Food waste management analysis in Istanbul by using a decision-making tool

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Abstract

The global economy is costed over USD 900 billion in wasted resources annually due to sending 1.32 billion tons of food waste (FW) to landfills (Mak et al., 2020) simultaneously producing 3.3 billion tonnes of greenhouse gases. (Lin et al., 2022; Maçin et al, 2023). The selection of a better management scenario involves considering several aspects (environmental, economic, social, and technical). Waste management (WM) systems consist of long-lived infrastructure, so decision-makers need to proactively plan for changing the composition of waste and policy requirements and a changing the energy system for cost-effective and sustainable management of solid waste. Decision-makers can simultaneously consider and incorporate opposing criteria through multiple-criteria decision making (MCDM) methods. Hence, an MCDM tool/framework was described and variety of WM options were assessed using Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods to select the most suitable FW management technology in Istanbul in this study.

The proposed tool in this study involves seven (I-VII) steps which form a open loop: (I) Problem Settling: identification research questions (RQs), (II) Food Waste Management Scenarios: that consists of identifying and mapping the WM systems, (III) MCDM Tool: determining the general environment, economy, social and technical indicators related to WM, (IV) Case Spesific Indicator Selection: environment, economy, social, technical sub-indicator selection for FW management in Istanbul (V) Data Inventory for MCDM: providing data by using life cycle assessment (LCA), cost calculations, questionnaire, literature (primary and secondary sources),(VII) MCDM application: by using AHP-I and TOPSIS methods, (VII) Results- Comments- Conclusion: Identify future needs scenarios, policy strategies, presenting potential polices and recommendations while reflecting on the process.

The indicators should be; meaningful, clear in content, appropriate in scale, robust and reproducible, comparable describe and understandable. The environmental indicators included in the study were those typically considered in LCA studies. For the MCDM study; circularity, climate change, particulate matter, eutrophication terrestrial and eutrophication marine were selected as environmental sub-indicators. Capital/investment costs, operation cost, public fee and revenue were considered for the economic sustainability assessment. Social indicators; considered within the decision-support framework were classified into five sub-categories namely; partnership potential, job creation, urban space requirement, public acceptability and public health. Finally, technical indicators; were classified into three categories as, flexibility, reliability and qualified employee Four scenarios were evaluated: anaerobic digestion, composting, incineration, and landfill (step II). In addition, the feedback from WM experts on the proposed set of indicators was received through an online survey (step V).

A total of 50 interviewers were considered, and 34% responded. The pairwise comparison was obtained by seeking the views of 17 experts.

According to AHP results, the selection of FW management technology in Istanbul is influenced by environmental, economic, technical and social criteria respectively. In terms of subcategories; circularity was found at its highest in the anaerobic digestion (AD) scenario at 42.6%, followed by composting at 36.1%, while for landfill and incineration circularity was zero (Figure 1). Incineration had the most savings followed by AD, composting and the landfill in terms of climate change. Incineration had the highest net costs in all scenarios, due to high OPEX (operating expenses) and CAPEX (capital expenses). AD had the second highest net cost (94 €/ tonne FW), due to high OPEX compared to landfill and composting. The AD technology was found to be the most sustainable option when it comes to social sustainability indicators. The land area used for AD was significantly smaller than that of landfilling and comparable to that of incineration. As a result of MCDM analysis (AHP followed by TOPSIS) the landfill is the least preferred FW management technology for Istanbul, while AD is the most preferred (Table 1).

%-AHP global weigth	Indicator	AD	Incineration	Landfill	Composting	Data Source
27.6	Circularity	42.6%	0	0	36.1%	LCA
14.2	Climate Change	(-126 kg CO_2-eq/ ton FW)	(-192 kg CO_2-eq/ton FW)	(924 kg CO_2-eq/ton	(119 kg CO_2-eq/ton FW)	LCA
8.0	Particulate Matter	(-108.8 kg PM2.5-eq/ ton FW)	(-106.5 kg PM2.5-eq/ ton	(-61.1 kg PM2.5-eq/ ton	(31.3 kg PM2.5-eq/ ton	LCA
1.9	Eutrophication Terrestrial	(944.8 kg N eq.)	(-676.9 kg N eq.)	(689.6 kg N eq.)	(2254.8 kg N eq.)	LCA
4.4	Eutrophication Marine	(919.2 kg N eq.)	(-65.2 kg N eq.)	(113.1 kg N eq.)	(662.8 kg N eq.)	LCA
2.9	Invesment Cost	71 €	105 €	63 €	58 €	primary
14.2	Operation Cost	55 €	72 €	40 €	40 €	primary
1.5	Public Fee	3 €	20 €	13 €	7 €	IMM
7.8	Revenue	- 32 €	- 36 €	- 5 €	- 6 €	primary
0.5	Partnership Potential	1	3	4	2	article
0.1	Job Creation	0.05 person/ton waste*day	0.25 person/ton waste*day	0.1012651 person/ton waste*day	0.16 person/ton waste*day	IMM-EIA
0.4	Urban Space Requirement	0.0060882800 m^2/ton	0.0054063926 m^2/ton	0.0049122807 m^2/ton	0.0060761278 m^2/ton	IMM-EIA
1.5	Public Acceptability	1	3	4	2	article
2.9	Public Health	1	3	4	2	EU report
0.9	Flexibility	1	4	3	2	article
7.9	Reliability	2	4	3	1	article
3.5	Qualified Employee	0.055 person/ton waste*day	0.055 person/ton waste*day	0.050632 person/ton waste*day	0.08 person/ton waste*day	IMM-EIA

Good — Bad

*LCA: life cycle assessment, IMM: Istanbul Metropolitan Municipality, EIA: Environmental Impact Assessment

Figure 1. MCDM inventory (colorful columns) and AHP analysis results for sub-categories (left column)

TOPSIS results also comply with WM hierarchy order. The composition of Istanbul's waste is largely dominated by organic waste, which presents a challenge to technology adoption. In addition, future WM scenarios in this study requires new systems for source separation and collection schemes. Hence, not only building WM facilities but coordination of every level of stakeholders is required for solving WM problems.

Table 1. TOPSIS method results

Scenario	Si+*	Si-*	Pi **	Rank
Anaerobic Digestion	0.0046	0.27172	0.98350	1
Incineration	0.2218	0.18856	0.459457	3
Landfill	0.2686	0.08620	0.242931	4
Composting	0.1099	0.22108	0.690712	2

* Euclidean distance from the ideal best **Si+:**ideal best value and **Si**: ideal worst value, ****Pi**: Performance Score

The acceptance of specific technologies hinges on the good engagement between local authorities, industry, and regulatory bodies with stakeholders. MCDM principles should be used by decision-makers to address WM problems. The FW can be processed by setting up an AD facility in Istanbul (food, park and bio-waste) as it is the best option in terms combined results of environmental, economic, technical and social aspect.

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