


Chapter 11

Data–Driven Waste Management in Smart Cities: Predicting, Preventing, and Processing

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ABSTRACT

Smart cities are grappling with increasing urban waste management challenges in practical applications that can reduce processing, disposal, and environmental impacts. This chapter discusses urban waste management through the lens of a data-driven process that involves predictive analytics, preventive measures, and intelligent processing systems. Technologies include (but are not limited to) Internet of Things, Machine Learning, and Cloud Computing to optimize waste collection, reduce environmental impact, and improve energy efficiency. By utilizing real-time data, cities can act proactively by enhancing stakeholder engagement, optimizing routing for waste collection, delivering services on time, and making better deci-

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sions. This chapter also covers case studies, proposes a technological framework for smart waste management practices and systems, and looks at possibilities for future work and how to scale up practical applications, including integration into broader smart city governance.

INTRODUCTION

Urbanization is a process that is occurring all over the world, prompted by an ever-growing demand for infrastructure, resources, and environmental sustainability. Currently, one of the most pressing urbanization issues is waste management, a complicated, multi-dimensional responsibility involving the collection, sorting, treatment & disposal, and recycling of waste. The fast-growing urban populace and consumption activities have already gone beyond the basic rules of waste management, thus creating a further need for design data-improved waste management systems. In this context, the advent of smart cities has emerged as a transformative idea for altering urban productivity through the incorporation of advanced technologies such as Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, and blockchain, thereby improving the quality of life for urban residents (Silva et al., 2018; Al Nuaimi et al., 2015).

The use of digital technologies as applied to urban systems is an integral component of smart cities. Al Nuaimi et al. (2015) emphasise that the application of big data enables predictive insights and operational efficiency in multiple urban domains, including waste management. Therefore, the transition must progress from a reactive waste management model to a proactive waste management model enabled by technology, to save operating costs, reduce environmental impact, and service sustainability goals. Likewise, the circular economy paradigm has become important in the emphasis on limiting the waste the economy generates and intending to maximise the re-use of materials as products and resources, which situates waste management as an important component in smart and sustainable city thinking. (Mazur-Wierzbicka, 2021; Goyal & Gupta, 2024).

Nonetheless, there are still several research gaps. Mora et al. (2018) pointed out that despite significant investments in smart cities over the last two decades, many implementations are still fragmented, siloed, and fixed to legacy systems. Waste models often do not interact with real-time data, specifically data analytics, user behaviour, and smart infrastructure. Liu and Zheng (2023) state that sustainable municipal solid waste treatment still operates on significant systemic inefficiency, especially in emerging economies, since there will often be limited data availability and limits on technical capabilities. Incorporating citizen participation and social

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