With the growing adoption of electric vehicles (EVs), numerous logistics companies have considered integrating EVs into their fleets to lower greenhouse gas (GHG) emissions, thereby cutting costs associated with CO2 emissions per kilometer. EVs offer several benefits over internal combustion engine vehicles (ICEVs): (i) they emit no local GHGs; (ii) they generate minimal noise; (iii) they can be charged using renewable energy; and (iv) they are not affected by volatile oil prices. EVs come in two primary types: battery electric vehicles (BEVs), which rely solely on onboard batteries for power, and hybrid electric vehicles (HEVs), which can use both internal batteries and other energy sources, typically an internal combustion engine. Plug-in HEVs (PHEVs) can also be recharged by connecting to an external power supply[1].

Due to the constraints of battery capacity, delivery BEVs can travel between 160-240 km on a full charge, which is significantly less than the 480-650 km range typical of ICEVs. To achieve a similar range, BEVs need to visit charging stations (CSs) more often. Currently, the road network infrastructure lacks sufficient CSs, and future plans should consider their locations and energy demands[2]. To make an empty BEV operational again, it must recharge at a CS. This can be done in two ways: (i) by swapping out the depleted battery for a fully charged one at a Battery Swapping Station (BSS), or (ii) by plugging in at a CS to recharge. The first method takes about the same amount of time as refueling an ICEV, while the second depends on several factors, including the state of charge (SoC) when arriving at the CS, the desired SoC upon departure, and the charging rate[3].

In the 21st century, the rapid increase in greenhouse gas (GHG) emissions has resulted in a continuous rise in global average temperatures. The transportation sector, responsible for more than 23% of global GHG emissions, consumes a significant portion of the world's oil production[4]. Electric vehicles (EVs) offer a promising solution to improve climate conditions due to their environmentally friendly features, including low GHG emissions, higher energy efficiency, and reduced noise pollution[5]. The GHG emissions associated with EVs can be cut to one-fifth of what is produced by fossil-fuel-powered vehicles, and the cost of electricity consumption can be reduced to as little as one-tenth of the original value. As a result, adopting electric vehicles is recommended as a technological approach to mitigating environmental degradation and combating climate change[6].

Despite challenges such as limited driving range and lengthy charging times, the global sales of electric vehicles (EVs) continue to rise steadily, particularly in the Chinese market, where the growth rate has exceeded 50% annually in recent years. The electric vehicle routing problem (EVRP) has emerged as a significant research focus in modern logistics, attracting attention from both academia and industry. Various EVRP models have been developed to address different fields, considering the specific characteristics and application scenarios of EVs[7].

Solid waste encompasses materials commonly referred to as rubbish, trash, junk, or garbage, depending on the type and regional terminology, and originates from manufacturing processes or activities within communities and households[8]. Managing solid waste has become a significant environmental challenge because improper disposal can have harmful effects on both society and the environment. This issue is further aggravated by the rapid rate of waste generation, driven by urbanization and population growth, insufficient funding, poor waste disposal practices among citizens, and a lack of political commitment[9].

Solid waste management encompasses the stages of generation, collection, transportation, treatment, value recovery, and final disposal. Any inefficiencies in the design of these processes can lead to higher operational costs and contribute to environmental pollution. For example, the collection and transportation of waste alone can constitute 60% to 80% of the total costs associated with solid waste management. Ineffective waste collection and transportation can significantly impact management companies by driving up operational expenses and, in turn, diminishing profits[10].

Waste collection and management practices differ across countries, with fixed station and house-to-house collection methods. In China, the fixed station approach is used, where residents dispose of their waste at designated dump sites. From these sites, the waste is transported to treatment facilities and then to final disposal locations [11]. Conversely, in Taiwan, fleets of garbage trucks follow fixed routes daily and nightly, making scheduled curbside pickups. Similarly, India employs house-to-house collection on fixed schedules, where trucks play distinctive music to alert residents to bring their waste to designated drop-off points[12].

Waste management encompasses more than just waste collection and routing; it involves a comprehensive process that includes the generation, collection, transportation, treatment, value recovery, and final disposal of waste. Ineffective waste management practices, such as inefficient transportation or routing, can lead to increased costs. The rising global population and the resulting increase in household waste have heightened interest among governments and researchers in addressing the challenges of waste collection and routing. Consequently, various models have been developed to optimize these processes[10].

The generation of municipal solid waste (MSW) is on the rise due to rapid economic growth, urbanization, and an increasing population. Global MSW production is projected to reach 3.40 billion tonnes by 2050 [13, 14]. This surge in waste necessitates that waste management departments seek effective and sustainable methods for its collection and disposal. Electric vehicles (EVs) offer a viable solution for achieving sustainability goals, as they produce lower greenhouse gas emissions and reduce air pollution. Known for their energy efficiency and low carbon emissions, EVs have been strongly advocated by countries such as China, the United States, Japan, and the EU[15]. However, data indicate that the adoption rate of EVs is slowing due to challenges like recharging limitations, higher costs, and shorter driving ranges. As a result, optimizing EV routes to meet specific requirements while minimizing overall costs has become critically important[16].

China faces significant challenges in waste management due to the rapid economic development, which has led to mass production and consumption. Additionally, the growing urbanization complicates the management of municipal solid waste (MSW), particularly in densely populated cities. MSW is considered the most complex type of solid waste, encompassing waste from residential, commercial, and institutional sources, while excluding industrial, construction, and hazardous waste [17, 18].

Approximately 75–80% of the solid waste management budget is allocated to collection and transportation costs, so even minor improvements in waste collection can lead to significant cost reductions. Additionally, the growing societal focus on sustainability demands an active organizational approach. In this context, municipal solid waste (MSW) collection management organizations encounter significant challenges in promoting the sustainable planning and operation of the collection process [19].

Globally, sustainable development is commonly understood to encompass three core pillars: economic growth, environmental protection, and social equity. To effectively tackle the challenges of sustainable development, organizations must manage the waste collection process by simultaneously considering economic, environmental, and social benefits[20].

Carbon dioxide emissions are a primary criterion for assessing the environmental impact of municipal solid waste (MSW) collection. Transportation, a key component of the MSW collection process, is a major consumer of energy and a significant contributor to carbon dioxide emissions in China [21]. These emissions have both direct and indirect effects on public health and global warming. In 2005, the Chinese government committed to reducing carbon dioxide emissions per unit of GDP by 40%–45% by 2020 [22].

Electric vehicles offer significant potential for reducing both transportation costs and pollution compared to fossil-fuel-powered engines. However, their limited driving range, lengthy charging times, and the scarcity of charging stations make charging operations more complex and critical than refueling for traditional vehicles [23]. The electric vehicle routing problem (EVRP) is an extension of the traditional vehicle routing problem (VRP) that focuses on optimizing routes for electric vehicles while accounting for battery limitations and charging requirements [24].

Electric vehicles (EVs) encompass battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and fuel-cell electric vehicles (FCEVs), which include a wide range of transport modes such as cars, vans, trucks, electric trains, airplanes, boats, and two-wheelers. In this paper, we focus on EVs as commercial road BEVs. EV fleets can be utilized for various transportation needs, including public transit, home deliveries from grocery stores, postal and courier services, and distribution operations across different industries. The primary benefits of EVs include zero tailpipe emissions, high efficiency, and low operating noise [25]. Additionally, EVs have fewer moving parts compared to internal combustion engine vehicles (ICEVs) and do not require regular oil changes. Regenerative braking also reduces brake wear, leading to lower maintenance costs. However, operating an EV fleet presents challenges such as limited driving range, a scarcity of recharging stations, and lengthy battery recharging times. These limitations add complexity to route planning, making the Electric Vehicle Routing Problem (EVRP) and its variations significant topics of interest in recent research [26].

The Electric Vehicle Routing Problem (EVRP) is an extension of the Capacitated Vehicle Routing Problem (CVRP), where a fleet of electric vehicles (EVs) is used in place of internal combustion engine vehicles (ICEVs). In the EVRP, the energy stored in the vehicle's battery is depleted as the vehicle travels, depending on the distance covered. To complete its route, an EV may need to recharge its battery. Recharging can occur at any battery state of charge (SoC), but charging stations are limited, and the process often requires considerably more time compared to the quick refueling stops at traditional petrol stations [25].

1. Schiffer, M., G. Walther, and S. Stütz, *Are ECVs breaking even?: Competitiveness of electric commercial vehicles in retail logistics*. 2017: GERAD, École des hautes études commerciales.

2. Martínez-Lao, J., et al., *Electric vehicles in Spain: An overview of charging systems.* Renewable and Sustainable Energy Reviews, 2017. **77**: p. 970-983.

3. Erdelić, T. and T. Carić, *A survey on the electric vehicle routing problem: variants and solution approaches.* Journal of Advanced Transportation, 2019. **2019**(1): p. 5075671.

4. Soleimani, H., Y. Chaharlang, and H. Ghaderi, *Collection and distribution of returned-remanufactured products in a vehicle routing problem with pickup and delivery considering sustainable and green criteria.* Journal of cleaner production, 2018. **172**: p. 960-970.

5. Zuo, X., et al., *A new formulation of the electric vehicle routing problem with time windows considering concave nonlinear charging function.* Journal of Cleaner Production, 2019. **236**: p. 117687.

6. Xiao, Y., et al., *Development of energy consumption optimization model for the electric vehicle routing problem with time windows.* Journal of Cleaner Production, 2019. **225**: p. 647-663.

7. Xiao, Y., et al., *Electric vehicle routing problem: A systematic review and a new comprehensive model with nonlinear energy recharging and consumption.* Renewable and Sustainable Energy Reviews, 2021. **151**: p. 111567.

8. Akhtar, M., et al., *Solid waste generation and collection efficiencies: Issues and challenges.* Jurnal Teknologi, 2015. **75**(11).

9. Xue, W., K. Cao, and W. Li, *Municipal solid waste collection optimization in Singapore.* Applied Geography, 2015. **62**: p. 182-190.

10. Sulemana, A., et al., *Optimal routing of solid waste collection trucks: A review of methods.* Journal of Engineering, 2018. **2018**(1): p. 4586376.

11. Mian, M.M., et al., *Municipal solid waste management in China: a comparative analysis.* Journal of material cycles and waste management, 2017. **19**: p. 1127-1135.

12. Liang, Y.-C., V. Minanda, and A. Gunawan, *Waste collection routing problem: A mini-review of recent heuristic approaches and applications.* Waste Management & Research, 2022. **40**(5): p. 519-537.

13. Lu, X., X. Pu, and X. Han, *Sustainable smart waste classification and collection system: a bi-objective modeling and optimization approach.* Journal of Cleaner Production, 2020. **276**: p. 124183.

14. Kaza, S., et al., *What a waste 2.0: a global snapshot of solid waste management to 2050*. 2018: World Bank Publications.

15. Zhang, S., M. Chen, and W. Zhang, *A novel location-routing problem in electric vehicle transportation with stochastic demands.* Journal of Cleaner Production, 2019. **221**: p. 567-581.

16. Verma, A., *Electric vehicle routing problem with time windows, recharging stations and battery swapping stations.* EURO Journal on Transportation and Logistics, 2018. **7**(4): p. 415-451.

17. Li, F., et al., *Changing patterns and determinants of transportation carbon emissions in Chinese cities.* Energy, 2019. **174**: p. 562-575.

18. Heidari, R., R. Yazdanparast, and A. Jabbarzadeh, *Sustainable design of a municipal solid waste management system considering waste separators: A real-world application.* Sustainable Cities and Society, 2019. **47**: p. 101457.

19. Qiao, Q., et al., *Optimization of a capacitated vehicle routing problem for sustainable municipal solid waste collection management using the PSO-TS algorithm.* International journal of environmental research and public health, 2020. **17**(6): p. 2163.

20. Sala, S., *Triple bottom line, sustainability and sustainability assessment, an overview.* Biofuels for a more sustainable future, 2020: p. 47-72.

21. Mohsenizadeh, M., M.K. Tural, and E. Kentel, *Municipal solid waste management with cost minimization and emission control objectives: A case study of Ankara.* Sustainable Cities and Society, 2020. **52**: p. 101807.

22. Wang, S., et al., *Optimization of vehicle routing problem with time windows for cold chain logistics based on carbon tax.* Sustainability, 2017. **9**(5): p. 694.

23. Kucukoglu, I., R. Dewil, and D. Cattrysse, *The electric vehicle routing problem and its variations: A literature review.* Computers & Industrial Engineering, 2021. **161**: p. 107650.

24. Schiffer, M. and G. Walther, *Strategic planning of electric logistics fleet networks: A robust location-routing approach.* Omega, 2018. **80**: p. 31-42.

25. Keskin, M. and B. Çatay, *A matheuristic method for the electric vehicle routing problem with time windows and fast chargers.* Computers & operations research, 2018. **100**: p. 172-188.

26. Hof, J., M. Schneider, and D. Goeke, *Solving the battery swap station location-routing problem with capacitated electric vehicles using an AVNS algorithm for vehicle-routing problems with intermediate stops.* Transportation research part B: methodological, 2017. **97**: p. 102-112.