

Implementation and Evaluation of a Pay-As-You-Throw Policy for Municipal Solid Waste: An AHP-Based Analysis

Gideon Oron^{1,2*}, Dana Ronen², Itamar Gruber² and Shani Byron²

¹Zuckerberg Water Research Institute, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Kiryat Sde-Boker, Israel.

²The Department of Industrial Engineering and Management, Ben-Gurion University of the Negev, Beer-Sheva, 8410500 Israel.

*Corresponding author

Gideon Oron, Zuckerberg Water Research Institute, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Kiryat Sde-Boker, Israel.

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ABSTRACT

The rapid growth of municipal solid waste (MSW) poses significant environmental, economic, and social challenges worldwide. In Israel, waste generation has increased steadily, with limited household-level accountability mechanisms. This study evaluates the feasibility of implementing a Pay-As-You-Throw (PAYT) policy as a strategy for improving waste management efficiency and reducing environmental impact. Four alternatives were assessed: (i) the current landfill-based system without monitoring, (ii) standardized garbage bags, (iii) smart bins equipped with weighing systems, and (iv) weighing systems integrated into waste collection trucks. The analytic hierarchy process (AHP) was applied to rank these alternatives based on technical, economic, environmental, and socio-cultural criteria. Additionally, a 28-day field experiment involving fifteen households examined behavioural responses to waste monitoring and incentive mechanisms. Results indicate that the collecting truck-based weighing system is the most favourable alternative (36.5%), followed closely by smart bins (34.7%). The field experiment demonstrates that both awareness and incentives significantly reduce waste generation. The findings highlight the importance of integrating technological solutions with behavioural interventions to ensure successful policy implementation.

Introduction

Municipal solid waste (MSW) management has become a critical environmental challenge due to rapid urbanization, population growth, and increasing consumption patterns. In Israel, the average waste generation rate is approximately 1.7 kg per capita per day, resulting in nearly seven million tons of waste annually. A massive portion of this waste is disposed off in landfills, contributing to greenhouse gas emissions, groundwater contamination, and land degradation.

Despite these challenges, the current waste management system lacks mechanisms for monitoring waste generation at the household level. Waste collection fees are typically embedded within municipal taxes, creating a disconnect between individual behaviour and environmental impact. Consequently, there is little incentive for households to reduce waste or increase recycling efforts.

The Pay-As-You-Throw (PAYT) model has been widely implemented in various countries as an economic instrument to

promote waste reduction. Under PAYT, households are charged based on the amount of waste they generate, thereby encouraging more sustainable consumption patterns. However, implementing such a system requires careful consideration of technical feasibility, economic costs, environmental benefits, and public acceptance.

This study aims to evaluate alternative PAYT implementation strategies in Israel using a combined analytical and experimental approach.

Literature Review

PAYT systems have been successfully implemented in countries such as Germany, South Korea, and the United States. Studies consistently show reductions in waste generation ranging from 10% to 40% following PAYT implementation. These reductions are often accompanied by increased recycling rates and improved public awareness.

Technological approaches to PAYT vary widely. Common methods include the followings: (i) volume-based pricing (standardized

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bags); (ii) a weight-based pricing (smart bins or collecting truck-mounted scales); and (iii) hybrid systems integrating digital tracking and billing. While weight-based systems offer higher accuracy, they require significant infrastructure investment and operational complexity. Conversely, volume-based systems are easier to implement but less precise. Behavioural studies emphasize that awareness and incentives play a critical role in shaping waste-related behaviours. Even minimal interventions, such as feedback on waste generation, can lead to measurable reductions. The analysis approach is based on a hierarchical model in which policy alternatives are assessed against a set of environmental, economic, operational, and social criteria. The decision-making process incorporates six primary criteria At the top of the hierarchy is the central objective: (i) waste quantity control - the extent to which the policy encourages reduction in waste generation at the source; (ii) system strength and operational efficiency - the robustness, reliability, and feasibility of implementation and enforcement; (iii) monitoring and measurability- the technical ability to accurately measure waste generation and apply billing accordingly; (iv) establishment and operational costs which includes both initial capital infrastructure investments and ongoing operational expenses; (v) environmental impact of the process that refers to The degree to which the policy reduces environmental harm, including landfill use, emissions, and resource depletion; and (vi) Socio-cultural considerations that refers to the account of public acceptance, behavioural adaptability, and social equity implications.

Methodology

The Analytical Hierarchy Process (AHP) is a structured decision-making technique for addressing complex problems, developed in the 1970s [1]. The method facilitates decision-making in situations characterized by high complexity, particularly when it is necessary to assign weights to multiple alternatives and rank criteria according to their relative importance. AHP is especially suitable when both quantitative and qualitative criteria are involved, enabling an effective balance between them [2]. Consequently, the method is widely applied in high-risk decision-making scenarios with long-term implications. The proper decision-making procedure is made on the following stages.

The decision-making process based on AHP consists of the following stages: (i) problem definition and regarding to the required knowledge and data; (ii) an hierachal structure has to be developed. The top level represents the overall goal or main problem, while the lowest level consists of the decision alternatives. Intermediate levels include the relevant attributes and evaluation criteria; (iii) during the process development a pairwise comparison matrix for the evaluated criteria must be developed; (iv) a consequent stage is to assign a score to each pair of criteria using a scale of 1–9 to represent their relative importance:

- Criterion i and j are equally important
- Criterion i is slightly more important than criterion j
- Criterion i is more important than criterion j
- Criterion i is much more important than criterion j
- Criterion i is more important than criterion j

All the other values such as 2, 4, 6, 8 – are intermediate values.

Next stages are related to extra additional stage: (i) Geometric mean calculation for each row of the comparison matrix, compute the geometric mean by multiplying all row elements and taking the n-th root (where n is the number of criteria); (ii) Normalization and weight determination and evaluate the final weight of each criterion by normalizing the geometric means, i.e., dividing each geometric mean by the sum of all row geometric means; (iv) reciprocal consistency check verify the reciprocal property of the matrix, ensuring that:

$$A_{ij} = \frac{1}{A_{ji}} \tag{1}$$

(v) defining maximum eigenvalue calculation λ_{max} , which must exceed the number of compared elements in the matrix. This value is obtained by multiplying each normalized criterion has to be satisfied weight by the sum of its corresponding column and summing the results. The condition, as given in equation (2) guarantees solution feasibility:

$$\lambda_{max} > n \tag{2}$$

The two other indexes that must be met are the Consistency Index (CI)

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

and the consistency ratio (CR) given by equation [Eq. (4)] where RI is the random index, obtained from a standard table of fixed values associated with the AHP model.

$$CR = \frac{CI}{RI} \tag{4}$$

A general layout of the AHP procedure is given in Figure 1.

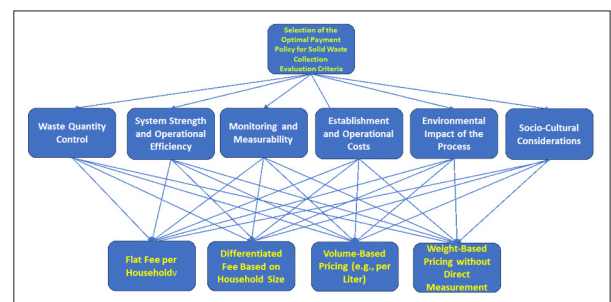


Figure 1: A General Layout of the AHP Procedure

AHP Model results

After all the intermittent calculations according to the theory and performing pairwise comparisons among the selected criteria to determine their relative weights, and ranking the alternatives with respect to each criterion, the results of the Analytic Hierarchy Process (AHP) model were obtained [3]. According to the model outcomes, the truck-mounted weighing system alternative was ranked as the most preferred option, with a normalized weight of 36.5%. The bin-based weighing system followed very closely, with a weight of 34.7%. The current baseline scenario ranked

third, with 14.7%, while the designated waste bag system was ranked last, with 14.0%. The difference between the collection car weight and the solid-wastes weight are negligible and depend mainly on local technical capacity and operation and maintenance skill. The results indicate a clear preference for technological solutions that enable accurate measurement and monitoring of waste quantities at the point of collection.

Table 1: AHP Model Results Summary

Alternative	Implementation & Development Complexity	Operation & Maintenance Complexity	Waste Quantity Control	Capital & Operational Costs	Socio-Cultural Acceptance	Socio-Cultural Acceptance	Normalized Weight (%)
Uncontrolled Landfilling (Current Practice)	0.567	0.561	0.036	0.048	0.064	0.508	0.147 (14.7%)
Designated Waste Bags	0.303	0.324	0.103	0.086	0.124	0.102	0.140 (14.0%)
Truck-Mounted Weighing System	0.076	0.068	0.357	0.382	0.475	0.346	0.365 (36.5%)
Bin-Mounted Weighing System	0.054	0.048	0.504	0.484	0.336	0.044	0.347 (34.7%)
Criteria Weights	0.035	0.107	0.299	0.107	0.402	0.049	1.000

Summary and Conclusions

Within the framework of this project, several alternative approaches were evaluated for the implementation of a “Pay-As-You-Throw” (PAYT) model in Israel, aimed at controlling household solid waste generation. The analysis was informed by established models implemented worldwide. Each alternative was assessed against a set of economic, social, and technical criteria to determine its relative suitability. The principal findings derived from the Analytical Hierarchy Process (AHP) comparative model and the field experiment are summarized as follows:

The preferred alternative is the integration of weighing systems on municipal waste collection trucks, enabling the measurement of waste quantities at the neighbourhood bin level, which achieved a score of 36%. This is closely followed by the alternative of installing weighing mechanisms directly on waste bins, with a score of 35%. From a short-term perspective, the current practice of landfilling remains the most economically favourable option, as it does not require additional allocation of resources for development, maintenance, or personnel training. From a long-term perspective, however, the implementation of a solution aimed at reducing household waste generation is essential. Under current conditions, municipal solid waste generation in Israel increases by approximately 2% annually, accompanied by escalating environmental impacts. Therefore, the adoption of a PAYT-based model is considered necessary for sustainable development [4].

Sensitivity analyses indicate that all proposed alternatives require substantial financial investment, and that, from a purely economic standpoint, the existing system remains preferable. Nevertheless, the analyses also demonstrate that meaningful

reduction of environmental impacts and effective control over household waste generation necessitate systemic change through the adoption of one of the proposed alternatives. Field experiments revealed that increasing public awareness regarding the environmental impacts of waste can lead to perceptual and behavioural changes among residents, thereby facilitating the successful implementation of the PAYT model.

In addition to the evaluated alternatives, the findings highlight the critical importance of investing in public environmental awareness. Without active public participation, achieving a large-scale behavioural shift will be challenging. It is essential that the current waste management situation be effectively communicated through social media and leading communication channels to support the long-term success of PAYT implementation. Current waste generation patterns are likely to result in irreversible environmental damage if left unaddressed. Accordingly, initiative-taking investment and policy implementation are required today, as future remediation efforts are expected to demand significantly greater resources than those needed for preventive action.

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