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ECONOMIC ANALYSIS OF THE WASTE COLLECTION AUTOMATION WITH THE PRESKO SYSTEM

Waste management companies have been experiencing a steady increase in operational costs in recent years, driven by a combination of regulatory, environmental, and logistical factors. One of the most cost-intensive components of municipal solid waste management is waste collection, which can account for up to 70% of total system costs. At the same time, effective organization of the collection process can enhance user participation in separate waste collection and improve system acceptance. In the context of evolving smart city technologies, this study presents the design, development, and real-world testing of an integrated solution for the segregation and collection of municipal waste, referred to as the PRESKO System. The system features a specialized hook-lift vehicle with an automated press-container and dedicated waste segregation containers, designed for single-operator use and full automation. The innovation emphasizes rapid container emptying and labor efficiency. Pilot implementation demonstrated the system's potential to reduce collection costs and increase separate collection rates. This paper includes a simulation of total waste management costs before and after the introduction of the PRESKO System in a municipality of 32 000 residents, focusing on service for multifamily housing areas.

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1. INTRODUCTION

Waste management is a fundamental element of municipal infrastructure, encompassing several interconnected stages: the temporary storage of waste at source, its collection and transport, and subsequent processes such as treatment, recovery, and final disposal. Among these, waste collection and transport serve as both operational and strategic backbones of the system. Financially, they represent a major cost driver, though the degree to which they dominate overall expenses varies significantly depending on local context, system maturity, and infrastructure development. While multiple studies confirm that waste collection and transportation can constitute between 50% and 70% of total waste management costs, such figures should not be treated as universal [1, 2]. Instead, these shares are highly dependent on a range of factors, including urban density, labor costs, fuel prices, infrastructure availability, and the sophistication of treatment technologies. For example, in less developed systems or rural municipalities, limited access to modern sorting and processing facilities often results in a higher relative share of collection costs, driven by longer transport distances and greater reliance on manual labor [3, 4].

In contrast, more advanced systems may display lower collection cost shares, not because collection is inherently cheaper, but because total system costs are inflated by investment-intensive treatment technologies such as mechanical-biological treatment (MBT), anaerobic digestion, or waste-to-energy. In Poland, for instance, the Supreme Audit Office (NIK) reported that in urban communes, collection accounted for approximately 38% of system costs, while treatment and disposal comprised nearly 60% [5].

Moreover, collection systems are not purely financial burdens; when well-designed, they can play a transformative role in enhancing system performance. Efficient and convenient collection systems directly contribute to increased recycling rates, improved public participation, and better-quality source separation [6]. The strategic importance of waste collection in meeting sustainability goals has made it a focal point for innovation, particularly in the context of smart cities and automation [6].

Emerging technologies such as automated side loaders, container-level sensors, and route optimization software enable municipalities to reduce labor requirements, minimize fuel consumption, and enhance operational efficiency. One such innovation is the PRESKO system, which integrates specialized press-containers and hook-lift vehicles capable of automated operation by a single driver. Designed for dense, multifamily residential zones, this solution has demonstrated not only lower labor intensity and shorter emptying cycles but also increased rates of separate collection. This paper explores the cost structure of conventional waste collection systems and evaluates the economic and operational benefits of partial automation using the PRESKO system as a case study in an urban municipality of 32 000 residents. It is based on the results of the research: *Integrated system for storage and collection of municipal waste – the PRESKO system* carried out by Hewea Sp. z o.o., with cofinancing by the National Centre for Research and Development (NCBR).

2. METHODS

The waste collection system in a selected city with 32 000 inhabitants was modelled using an updated waste logistics model developed for the analysis of the sustainability of municipal waste management systems [7]. The model achieves its main objectives while applying necessary simplifications. Specifically, it provides realistic estimates of:

- total collection and transport distances (needed to calculate fuel consumption),
- time required for collection and transport (influences personnel costs),
- number of trucks needed (important for estimating vehicle purchase costs).

The model includes separate modules for waste collection and transport, with collection covering the emptying of bins or/and sacks in the municipal area and transport referring to the haulage of the collected waste to the facility or treatment plant. It covers the collection of both sorted waste fractions and mixed waste, with a distinction made between different urban zones – specifically, single-family and multi-family residential areas. The transportation component simulates the transfer of waste by designated vehicles and its subsequent delivery to processing or disposal facilities. Input data includes the type and quantity of waste placed in bins and bags at the time of collection, which are then tracked through to their designated facilities. The model also enables the assessment of environmental, economic, and social impacts, with the economic evaluation including personnel costs, fleet acquisition and maintenance expenses, fuel consumption, and related operational costs.

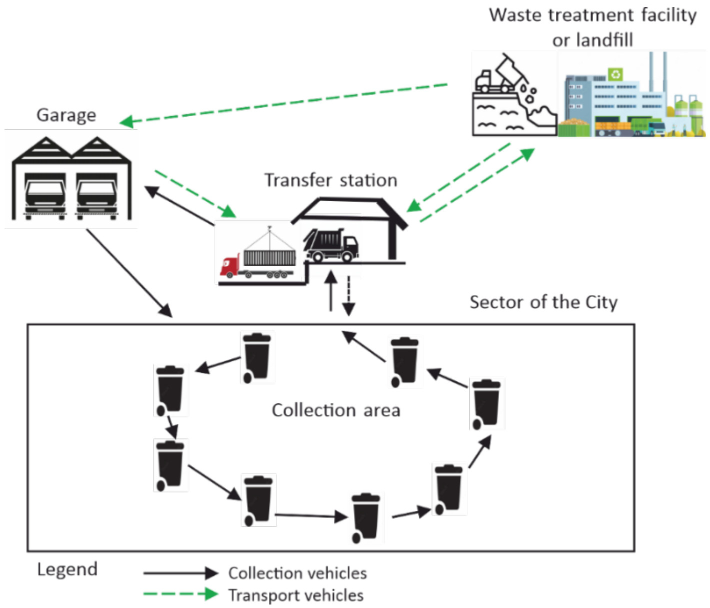

Fig. 1. Collection and transport scheme
with waste reloading at a transfer station (Case 1) [7]

Two general logistical scenarios are considered for the management of each waste fraction:

- Case 1. Collection followed by transfer station reloading before transport.
- Case 2. Collection and direct transport to the treatment facility or landfill.

Figure 1 shows the collection and transport scheme with an existing transfer station (Case 1) consisting of the collection (Case 1a) and the transport (Case 1b) with different vehicles. Case 2 is a model in which waste is transferred to the treatment plant directly by the collection truck. The model was used to simulate and assess waste collection in two scenarios:

- a conventional waste collection system based on door-to-door collection in a single-family area, and a bring system with 1100 dm^3 containers in a multifamily residential area,
- a modified system where the PRESKO collection system replaced conventional collection in multifamily buildings.

For the modelled municipality, Case 1 was applied, due to a relatively long distance (55 km) from the municipal area to the treatment facility. It means that waste, after collection with a typical collection truck, is reloaded at the transfer station and transported with an alternative vehicle to the treatment facility.

Table 1

Collection and transport subprocesses on a working day[a] [7]

Collection (Case 1a)		Transportation (Case 1b)		Collection and transportation (Case 2)	
1	Garage–sector	1	Garage–TS	1	Garage–sector
2	Collection in a sector	2	Loading at TS	2	Collection in sector
3	Sector–TS	3	TS–facility	3	Sector–facility
4	Unloading at TS	4	Unloading at the facility	4	Unloading at the facility
5	TS–sector[b]	5	Facility–TS[b]	5	Facility–sector[b]
6	Collection in sector[b]	6	Loading at TS[b]	6	Collection in sector[b]
7	Sector–TS[b]	7	TS–facility[b]	7	Sector–facility[b]
8	Unloading at TS[b]	8	Unloading at the facility[b]	8	Unloading at the facility[b]
9	TS–garage	9	Facility–garage	9	Facility–garage

[a]TS is a transfer station.
[b]For every additional collection or transport trip on a working day.

Table 1 contains unit processes occurring on a daily basis, modeled for the conventional waste collection system and a partly automated collection system [7, 8]. The model has been applied to calculate the costs of waste collection and transport, assuming the actual collection results and data obtained during pilot collection with the PRESKO system.

3. RESULTS

The HEWEA developed a prototype vehicle equipped with construction elements enabling automated waste collection: a hook lift and a manipulator (Fig. 2). The vehicle has a compactor (press-container) with a capacity of 18 000 dm^3 and a prototype support roller ensuring vehicle stability during loading and unloading of the compactor [9]. Figure 3 shows the vehicle collecting waste.

Fig. 2. Computer model of the PRESKO waste truck [9]

Fig. 3. Emptying containers in the PRESKO system [9]

The feasibility and effectiveness of the waste collection service in the PRESKO system were verified through the pilot application [9]. The conventional collection systems compared with the PRESKO during pilot application are shown in Fig. 4.

Fig. 4. Selected locations of waste containers
conventional (top) and after introducing the PRESKO system (bottom)

Table 2

The amount of waste collected in the city

Fraction	Code	Mass [Mg/year]
Unsorted (mixed) municipal waste	20 03 01	6477
Paper and cardboard packaging	15 01 01	570
Plastics packaging	15 01 02	764
Glass packaging	15 01 07	682
Biodegradable kitchen waste	20 01 08	1688
Bulky waste	20 03 07	359
Expired medications	20 01 32	1.8
Batteries and accumulators	20 01 34	0.6
Total		10 584

Current waste collection results, assumed as model input waste streams, are summarized in Table 2. These are the waste streams that need to be collected from the city. The average waste generation per capita amounts to 331 kg/year. This value is rather low compared to the average amount of municipal waste in Poland (364 kg per capita and year). Additional streams include waste collected in civic amenity sites and waste collected from institutions, which, however, are not collected within the municipal collection system. The data shows that the current collection system is not efficient, as residual waste accounts for 61% of all waste collected in the system. This is not sufficient in view of environmental efficiency and the legally binding recycling obligation of 55% of municipal waste volume in 2025.

Additional key assumptions for the model are summarized in Table 3. Data input is provided separately for each city sector. Sector 1 represents multi-family residential buildings, which account for approximately 80% of the total population, while sector 2 includes single-family housing areas.

Table 3

Main model assumptions and the system data

Description	Conventional waste collection system	Collection based partly on the PRESKO system
Average distance from the garage to the first pick-up in a defined sector	2 km	
Average distance from the transfer station to the first pick-up in a defined sector (enter 0, if no transfer station exists for this sector)	2 km	
Average distance from the transfer station to the designated facility (Case 1)	55 km	
Number of collection containers at a multifamily housing area (sector 1)	1092 containers of 1100 dm^3 at 77 locations	403 containers of 2250–7500 dm^3 at 77 locations
Number of collection containers at a single-family housing area (sector 2)	9948 individual containers up to 240 dm^3 volume	9948 individual containers of 240 dm^3 volume

Waste collection follows a standard municipal scheme, covering streams such as paper and cardboard, glass, plastics, biowaste, bulky waste, residual waste, and special waste (e.g., expired medications and waste electrical and electronic equipment). In the single-family housing sector, waste is collected through a door-to-door system, using individual containers assigned to each household. This collection method remains unchanged after the implementation of the PRESKO system.

In the multi-family sector, waste is currently collected using common 1100 dm^3 containers placed at 77 collection points, resulting in an average distance of approximately 200 meters between collection points within the service area. Within this sector, the PRESKO system is assumed to be introduced. It includes the deployment of 403 PRESKO containers of varying capacities – from 2250 to 7500 dm^3 – allocated across five separate waste streams. The total waste storage volume provided by the new system is equivalent to that of the existing setup, ensuring continuity in service capacity while enabling improved collection efficiency.

The current and modified collection systems were modeled and assessed. For the financial part, average data was assumed – monthly costs of employment in the enterprise sector in December 2024 – PLN 8821[4] (as average gross salary according to GUS, plus 20% of additional employer costs were assumed as input data to the model.

Fuel costs (diesel) at a wholesale price were assumed at 4.8 PLN/dm^3. Results of the modification of waste collection systems by the introduction of the PRESKO system in multi-family housing is demonstrated by the costs overview in Table 4.

Table 4

Costs of waste management before and after introducing the PRESKO system

Cost category	Current collection model		PRESKO system	
	Total [PLN] [USD][a]	Share in total costs [%]	Total [PLN] [USD][a]	Share in total costs [%]
Temporary storage (containers)	484 466 133 830	4.9	295 407 81 604	3.2
Collection and transport	3 227 038 891 447	32.9	2 713 335 749 540	29.8
Treatment and disposal	5 466 404 1 510 056	55.7	5 466 404 1 510 056	60.0
Civic amenity site pharmacies, other	384 715 106 275	3.9	384 715 106 275	4.2
Administration (municipality)	253 650 70 069	2.6	253 650 70 069	2.8
Total costs	9 816 273 2 711 678	100	9 113 510 2 517 544	100

[a]Conversions of PLN to USD were based on: https://nbp.pl/en/statistic-and-financial-reporting/rates/table-a/

The model for the current situation was calibrated and adjusted to the financial data reported by the analyzed municipality. It can be seen that the implementation of the PRESKO system in the waste management system results in a significant reduction of the overall waste management cost from 9.8 to 9.1 million PLN (2.7–2.5 million USD), equivalent to the reduction of approximately 8% of the overall waste management costs. In the overall waste management cost, the highest share is related to waste treatment and disposal, amounting to 55.7% in the current system, and 60% after implementation of the PRESKO system. Waste temporary storage and collection together account for 38.7% in the current system and 33.0% after introducing the PRESKO collection model. In Figure 5, the shares of individual cost categories in waste temporary storage, collection, and transport systems are presented.

[4]Average employment and wages in the enterprise sector in December 2024, Central Statistical Office.

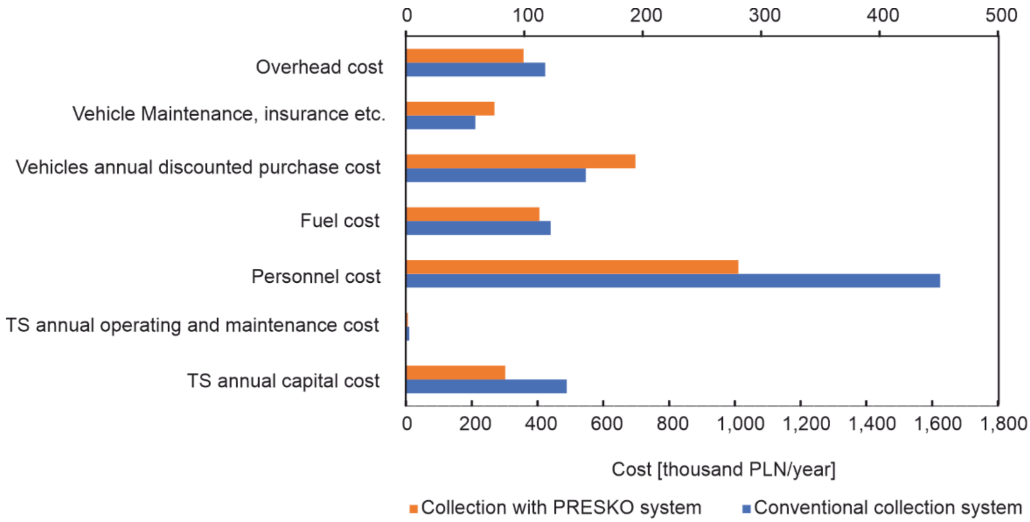

Fig. 5. Costs of waste collection and transportation
after introducing the PRESKO system versus conventional waste collection

The most significant difference between the two systems lies in personnel costs. This disparity results from the lower labor intensity of the PRESKO system, which eliminates the need for waste collectors on board collection vehicles due to its automated operation. Personnel expenses represent a major component of total waste management costs, and their impact has grown in recent years. In Poland, the average salary has increased markedly between 2021 and 2025 (see Fig. 6), further emphasizing the financial burden of labor-intensive systems. Consequently, reducing labor requirements through automation emerges as a key strategy for minimizing overall waste management costs.

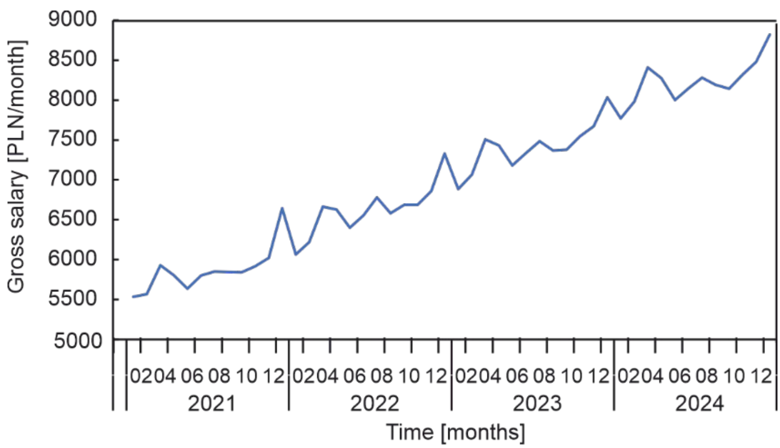

Fig. 6. Average salary in the sector
of enterprises (2021–2024) according to GUS [10]

4. DISCUSSION

In recent years, alongside rising labor costs, waste treatment expenses have also seen a significant and widespread increase. According to the IOŚ-BIP report [11], operational cost escalations have been observed consistently across the country. Between 2019 and 2020, gate fees rose by 36% for residual (mixed) waste, 96% for selectively collected waste, 78% for bulky waste, and 40% for biodegradable waste. The cost of accepting 1 Mg of mixed municipal waste currently ranges from PLN 270 to PLN 800 (USD 75–221), while for selectively collected waste, the range is even broader – PLN 50 to PLN 1200 (14–331 USD) – depending on the facility and its geographic location. These price increases have been attributed not only to rising minimum wages but also to regulatory and market factors, such as the prohibition on landfilling waste fractions with a calorific value above 6 MJ/kg, higher marshals' fees for waste disposal, and a declining demand for secondary raw materials separated from municipal waste. Furthermore, legislative changes have required investments in video surveillance systems, infrastructure upgrades to meet specific storage standards, and adjustments to comply with BAT (best available techniques) requirements.

In the context of rising prices, reducing costs through process optimization is very important. In the PRESKO collection system, the driver can operate the whole collection by himself, which allows for reducing the waste truck staff from three to only one person. This compensates for the higher investment costs of both containers and collection vehicles within the PRESKO system, as opposed to traditional waste containers and trucks. Due to the larger container volume, the amount of waste collected per vehicle per day is slightly higher, leading to a slightly lower number of needed vehicles. However, this does not compensate for the higher unit prices of the vehicles in the PRESKO system.

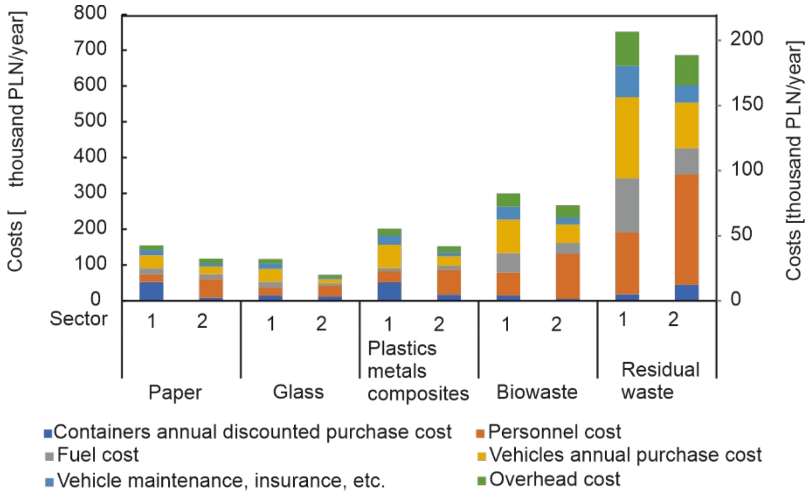

Fig. 7. Temporary storage, collection and transport costs in the traditional and the PRESKO systems

Figure 7 depicts the costs of temporary storage, collection, and transport of waste in a system with PRESKO, subdivided into individual waste categories. The highest costs are associated with residual waste collection. In the case of sector 1, for which the PRESKO system was assumed, the highest cost component is associated with the annual vehicle purchase cost. In the case of sector 2, personnel costs are the main important contributor. It can also be seen that the costs related to sector 1 are at a similar level as the costs related to sector 2, although 80% of waste is collected from sector 1 and only 20% from sector 2. It indicates high economic efficiency of waste collection in multi-family housing estates, with respect to single-family districts, with additional improvement potential through collection automation with the PRESKO system.

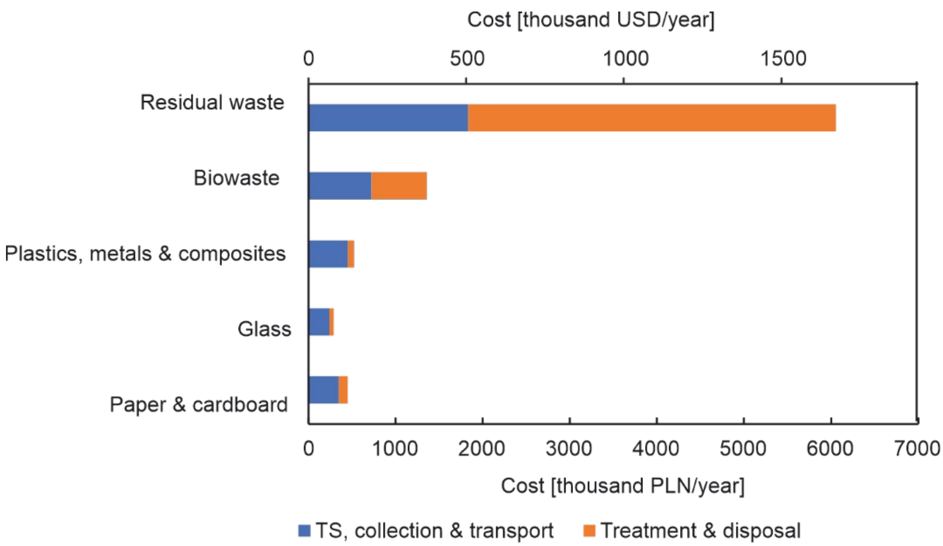

Fig. 8. Temporary storage, collection, and transport related to treatment and disposal costs

Finally, Figure 8 shows the distribution of temporary storage, collection, and transport costs related to treatment and disposal costs for each waste stream. In the case of residual waste, the share of treatment and disposal costs is a few times higher than the cost of waste storage, collection, and transport. The opposite is true for the separately collected waste fractions, for which storage and collection contribute a higher impact than waste treatment and disposal. This underpins the importance of efficient separate collection for the overall economic efficiency of the system. It is worth mentioning that during the pilot implementation of the PRESKO system, a substantial improvement in separate collection levels was achieved, as compared to the traditional system. This is most likely due to a more positive social attitude towards the PRESKO system and the visual uniformity than in the case of the traditional system. The improvement of separate collection levels was, however, not taken into consideration for the financial comparison of both models.

5. CONCLUSIONS

Although automated waste collection systems involve higher upfront investment, they offer considerable long-term benefits in terms of cost savings, operational efficiency, and sustainability. Modern collection vehicles equipped with automation and self-positioning grabbers can significantly reduce expenses related to fuel, maintenance, and wear, while also enabling more efficient route planning through GPS and sensor integration. One of the most impactful advantages is the reduction in labor requirements – often from a multi-person crew to a single operator – leading to substantial savings in personnel costs, as well as improvements in safety and working conditions. In the analysed case, the automation lowered total operating costs of waste logistics by over 23%. It makes it a compelling solution in the face of rising labour costs and increasing demands for sustainable urban infrastructure. Despite the higher initial costs, the transition to automated waste collection is becoming increasingly viable and aligned with long-term economic and environmental goals.

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