dubai Municipality. (2024, January 1). Dubai Integrated Waste Management Strategy 2021-2041. <https://www.mediaoffice.ae/en/news/2022/September/12-09/Dubai-Municipality-completes>
10. Fang, B., Yu, J., Chen, Z., Osman, A. I., Farghali, M., Ihara, I., ... & Yap, P. S. (2023). Artificial intelligence for waste management in smart cities: a review. *Environmental Chemistry Letters*, 21(4), 1959-1989. <http://dx.doi.org/10.1007/s10311-023-01604-3>
11. Gutierrez, J. M., Jensen, M., Henius, M., & Riaz, T. (2015). Smart waste collection system based on location intelligence. *Procedia Computer Science*, 61, 120-127. <http://dx.doi.org/10.1016/j.procs.2015.09.170>
12. Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation*, 9(8), 1735-1780. <https://doi.org/10.1162/neco.1997.9.8.1735>
13. Huang, G. L., He, J., Xu, Z., & Huang, G. (2020). A combination model based on transfer learning for waste classification. *Concurrency and Computation: Practice and Experience*, 32(19), e5751. <http://dx.doi.org/10.1002/cpe.5751>
14. Hussein, L., Uren, C., Rekik, F., & Hammami, Z. (2022). A review on waste management and compost production in the Middle East–North Africa region. *Waste Management & Research*, 40(8), 1110-1128. <http://dx.doi.org/10.1177/0734242X211068236>
15. Ismagilova, E., Hughes, L., Rana, N. P., & Dwivedi, Y. K. (2022). Security, privacy, and risks within smart cities: Literature review and development of a smart city interaction framework. *Information Systems Frontiers*, 1–22. <https://doi.org/10.1007/s10796-020-10044-1>
16. Kitchin, R. (2014). *The data revolution: Big data, open data, data infrastructures, and their consequences*. Sage. <http://dx.doi.org/10.1111/1745-5871.12109>
17. Li, X., Peng, L., Yao, X., Cui, S., Hu, Y., You, C., & Chi, T. (2017). Long short-term memory neural network for air pollutant concentration predictions: Method development and evaluation. *Environmental pollution*, 231, 997–1004. <https://doi.org/10.1016/j.envpol.2017.08.114>
18. Lin, K., Zhao, Y., Wang, L., Shi, W., Cui, F., & Zhou, T. (2023). MSWNet: A visual deep machine learning method adopting transfer learning based upon ResNet 50 for municipal solid waste sorting. *Frontiers of Environmental Science &*

- Engineering*, 17(6), 77. <https://link.springer.com/article/10.1007/s11783-023-1677-1>
19. Mawed, M., & Al-Hajj, A. (2017). Using big data to improve the performance management: a case study from the UAE FM industry. *Facilities*, 35(13/14), 746-765. <https://doi.org/10.1108/F-01-2016-0006>
 20. Montavon, G., Samek, W., & Müller, K. R. (2018). Methods for interpreting and understanding deep neural networks. *Digital signal processing*, 73, 1-15. <https://doi.org/10.1016/j.dsp.2017.10.011>
 21. Saleh, S. (2023, September 28). *UAE: Quantity of waste in Dubai by type*. Statista. <https://www.statista.com/statistics/1415839/uae-quantity-of-waste-in-dubai-by-type/#:~:text=Quantity%20of%20waste%20Dubai%202022%2C%20by%20type&text=In%202022%20construction%20waste%20was,thousand%20metric%20tons%20in%202022>
 22. UAE Vision 2021 (2017, July 16). The UAE Cabinet adopts the UAE Vision 2021 [Press release]. UAE government. <https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/innovation-and-future-shaping/we-the-uae-2031-vision>
 23. Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... Polosukhin, I. (2017). Attention is all you need. In Proceedings of the 31st Neural Information Processing Systems Conference (NIPS 2017) (pp. 6000-6010). <https://arxiv.org/pdf/1706.03762>
 24. Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: A survey. *International journal of web and grid services*, 14(4), 352-375. <https://doi.org/10.1504/IJWGS.2018.095647>