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Fostering community participation in sustainable municipal solid waste management at multiple scales in Tehran, Iran

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ABSTRACT

This article delves into the intricacies of waste management in Tehran, offering insights into the structured framework governing the control of solid waste materials. As collected, the average daily generation of municipal solid waste (MSW) in the region is 0.645 kg per inhabitant. Unexpectedly, the impact of socio-economic factors on processes such as garbage sorting, creating products from recyclable waste, and composting was shown to be comparatively weaker than that of supporting elements. The initial approach entails providing environmental cadres and the community with more comprehensive MSW reduction training, which will cultivate a nuanced comprehension of waste management. The second strategy focuses on amplifying information dissemination through mass media and targeted campaigns, emphasizing effective MSW practices. The objective of the third endeavor is to augment the quantity of environmental cadres, which will be comprised of community and local leaders, in order to inspire and direct endeavors to reduce MSW. The fourth and final strategy underscores the expansion and diversification of waste storages, positioning them as customer-centric institutions dedicated to environmental campaigns and training. Ultimately, the collaborative implementation of these strategies is poised to instigate a positive shift towards heightened community participation in MSW reduction practices.

1. Introduction

Waste management is a structured and methodical framework that governs production control as well as the organized operations of storing, collecting, transporting, processing, and disposing of solid waste. This framework follows a set of guiding principles, which include hygiene, general welfare, economic efficiency, resource conservation, aesthetics, and compliance with other environmental criteria [1]. The overarching goal is to serve the public interest, demonstrating a dedication to resolving community needs and concerns [2,3]. The engineering side is also covered, highlighting the technical dimensions involved in designing and executing efficient garbage collection, transportation, and processing systems [4]. The statement offers a comprehensive view of waste management, recognizing its interdisciplinary character while emphasizing its broader societal, economic, and environmental ramifications [5–7].

Various factors influence the quality and quantity of materials in a given context, including economic concerns, the urban setting, land use patterns, cultural influences, social behaviors, and population density [8]. Economic considerations, such as a region's degree of development, influence material use, disposal practices, and total material life cycles. Residential, commercial, and industrial land use activities all contribute to the types and volumes of materials produced [9]. Social habits, particularly in densely populated regions, have an additional impact on material dynamics, reflecting how people interact with and manage materials [10]. The solution to this problem then demands a holistic approach and the combination of several tactics to ensure effectiveness [11,12].

Experts now consider strategic waste management to be one of the most effective techniques [13–15]. Strategic planning and waste management are tools that help decision-makers and communities solve critical concerns in our complex and ever-changing environment. The objective is to identify strengths, recognize weaknesses, master rapid changes, and develop a model to maximize opportunities and navigate challenges [16].

The hierarchical strategic planning method can help decision-makers in this industry. This technique is based on engineering design concepts, and provides a structured and systematic approach to addressing waste

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management concerns [17–19]. The fundamental ideas of the design technique have been stated at MIT's School of Mechanics. The design process begins with identifying the link between two major scopes: functional and physical [20]. Two domains are taken into account by the hierarchical strategic planning method: the objective (needs) and the strategy (action). Each of these domains is organized in a hierarchical fashion, and strategies are generated using the matrix concept. By utilizing the design relationship, the connections between the objective and strategy spaces are illustrated [21].

It is critical to recognize that the development of a waste management strategy is only one component of a larger strategic planning process. Strategic planning includes not only strategy creation but also strategy implementation and evaluation [22]. It is critical to introduce indicators in the field of waste management and determine the target function or functions using these indications [23]. The metrics chosen should help to close the waste management gap between different areas of the Tehran municipality [24].

Although the importance of strategic planning in waste management is widely recognized, there is frequently an absence of comprehensive research that integrates the evaluation of strategy implementation and formulation in the context of community engagement. Moreover, although the previous researches delineate precise aims to evaluate MSW attributes and community engagement, a conspicuous dearth of a cohesive structure exists for assessing the efficacy of waste management approaches in relation to socio-economic and facilitating factors. As a result, the integration of strategic planning principles with the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) method to assess the degree of community engagement in MSW management in a comprehensive manner constitutes a novel contribution. This research provides a comprehensive understanding of MSW dynamics by utilizing MuSIASEM, which incorporates qualitative aspects of community involvement as well as quantitative waste metrics. This methodology enables the formulation of waste management strategies that are specifically designed to tackle the unique requirements and obstacles encountered in Tehran municipality. In doing so, it contributes to the advancement of the discipline by providing a comprehensive structure for the planning and implementation of sustainable waste management. Specific objectives guide the research in order to reach this broad goal.

- ✓ To assess the rate of production and identifiable characteristics of MSW in three sample areas located inside Tehran city.
- ✓ To identify the socioeconomic characteristics of individuals.
- ✓ To explore the impact of various facilitating components on community engagement in MSW sorting, recycling, and composting activities.
- ✓ To analyze the cumulative influence of socioeconomic characteristics and enabling variables on MSW mitigation utilizing sorting, recycling, and composting procedures.

These working objectives are meticulously crafted to provide a thorough understanding of the dynamics surrounding MSW management in the defined location, taking into account both the quantitative aspects of waste generation and the qualitative features of community participation. The findings of this study will be useful in informing effective waste management strategies and promoting sustainable behaviors in Tehran.

2. Research method and mathematical

Individuals working in the delicate world of comprehensive waste management, particularly planners and decision-makers, are currently confronted with issues typified by increasing complexity [25]. The problems stem from a lack of confidence and the diverse character of waste management aims [26,27]. Initially, the decision to enter waste management was basic, including simple comparisons of several options. However, the comprehensive waste management system now takes into account several elements and combinations of diverse components, resulting in increasing decision-making complexity.

The definition of grammar relevant for analyzing performance, as illustrated in Fig. 1, is the beginning point for applying MuSIASEM to MSWMS.

Given the difficulties of comprehensive management, decision-makers must now distinguish between optimal, satisfactory, and arbitrary decision-making as part of the decision-making process. This solution method often takes restrictions (criteria) into account and attempts to optimize them, or it involves the comparison of error functions.

2.1. Assumptions of the model

To put the model into action, we needed garbage data from Tehran. This included conducting in-person interviews with recycling officials in each of Tehran's 22 districts and working with officials from the Waste Management Organization. Information is gathered from appropriate officials during visits to the Aradkoh disposal and processing plant in Tehran (Fig. 2).

The present status of the management system is as follows, based on data received from various sources. The decrease in waste production in 2022 compared to 2021 can be attributed mostly to economic causes, taking into account the influence of numerous economic, social, cultural, and other aspects on garbage generation [28]. According to the statistics available on the constituent elements of urban garbage in Tehran, the quantity of wet waste has been reduced in recent years in comparison to dry waste. Closer examination of dry trash in Tehran predicts an increase in the manufacture of plastic, nylon, and linoleum. This is due to the increased use of plastic products in households, as well as residents' preference for plastic bags over conventional packing, such as paper envelopes or baskets [29]. Fig. 3 shows the urban waste flow of 22 regions of Tehran in 2022.

3. Case study

The survey sample size was set using recognized statistical techniques, and households were chosen using stratified random sampling. The districts were chosen based on development level, with "District 1″ being the least dense at 114 people per hectare as developed, "District 5″ being medium density at 175 people per hectare as developing, and "District 17″ having a medium density of 375 people per hectare as undeveloped. Aside from variances in population density, the selected households revealed a wide range of socioeconomic and other identifiable characteristics, such as gender, age, educational achievement, and family income. The total 300 respondents interviewed and there were 2 MSW officials and 1 government official included in the study. However, the data did not specify the exact number of residents and officials working with NGOs who participated in the interviews. Nonetheless, their insights and perspectives were considered as part of the broader data collection process to ensure a comprehensive understanding of community engagement in MSW reduction efforts. The social stratification was classified into three groups based on residence type: developed, developing, and undeveloped. This multidisciplinary approach ensured a thorough representation of the neighborhood, allowing for a detailed examination of many demographic and socioeconomic variables. Municipal solid waste (MSW) was sampled in Aguest 2022, and the sample size was established using the Standard Test Method ASTM D 5231-92 -1994. Each sample required to be at least 100 kg in weight (see table 1). With an average household size of four individuals, the assumption guiding this process was an MSW generation rate of 0.645 kg/capita per day.

In each district, one hundred families were purposefully chosen for MSW sampling and survey. The sample was collected over the course of seven days. Participants were instructed to collect their daily MSW in

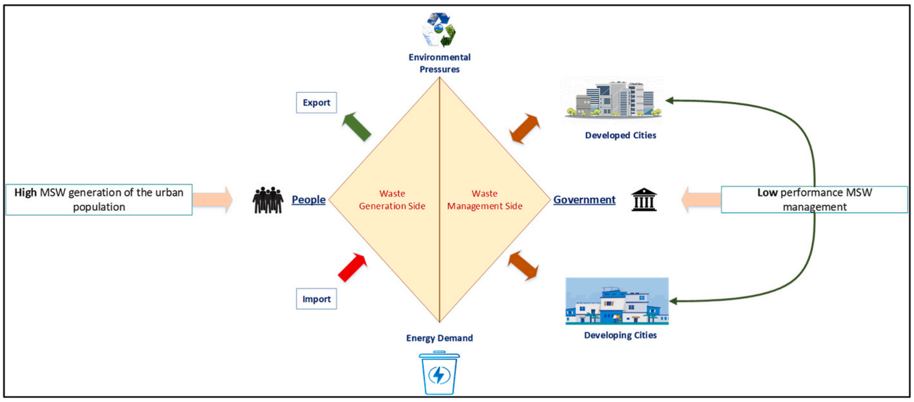

Fig. 1. Systematic interaction for the Waste management.

Fig. 2. On-site visit of central waste collection in Tehran.

garbage bags provided one day ahead to the scheduled collection period. This methodical methodology aims to collect a representative collection of data for establishing both the MSW generation rate and its composition, providing significant insights into community waste management methods.

3.1. Survey on community participation

To ensure participation in the survey, we began contact with the selected respondents, seeking their permission to actively participate. Each recognized respondent received a questionnaire, emphasizing the significance of their contribution. Following that, each respondent was visited to ensure that the questionnaire was complete and to gather the relevant data. The survey sample size was rigorously determined using Slovin's Formula, as explained by Ref. [31]. As it is shown in formula 1, according to this formula, the number of respondents for each district was fixed at 100, ensuring a thorough and representative dataset. This approach was critical in maintaining the survey's statistical integrity, allowing for thorough insights into the studied population's viewpoints and experiences.

$$n = \frac{N}{N \times d^2 + 1} \tag{1}$$

Where n = number of sample; N = total population; d = error margin = 0.05.

4. Data analysis

4.1. ntroduction

In the current study, a multi-criteria regression approach was used to elucidate the correlations between one or more predictor factors and a response variable. Respondents were asked about their involvement in three unique activities: sorting Municipal solid waste (MSW), developing homemade projects, and engaging in MSW composting. Each respondent's involvement in these activities was assessed by awarding a "1″ if they were involved and a "0″ if they were not. To delve into the complexities of these activities, the acquired data from the surveys was thoroughly compiled and processed using binary logistic regression. This analytical method enabled a more in-depth investigation of the correlations between the defined activities and numerous predictor factors. The logistic regression model permitted a complete examination of the factors impacting sorting MSW, producing handmade goods, and composting behaviors within the examined community by giving binary values to respondents' engagement levels. The data were thoroughly processed, which involved identifying and evaluating predictive variables that included extra features as well as socioeconomic aspects.

4.2. The predictor factors

The predictor factors under consideration included:
➢Included among the socioeconomic characteristics were.

(A) "Gender" (X1) was a variable with two discrete category values. Respondents who identified as male were represented by X1 equal to 1, whereas respondents who identified as female were represented by X1 equal to 2.
(B) There were four categorical components in the attribute "Age" (X2). In the instance of X2, values 1 and 2 represented respondents under the age of 30, whereas values 3 and 4 represented respondents between the ages of 46 and 60, respectively.
(C) There were six category items in the "Educational background" (X3) variable. Respondents who were uninformed or had not completed elementary school were assigned the value 1 for X3 in the given situation. Six categorical variables were included in "Educational background" (X3). In this context, X3 equaled 1 for responders who had never completed elementary school or who were ignorant. X3 equals 2 for those who just completed elementary school, 3 for those with a junior high school diploma, 4 for those with a senior high school diploma, 5 for those with an academy or diploma degree, and 6 for those with an undergraduate or postgraduate degree.
(D) Eight categorical factors defined "family income" (X4). Specifically, X4 equaled 1 for family incomes less than $200, 2 for

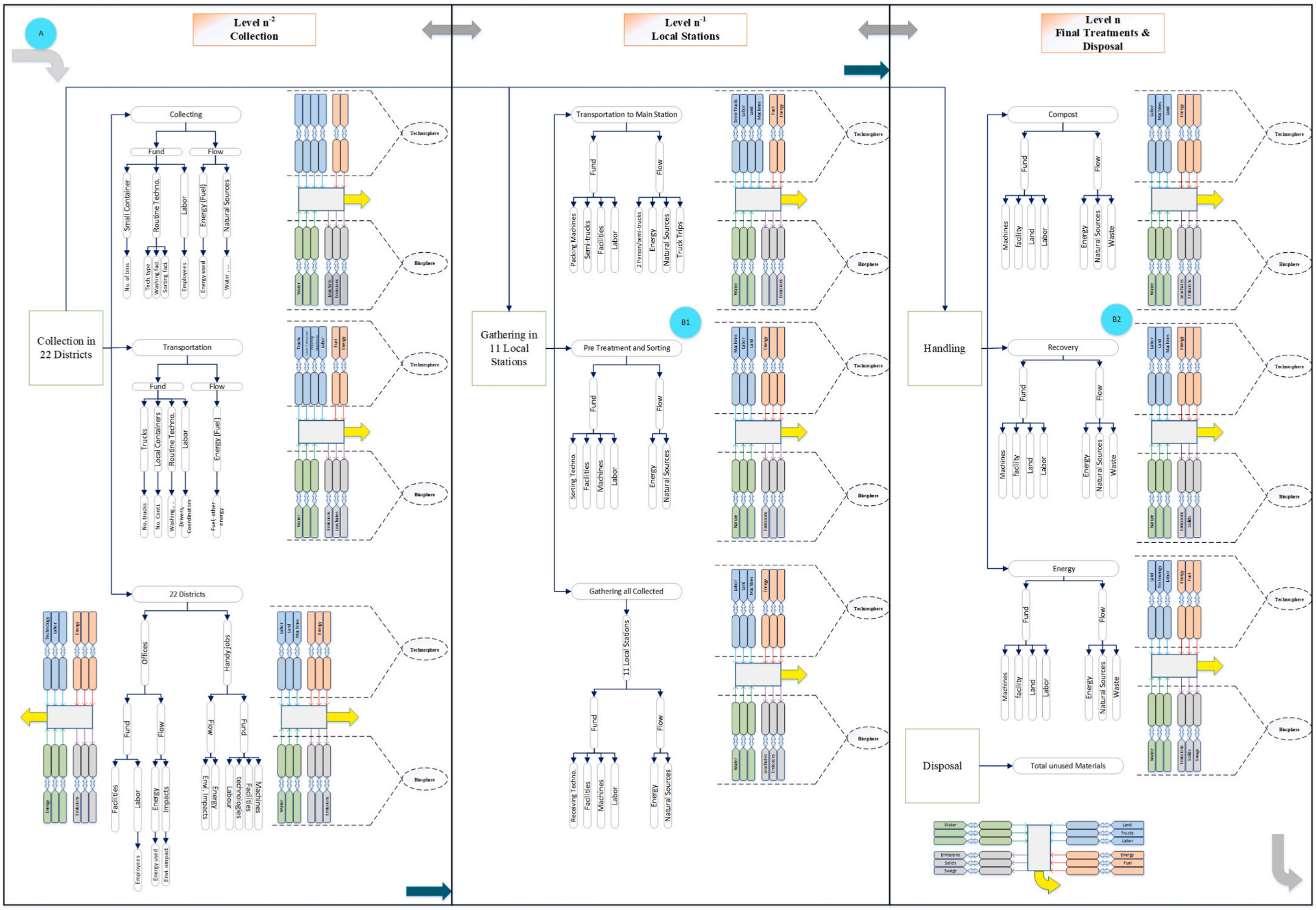

Fig. 3. Tehran's comprehensive Waste system schematic [30].

incomes between 200 and 300 $, 3 for incomes between 300 and 400 $, 4 for incomes between 400 and 500 $, 5 for incomes between 500 and 600 $, 6 for incomes between 600 and 700 $, 7 for incomes between 700 and 800 $, and 8 for incomes exceeding 800 $.

4.3. The supporting factors

➢The supporting factors included.

(i) Respondents' knowledge levels included solid waste (SW) sorting, recycling, composting degradable high-solubility waste (MSW), and converting MSW into biogas for use in livestock feed. In addition, the participants' grasp of the definitions of compost and biogas, as well as the procedures involved in recycling and composting, was evaluated. The replies of the participants were divided into three categories based on a scale that included "sufficient knowledge," "high degree of knowledge," and "low level of knowledge." The fifth predictor variable (X5) was the level of knowledge, which had an effect on MSW sorting, recycling, and composting methods [32].

(ii) The sixth predictor variable (X6) included media-obtained information on solid waste (SW) categorization, separation, and management, which included both biodegradable and recyclable items. X6 was made up of two categorical factors: if the respondent never learned about 3R from the media, X6 = 1; otherwise, if the respondent learned about 3R from the media, X6 = 2.

(iii) The seventh predictor variable (X7) was associated with MSW reduction training, which included instructional sessions and activities about SW sorting, recycling, and composting led by local government, private sector, or non-governmental entities (NGOs). X7 used two categorical variables: if the respondent had never received MSW reduction training, X7 = 1; otherwise, X7 = 2 if the respondent had received at least one MSW reduction training.

(iv) The eighth predictor variable was the presence of environmental cadres in the community, as well as those who provide inspiration and guidance for MSW reduction (X8). X8 incorporated two category variables: X8 = 1 indicated the absence of an environmental cadre in the respondent's immediate neighborhood, while X8 = 2 indicated the presence of at least one environmental cadre.

(v) The ninth predictor variable was the availability of a waste processing plant that receives recyclable garbage from clients and resells it to an agent (X9). X9 was connected with two categorical variables: X9 = 1 indicated the lack of a waste processing center in the respondent's vicinity; and X9 = 2 indicated the presence of a waste processing center in the respondent's vicinity.

4.4. The response variables

Additionally, the response variables are as below.

❖ Sorting behavior (Y1) refers to the process of sorting solid waste (SW) into recyclable or decomposable components by participants.

- ❖ Recycling engagement (Y2) refers to respondents' practice of manually making one-of-a-kind items from recyclable garbage, such as purses, wallets, pencil cases, and beautiful flowers.
- ❖ (Y3) Composting participation refers to the extent to which respondents helped to adopt sustainable waste management strategies by transforming decomposable garbage into nutrient-rich compost.

4.5. The logistic regression model

The survey of public opinion on the approval of a recycling program [33] and source separation involved the application of logistic regression. SPSS 25.0 software was employed for conducting these regression analyses. The logistic regression model, as outlined by Ref. [34], was utilized for this purpose.

$$g(\chi) = \beta_0 + \beta_1\chi_1 + \ldots + \beta_p\chi_p \tag{2}$$

$$\pi(\chi) = \frac{e^{[g(\chi)]}}{1 + e^{[g(\chi)]}} = \frac{e^{\beta_0+\beta_1\chi_1+\ldots+\beta_p\chi_p}}{1 + e^{\beta_0+\beta_1\chi_1+\ldots+\beta_p\chi_p}} \tag{3}$$

In the context of binary logistic regression modeling as written in formula 2 and formula 3, where β_0 represents the vector of parameters to be estimated, β_p denotes the coefficients associated with predictor variables, X_p is a vector comprising predictor variable data, and the conditional mean P(x) is an important component. The Odds Ratio is used in the interpretation of this binary logistic regression model (OR). The following (formula 4) is the formula for computing the Odds Ratio [35]:

$$oddRatio = \exp^{B} \tag{4}$$

5. Results

5.1. The MSW composition in Tehran

The average daily generation of municipal solid waste (MSW) per inhabitant in Tehran was 0.645 kg. When generation rates were broken down by district, district 1 had the highest rate at 0.729 kg/capita/day, followed by district 17 at 0.588 kg/capita/day and district 5 at 0.559 kg/capita/day. District 1 has the greatest MSW generation rate, followed by districts 17 and 5. Food waste made up the majority of MSW in each district, accounting for 61.2 % of total garbage. Plastics made up 8.3 % of the total, paper waste made up 13.2 %, and dirty diapers made up 2.5 % of the total [36]. A detailed breakdown of the MSW composition in Tehran is presented in Table 2.

Food waste in the current context includes discarded fruit seeds, peels, and vegetables, as well as expired bread and groceries. Plastic garbage includes plastic packaging, medicine bottles, shampoo and liquid soap bottles, cosmetics containers, plastic bags, food packaging, Styrofoam food packaging, and other plastic goods. Paper garbage comprises office paper, milk cartons, paper wax, newspaper or laminated wrapping paper, and a variety of other paper-based items. Among the diapers that have been utilized are sanitary napkins and newborn diapers. Garden waste is made up of yard trimmings, whereas glass debris is made up of used bottles from things such as medicine, vitamins, tomato ketchup, and perfume. Coconut shells and bamboo packaging are examples of materials designated as wood garbage.

Table 1
District-specific sample sizes determined by Slovin's Formula.

District	Population	No. Families	Sample
1	531,274.00	132,818.50	100.00
5	928,738.00	232,184.50	100.00
17	309,230.00	77,307.50	100.00

5.2. The socio-economic characteristics of the respondents in Tehran

Fig. 4 provides a complete summary of the socioeconomic characteristics of the homes polled. 50.24 % of respondents were female, while 49.76 % were male. The age distribution of respondents varied between groups, with 16 % under the age of 30, 32 % between the ages of 31 and 45, 39 % between the ages of 45 and 60, and 13 % aged 61 and up.

The respondents' educational backgrounds were broad, with 40 % having completed a university degree, 30 % having graduated from senior high school, and 10 % having attended elementary school. The distribution of respondents' family income ranged from $100 to more than $800. Notably, the biggest %age (23 %) claimed a monthly income of $300 to $400, while 14 % reported a monthly income of $300 to $400. Only 3 % reported a monthly income of less than $200, while 7 % claimed a monthly income of more than $800. This disparity in socioeconomic indices sheds light on the demographics of the residences under study.

5.3. Facilitating elements that promote community engagement in sorting, composting, and recycling initiatives

Fig. 5 depicts the five most important supporting elements that contribute to the reduction of municipal solid waste (MSW). The aforementioned aspects include the participant's level of knowledge, information obtained from mass media on MSW management and reduction, participation in educational and training programs, the availability of environmental cadres, and the accessibility of a waste storage facility. The first supporting factor, the respondent's level of knowledge, has a distribution of 27.67 % for "low level of knowledge," 56 % for "sufficient knowledge," and 16.33 % for "great level of knowledge," respectively. The second element, information from mass media, shows that 32.67 % of respondents learned about MSW decrease from various media sources, including television, radio, newspapers, magazines, and others, while 67.33 % did not. The third supporting factor, involvement in MSW management and reduction education and training programs, shows that 18.33 % of respondents participated in these programs, whereas 81.67 % did not receive any training. The presence of environmental cadres, the fourth component, is especially notable because just 41.33 % of respondents indicated they could find any in their neighborhood, while 58.67 % said they couldn't. The fifth supporting element, the existence of a waste storage facility in the neighborhood, reveals that only 21.33 % of respondents indicated there was one, while 78.67 % stated there wasn't. This comprehensive overview provides light on the various aspects driving MSW reduction practices among respondents, offering significant insights for additional investigation and intervention efforts.

Fig. 6 provides a comprehensive account of the respondent's MSW activities, which include composting, sorting, and manufacturing distinctive handcrafted things from recyclable garbage. Sorting activity was actively participated in by 32.7 % of respondents, whereas 67.3 % did not sort. The top incentive for those who sorted was "self-awareness" (53.1 %), with "profit for community needs" being the least popular purpose (8.2 %). In contrast, the most common reasons for not sorting were "lack of time" (25.2 %) and "laziness" (34.2 %). Surprisingly, a sizable proportion of respondents (77.7 %) reported a readiness to segregate MSW, outnumbering those hesitant to assist in sorting activities. This inclination toward segregation suggests a potential openness to waste management practices that align with environmental consciousness. Fig. 6's extensive insights shed light on the elements influencing individuals' decisions to engage in sorting activities as well as their motives, providing significant information for building targeted interventions aimed at promoting sustainable waste management practices in the community. According to the data supplied, just 12.3 % of respondents in Tehran's research locations made unique handcrafted goods from recyclable refuse. The respondents' top motivations for recycling were "self-awareness" (54.1 %) and "commands from

Table 2
MSW Compositions in sample districts.

District	Electrical and electronic waste	Non-ferrous metals (copper, zinc, aluminum, brass, etc.)	Heavy iron (door and window, iron beam, rebar)	light iron (tin cans)	Paper and cardboard	Shrink	Plastic	bread	Glass	Branches and wood waste	Tires	PET
District 1	3441	261,100	246,500	828,300	9,775,000	1,479,000	2,470,300	1,615,000	5,242,000	922,000	–	1,999,000
District 5	1533	66,781	28,802	298,377	1,353,922	2,766,760	1,451,911	909,578	316,798	1,866,100	–	785,285
District 17	12,000	142,000	134,000	151,000	717,000	784,000	903,000	830,000	12,000	102,400	33,800	911,000

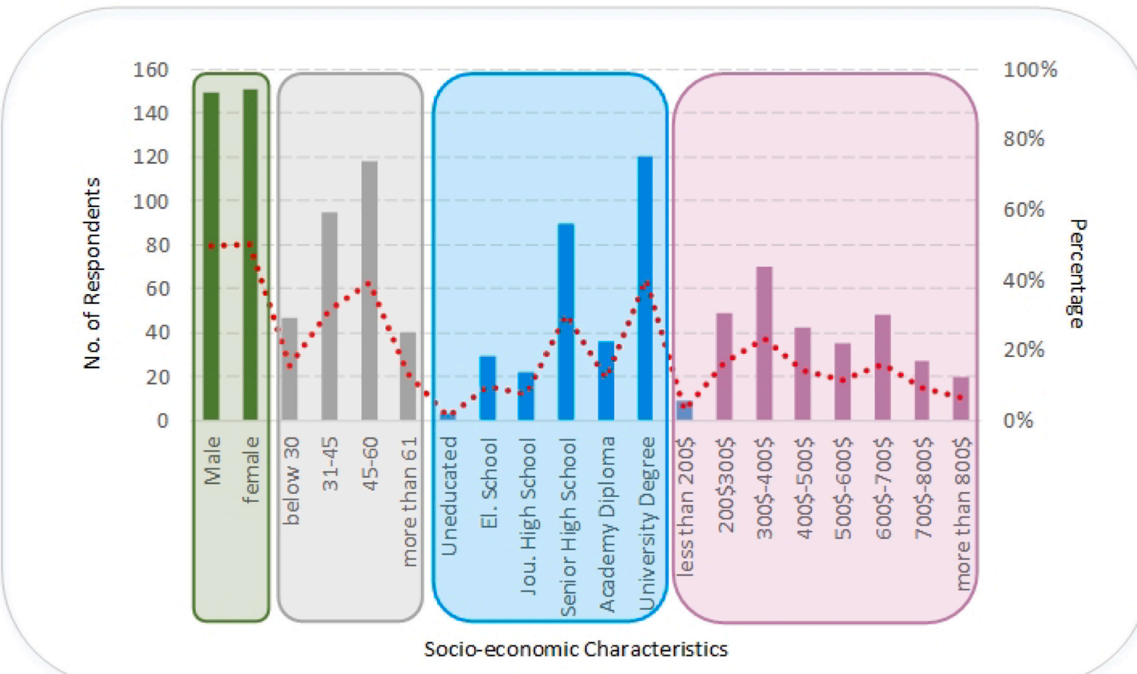

Fig. 4. Socio-economic characteristics of the respondents in the sample districts.

neighborhood/community association leaders" (24.3 %). Reasons for not recycling included "laziness" (38.4 %), "lack of information about the method" (27.8 %), "time constraints" (21.3 %), and other considerations (12.5 %). It's worth noting that 41.4 % of respondents said they would be willing to use recyclable waste to produce one-of-a-kind handcrafted items. This statistic was slightly lower than the proportion of respondents who were hesitant to recycle municipal solid garbage (MSW). These findings highlight the importance of targeted public awareness initiatives to promote recycling and the creation of handcrafted goods from recyclable materials. Concerning composting operations, only 9 % of respondents acknowledged doing so, while the vast majority (97 %) did not engage in this waste reduction method. The most common reasons for not composting were "lack of time" (38.1 %) and "unfamiliarity with the method" (15.8 %). However, 30.7 % of respondents indicated a readiness to compost, indicating a possible opportunity for community-level initiatives and education on the benefits of composting and its simple procedures.

5.4. The effect of socioeconomic characteristics and enabling variables on MSW decline

Table 3 displays the results of the binary logistic regression analysis performed on the community sorting activities. The findings show that a number of important parameters have a significant impact on municipal solid waste (MSW) sorting. Notably, the respondent's age, knowledge level, the presence of an environmental cadre, and the availability of a waste storage facility all had a significant impact on the sorting process. These factors' statistically significant values—0.000, 0.000, 0.064, and 0.000, respectively—support this conclusion. Each of these significant values is less than 0.1 (10 %), it is clear that these variables have a significant impact on the sorting activities of the community. The logistic regression model for the sorting activity is given by Eq. (2) as follows: [Include here the logistic regression model equation]. This model captures the interactions of the aforementioned factors, providing a useful framework for understanding and predicting the dynamics of MSW sorting behavior in the community.

A respondent between the ages of 31 and 45 was more likely to engage in municipal solid waste (MSW) sorting than one under the age of 30. Similarly, respondents aged 45–60 years and over 61 years were more likely to participate in MSW sorting than those under 31. Furthermore, respondents with "sufficient knowledge" were twice as likely as those with "low knowledge" to sort MSW, and seven times more likely than those with "high knowledge." When an environmental cadre was present, the likelihood of sorting increased twofold, and it increased fivefold when a waste storage facility was present. These findings highlight the critical roles that age, knowledge level, waste storage fa-

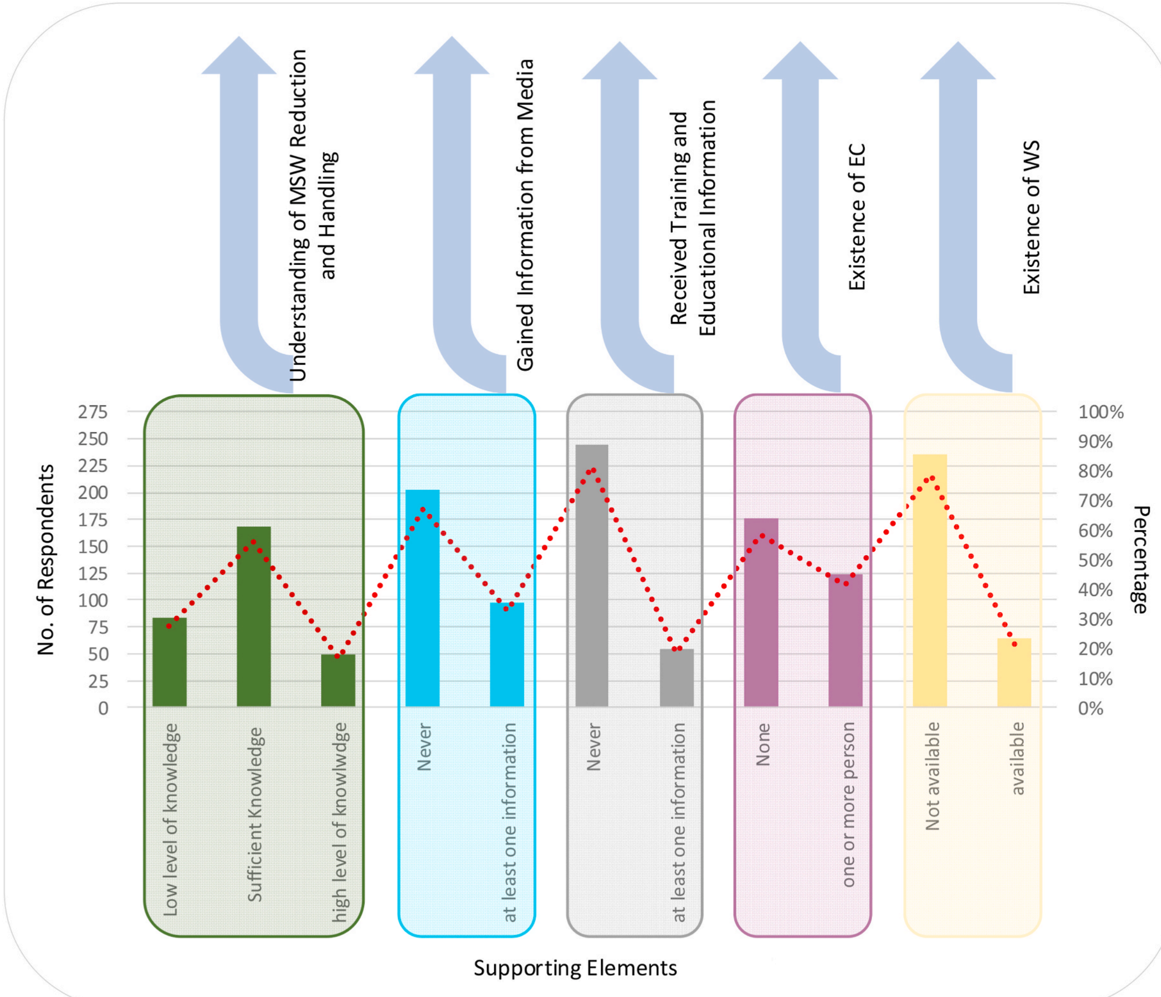

Fig. 5. Supporting elements.

cility availability, and the presence of an environmental cadre play in shaping community sorting behavior. Using the fitted model for sorting activity, we can calculate the likelihood that a specific respondent will participate in sorting activities. A 38-year-old respondent with extensive knowledge, a nearby environmental cadre, and access to a waste storage facility, for example, would have a calculated likelihood of participating in sorting operations. Because of this nuanced understanding, targeted interventions and strategies to encourage sorting practices based on individual characteristics and community resources are possible.

$$g(x) = -2.322 + 2.015(1) + 0.899(0) + 1.002(0) + 0.722LK(0) + 1.889(1) + 0.496(0) + 1.315(0) = 1.58$$

$$g(x) = -2.322 + 2.015(1) + 0.899(0) + 1.002(0) + 0.722LK(0) + 1.889(1) + 0.496(0) + 1.315(0) = 1.58$$

$$\pi(\chi) = \frac{e^{[g(\chi)]}}{1 + e^{[g(\chi)]}} = \frac{e^{\beta_0 + \beta_1\chi_1 + \ldots + \beta_p\chi_p}}{1 + e^{\beta_0 + \beta_1\chi_1 + \ldots + \beta_p\chi_p}} = \pi(\chi) = \frac{e^{1.58}}{1 + e^{[1.58]}} = 0.83 = 83\%$$

After accounting for variables such as age, education level, and proximity to both an environmental cadre and a trash storage, the estimated logistic chance of a respondent participating in sorting activities reached 83 %. These findings highlight the importance of age, knowledge level, and the presence of community resources in sorting behaviors.

Table 4 shows the results of a binary logistic regression on the production of unique handcrafted items from recyclable waste. The presence of a waste storage and an environmental cadre were discovered to be the activity's influencing elements, with significant values of 0.0.115 and 0.0650, respectively. These values are less than 0.1 (10 %), and are likely to have a significant impact on recycling-related behaviors. It's interesting to note that respondents' willingness to create unique handcrafted items from recyclable waste was unaffected by their socioeconomic status. Rather, the presence of an environmental cadre and the availability of a trash storage facility were the deciding factors, demonstrating their importance in shaping and encouraging recycling practices in the community.

Based on Equation (2), the logistic regression model for recycling activity was as follows:

$$g(x) = -5.2 + 2.116WS + 2.141EC$$

In comparison to scenarios where no environmental cadre was present, there was a significant increase in the likelihood that respondents would create handcrafted objects from recyclable garbage when an environmental cadre was present. Similarly, when respondents had access to a waste storage, the likelihood that they would engage in the production of unique handcrafted items from recyclable garbage increased dramatically, and this was far greater than when there was no waste storage.

Using the fitted model for recycling activity, we can calculate the

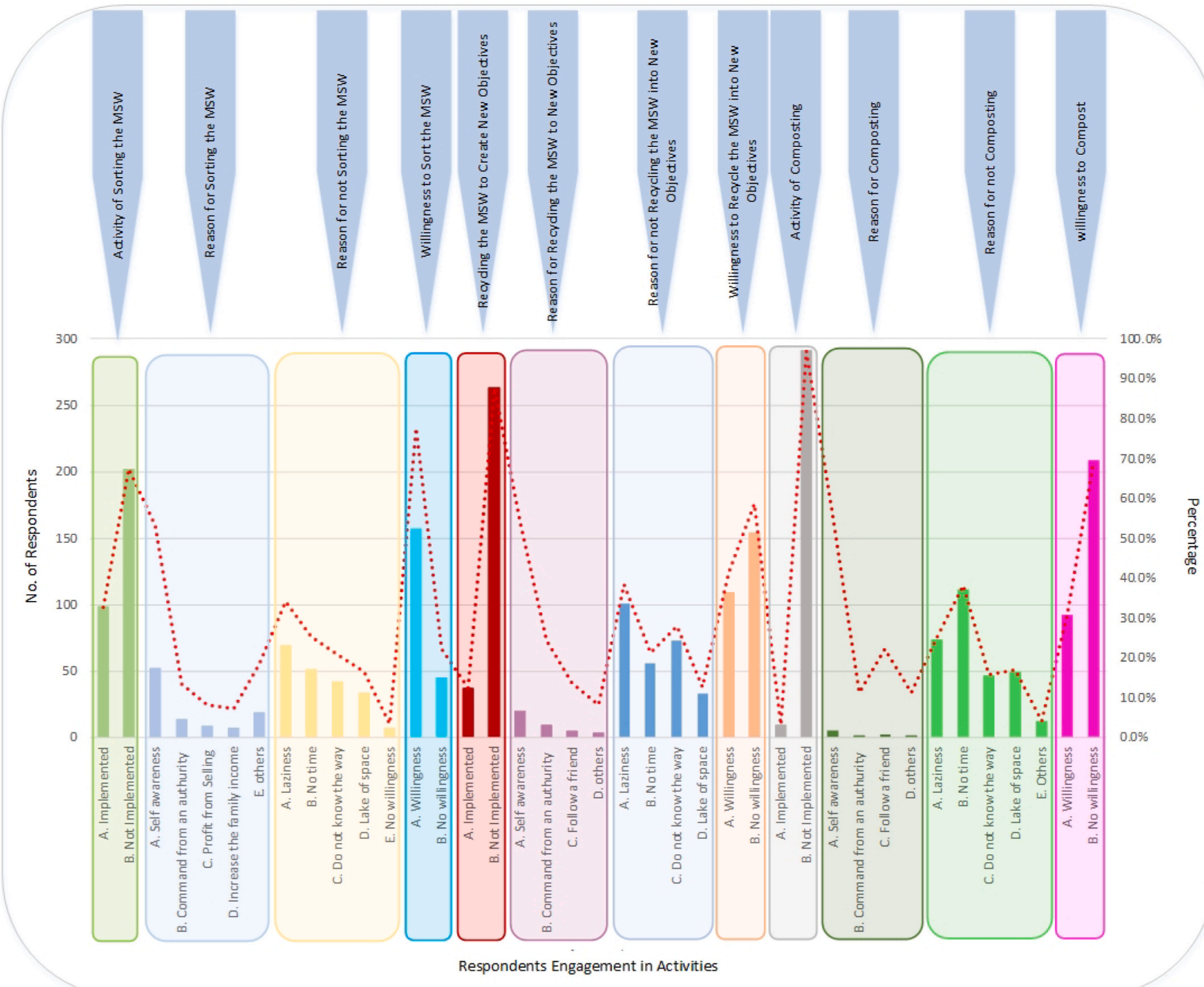

Fig. 6. Respondents Engagement in activities.

Table 3
Result from Regression on sorting activity.

$$g(x) = -2.322 + 2.015age(1) + 0.899age(2) + 1.002age(3) + 0.722LK(1) + 1.889LK(2) + 0.496EC + 1.315WS$$

	B	S.E.	Wald	df	Sig.	Exp (B)
Age			22.355	3	0.0000	
Age (1)	2.015	0.442	20.013	1	0.0000	7.744
Age (2)	0.899	0.39	5.02	1	0.0210	2.336
Age (3)	1.002	0.533	4.4	1	0.0320	3.039
Level of knowledge			23.288	2	0.0000	
Level of knowledge (1)	0.722	0.399	3.963	1	0.0500	2.18
Level of knowledge (2)	1.889	0.456	20.112	1	0.0000	6.366
Environmental Cadre (1)	0.496	0.366	3.781	1	0.0640	1.6
Waste storage	1.315	0.426	14.223	1	0.0000	4.622
Constant	−2.322	0.6	29.4	1	0.0000	0.061

likelihood that a person will use recyclable waste to create one-of-a-kind handcrafted goods. For example, if an environmental cadre (coded as 1) is present in the respondent's area and a waste storage facility (coded as 1) is available, the calculated probability of participating in the creation of one-of-a-kind handcrafted goods is as follows. [Include the probability calculation here]. This knowledge enables targeted interventions and strategies that take advantage of the presence of an environmental cadre and the availability of a waste storage facility to encourage and improve recycling activities in the community.

Table 4
RG on creating new objectives from recyclable wastes.

	B	S.E.	Wald	df	Sig.	Exp(B)
Environmental Cadre	2.141	1.116	3.355	1	0.0650	7.899
Waste storage	2.116	0.812	6.458	1	0.1150	8.584
Constant	−5.2	1.05	28.742	1	0.0000	0.004

$$g(x) = -5.2 + 2.116WS + 2.141EC = -5.2 + 2.116(1) + 2.141(1) = -0.94$$

$$\pi(\chi) = \frac{e^{-0.94}}{1 + e^{[-0.94]}} = 0.28 = 28\%$$

In contrast, the probability of engaging in the creation of unique handmade objectives from recyclable waste is as follows in scenarios where there is no environmental cadre (coded as 0) and no waste storage (coded as 0) in the respondent's area: [Include the probability calculation here]. This contrasting scenario sheds light on the impact of the absence of an environmental cadre and a waste storage facility on the likelihood of recycling activities. Understanding these probabilities aids in the development of targeted strategies to overcome barriers and promote recycling behaviors in the community when these critical resources are unavailable.

$$g(x) = -5.2 + 2.116WS + 2.141EC = -5.2 + 2.116(0) + 2.141(0) = -5.2$$

$$\pi(\chi) = \frac{e^{-0.94}}{1 + e^{[-0.94]}} = 0.0.005 = 0.5\%$$

When a waste storage facility and an environmental cadre were nearby, the likelihood that a respondent would create handmade items that were unique was estimated to be 28 %. In the absence of both an environmental cadre and a waste storage, the predicted probability of the respondent engaging in the production of handmade goods decreased dramatically to 0.5 %. These calculations show how the presence or absence of these key resources has a significant impact on the likelihood of engaging in recycling activities in the community.

Table 5 displays the results of a binary logistic regression centered on composting activity. Gender, MSW reduction training, media information, and the presence of an environmental cadre were discovered to be influencing factors on composting. Significant values for these factors were 0.0.0440, 0.0760, 0.0290, and 0.0190, in that order. The fact that all of these values are less than 0.1 (10 %) indicates that these variables have a significant impact on composting activity. Understanding the impact of these factors provides valuable insights for tailoring interventions and strategies to improve community composting practices.

The composting activity logistic regression model, which was based on Eq. (2), was as follows:

$$g(x) = -5.788 + 1.184EC + 1.076\,Inf + 1.084RT + 1.063Gender$$

A female respondent was three times more likely than a male respondent to engage in composting activities. Furthermore, the likelihood of composting increased threefold for respondents who received Municipal solid waste (MSW) reduction training versus those who did not. Furthermore, respondents who had received 3R (reduce, reuse, recycle) information from the media were five times more likely to compost than those who had not received such information. Furthermore, respondents with an available environmental cadre were three times more likely than those without an environmental cadre to engage in composting activities.

The fitted model for composting activity allows for probability estimation based on specific characteristics. For example, if the respondent is female (=1), has received MSW reduction training (=1), has obtained information from mass media (=1), and is in the presence of an environmental cadre (=1), the following is the computed chance of participating in composting activities: (This is where you include the precise probability calculation). These findings provide a more nuanced understanding of the factors influencing composting behaviors and help to develop targeted interventions to promote composting practices in the community.

$$g(x) = -5.788 + 1.184(1) + 1.076(1) + 1.084(1) + 1.063(1) = -2.45$$

$$\pi(\chi) = \frac{e^{-2.45}}{1 + e^{[-2.45]}} = 0.079 = 7.9\%$$

In contrast, in scenarios where the respondent is female (=1), has never received MSW reduction training (=0), has not received information about 3R from the media (=0), and does not have an environmental cadre in her area (=0), the likelihood of engaging in composting activities is as follows: (Include the specific probability calculation here). When specific supportive factors are absent, this contrasting scenario provides insights into the potential challenges or barriers that may influence a female respondent's likelihood of participating in composting activities. Understanding these probabilities is critical for developing targeted strategies to address barriers and improve community composting behaviors.

$$g(x) = -5.788 + 1.184(0) + 1.076(0) + 1.084(0) + 1.063(1) = -4.72$$

$$\pi(\chi) = \frac{e^{-4.72}}{1 + e^{[-4.72]}} = 0.0088 = 0.88\%$$

The calculated probability of a respondent engaging in composting activities was 7.9 % under the conditions of being a female respondent who had undergone MSW reduction training at least once, with the additional presence of an environmental cadre and a waste storage in the area. In the absence of both a waste storage facility and an environmental cadre, the predicted likelihood of the responder engaging in composting activities fell dramatically to 0.88 %. These calculations highlight the significant impact of factors such as gender, MSW reduction training, and the availability of community resources on the likelihood of a community engaging in composting practices. Understanding these probabilities can help you tailor targeted interventions and initiatives to promote composting behaviors in a variety of situations.

6. Discussions

The study reveals a significant increase in Tehran's municipal solid waste generation, with higher %ages of paper and plastic and lower amount of decomposable trash [37]. The study reveals that used diapers make up 6.97 % of Tehran's solid waste, while organic materials make up 42–80 % [38]. According to Fig. 6, the primary reasons cited by respondents for not sorting Municipal solid waste (MSW) were factors such as a lack of time, laziness, and a lack of familiarity with the sorting procedures. Surprisingly, these findings are consistent with previous research findings, which identified common barriers to sorting, such as "lack of time.", insufficient space for storing recyclables at home, and limited local facilities, as well as the absence of a collection service [39]. Similarly, as shown in Fig. 6, the reasons for respondents not recycling MSW were centered on themes of laziness, unfamiliarity with recycling procedures, and a perceived lack of time. These reasons are consistent with previous research findings indicating barriers to recycling, such as time constraints, a lack of incentives for recycling, public attitudes toward recycling activities and their perceptions of constraints in recycling, the assumption of "producing little waste", apathy towards recycling, and a lack of public awareness and participation, as well as a deficiency in enthusiasm [39]. The findings corroborate previous research highlighting composting constraints, specifically a lack of interest and awareness in selling and promotion [40]. Composting is a promising solid waste management solution due to its ability to decrease waste volume, provide essential plant nutrients, and enhance soil quality [41]. Composting's decentralized nature, requiring minimal technology and budget, adds to its allure [42]. Composting has garnered support from various stakeholders, including local governments,

Table 5
RG on composting activity.

	B	S.E.	Wald	df	Sig.	Exp (B)
Gender	1.063	0.554	4.055	1	0.0440	2.844
MSW Reduction Training	1.084	0.598	3.256	1	0.0760	2.902
Information from media	1.076	0.699	4.589	1	0.0290	5.226
Environmental Cadre	1.184	0.501	5.699	1	0.0190	3.117
Constant	−5.788	0.8	35.988	1	0.0000	0.004

communities, private sectors, and NGOs, due to its numerous benefits.

As shown in Table 3, there is a strong relationship between environmental knowledge and environmental behavior. Furthermore, environmental knowledge contributes to an improvement in residents' attitudes toward the environment [43], and knowledge transfer plays a pivotal role in enhancing solid waste management practices [44].

Table 3 reveals that predictor variables like age, knowledge level, environmental cadre, and trash storage significantly influence sorting activities, with knowledge level being a key factor [32]. As shown in Table 4, the presence of a waste storage facility is critical in encouraging community participation in municipal solid waste (MSW) sorting and recycling activities. Customers of the waste storage actively participate within this framework by selling recyclable waste items with intrinsic value, such as paper, plastic, metal, and glass.

As a result, waste storage serves as a catalyst for community members to actively participate in MSW sorting and recycling. Aside from environmental benefits, participants gain a tangible economic advantage by turning their recyclable waste into a source of income. This dual benefit system strengthens the incentive for individuals to contribute to sustainable waste management practices, highlighting the positive impact of waste storage on both the environmental and economic fronts within the community. Beyond their traditional role as waste transaction facilitators, waste storage facilities have been instrumental in fostering community initiatives, particularly in the creation of one-of-a-kind handcrafted goods, as demonstrated by programs such as training initiatives [45].

In the broader context of waste reduction and recycling, the pivotal roles of public awareness [46] and knowledge transfer [44] come to the forefront. Recognizing these elements' transformative potential, training programs emerge as powerful tools for disseminating knowledge and technology. Communities see an increase in their knowledge levels as a result of targeted training efforts, raising their awareness of Municipal solid waste (MSW) reduction practices. Importantly, this increased knowledge frequently translates into tangible actions, indicating a shift from awareness to proactive waste management engagement.

Table 5 shows that gender, participation in municipal solid waste (MSW) reduction training programs, media exposure, and the presence of environmental cadres all have a significant impact on composting activities. The importance of information in shaping attitudes toward solid waste management becomes clear (SWM). This informational landscape extends through a variety of channels, including mass media and electronic platforms, providing citizens with valuable insights gained through education and training initiatives. Environmental education has been found to be a catalyst for encouraging pro-environmental actions, raising awareness, causing concern, and recognizing the impact of citizens' activities, which is consistent with previous research [47].

Furthermore, gender dynamics are important in the implementation of the 3Rs (Reduce, Reuse, Recycle), with a predominance of women in cadre roles [40]. This trend is also evident in other developing countries, such Thailand, where women play critical roles in MSW reduction efforts [48].

Four strategic initiatives are proposed to increase community engagement in municipal solid waste (MSW) reduction in Tehran. The primary strategy focuses on improving MSW reduction at the source through increased training programs for both community and environmental cadres. These training sessions serve as platforms for the dissemination of critical information about MSW handling and reduction, which contributes to the participants' knowledge. The training is inclusive in its approach and welcomes collaborative contributions from the government, private sector, NGOs, institutions, and community members. This collaborative effort includes the provision of training materials, funding, and qualified MSW reduction trainers. The second strategy entails increasing the dissemination of information about MSW handling, reduction, and recycling through mass media channels and targeted campaigns. This proactive outreach aims to raise community awareness and understanding, fostering a culture of responsible waste management practices. The third strategy aims to increase the number of environmental motivators and guides committed to MSW reduction initiatives. These environmental cadres, comprised of both external residents and community leaders, serve as critical catalysts for motivating and guiding community members. The fourth strategy emphasizes the importance of increasing the availability and functionality of waste storage facilities. These institutions serve as both community recycling centers and customer-oriented storage facilities, as well as organizations dedicated to community development through environmental campaigns and training programs. This strategy aims to strengthen community-driven efforts in sustainable waste management by expanding waste storage facilities and expanding their multifaceted roles. Tehran aims to create a comprehensive and collaborative framework for effective MSW reduction by involving diverse stakeholders and fostering a shared commitment to environmental sustainability through the coordinated implementation of these four strategies.

7. Conclusions and suggestions

The mean daily municipal solid waste (MSW) generation rate in Tehran is 0.645 kg per capita. Food waste comprises 64.19 % of the MSW, with paper (9.24 %), plastics (10.79 %), used diapers (6.97 %) and remaining (Garden waste, Wood, Textiles and Glass, Metals) accounts for 8.81 %. The influence of socioeconomic characteristics of respondents on MSW sorting, crafting recyclable waste, and composting was found to be less significant in comparison to supporting factors. Government, private sector, and NGO collaboration is essential for the promotion of Reduce, Reuse, and Recycle (3R) practices. Enhancing MSW reduction training for community and environmental cadres, increasing information dissemination via media and targeted campaigns, increasing the number of environmental cadres, and diversifying the functions of waste storage facilities are proposed as four key strategies. The objective of these strategies is to promote active involvement of the community in sustainable waste management and stimulate increased implementation of MSW reduction practices. Further investigation in these areas would provide valuable insights for enhancing sustainable waste management practices, including the impact of environmental cadres on community engagement, the effects of expanding waste storage facilities, and the behavioral influences on MSW sorting.

CRediT authorship contribution statement

Hamed Alimoradiyan: Writing – original draft, Investigation, Formal analysis. **Ahmad Hajinezhad:** Writing – review & editing, Supervision. **Hossein Yousefi:** Validation, Project administration, Data curation. **Mario Giampietro:** Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rineng.2024.102174.

Table Related to Fig. 3

Socio-exonomic Characteristics	Parameter	No. Respondents	Percentage
Gender	Male	149	49.76 %
	female	151	50.24 %
Age	below 30	47	16 %
	31–45	95	32 %
	45–60	118	39 %
	more than 61	40	13 %
Education	Uneducated	3	1 %
	El. School	29	10 %
	Jou. High School	22	7 %
	Senior High School	90	30 %
	Academy Diploma	36	12 %
	University Degree	120	40 %
family Income Level	less than 200$	9	3 %
	200$300$	49	16 %
	300-400	70	23 %
	400-500	42	14 %
	500-600	35	12 %
	600-700	48	16 %
	700-800	27	9 %
	more than 800$	20	7 %

Table Related to Fig. 5

Supporting elements	No. of Respondents	%
Low level of knowledge	83	27.67 %
Sufficient Knowledge high level of knowledge	168	56.00 %
	49	16.33 %
Never at least one information	202	67.33 %
	98	32.67 %
Never at least one information	245	81.67 %
	55	18.33 %
None one or more person	176	58.67 %
	124	41.33 %
Not available available	236	78.67 %
	64	21.33 %

Table Related to Fig. 6

Respondent's activity in sorting, recycling and composting the HSW		
	No.of Respondents	%
A. Implemented	98	32.7 %
B. Not Implemented	202	67.3 %
A. Self-awareness	52	53.1 %
B. Command from an authority	13	13.3 %
C. Profit from Selling	8	8.2 %
D. Increase the family income	7	7.1 %
E. others	18	18.4 %
A. Laziness	69	34.2 %
B. No time	51	25.2 %
C. Do not know the way	42	20.8 %
D. Lake of space	33	16.3 %
E. No willingness	7	3.5 %
A. Willingness	157	77.7 %
B. No willingness	45	22.3 %
A. Implemented	37	12.3 %
B. Not Implemented	263	87.7 %
A. Self-awareness	20	54.1 %
B. Command from an authority	9	24.3 %
C. Follow a friend	5	13.5 %
D. others	3	8.1 %
A. Laziness	101	38.4 %
B. No time	56	21.3 %
C. Do not know the way	73	27.8 %

(continued on next page)

(*continued*)

Respondent's activity in sorting, recycling and composting the HSW		
	No.of Respondents	%
D. Lake of space	33	12.5 %
A. Willingness	109	41.4 %
B. No willingness	154	58.6 %
A. Implemented	9	3.0 %
B. Not Implemented	291	97.0 %
A. Self-awareness	5	55.6 %
B. Command from an authority	1	11.1 %
C. Follow a friend	2	22.2 %
D. others	1	11.1 %
A. Laziness	73	25.1 %
B. No time	111	38.1 %
C. Do not know the way	46	15.8 %
D. Lake of space	49	16.8 %
E. Others	12	4.1 %
A. Willingness	92	30.7 %
B. No willingness	208	69.3 %

References

[1] L. Andeobu, S. Wibowo, S. Grandhi, Artificial intelligence applications for sustainable solid waste management practices in Australia: a systematic review, Sci. Total Environ. 834 (2022) 155389.
[2] S. Najafi, et al., Development of municipal solid waste management guidelines in biological crisis based on international experiences and considering local techno-economic characteristics, Results in Engineering (2024) 102052.
[3] L.L.B. Lazaro, et al., Water-energy-food Nexus and Climate Change in Cities, Springer Nature, 2022.
[4] C. Rossitto, et al., Towards digital environmental stewardship: the work of caring for the environment in waste management, in: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems, 2022.
[5] Jingjing Zhang, Guifang Luo, Yan Yan, Toward an effective policy mix for domestic waste management in China: Interdepartmental cooperation as an enabler, Rev. Policy Res. (2023).
[6] Y.A. Fatimah, et al., Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: a case study of Indonesia, J. Clean. Prod. 269 (2020) 122263.
[7] A. Altassan, Sustainable integration of solar energy, behavior change, and recycling practices in educational institutions: a holistic framework for environmental conservation and quality education, Sustainability 15 (20) (2023) 15157.
[8] S. Hemidat, et al., Solid waste management in the context of a circular economy in the MENA region, Sustainability 14 (1) (2022) 480.
[9] A.K.A. Ahmed, A.M. Ibraheem, M.K. Abd-Ellah, Forecasting of municipal solid waste multi-classification by using time-series deep learning depending on the living standard, Results in Engineering 16 (2022) 100655.
[10] D. Knickmeyer, Social factors influencing household waste separation: a literature review on good practices to improve the recycling performance of urban areas, J. Clean. Prod. 245 (2020) 118605.
[11] R. Sarc, et al., Digitalisation and intelligent robotics in value chain of circular economy oriented waste management–A review, Waste Manag. 95 (2019) 476–492.
[12] K. Govindan, Y. Zhuang, G. Chen, Analysis of factors influencing residents' waste sorting behavior: a case study of Shanghai, J. Clean. Prod. 349 (2022) 131126.
[13] M. Sharma, S. Joshi, A. Kumar, Assessing enablers of e-waste management in circular economy using DEMATEL method: an Indian perspective, Environ. Sci. Pollut. Control Ser. 27 (12) (2020) 13325–13338.
[14] S. Narayanamoorthy, et al., An approach to assess PWR methods to cope with physical barriers on plastic waste disposal and exploration from developing nations, Expert Syst. Appl. 207 (2022) 117996.
[15] M.M. Shahsavar, et al., Bio-recovery of municipal plastic waste management based on an integrated decision-making framework, J. Ind. Eng. Chem. 108 (2022) 215–234.
[16] A.A. Zorpas, Strategy development in the framework of waste management, Sci. Total Environ. 716 (2020) 137088.
[17] K. Kabirifar, et al., Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: a review, J. Clean. Prod. 263 (2020) 121265.
[18] A. Di Vaio, et al., The transition towards circular economy and waste within accounting and accountability models: a systematic literature review and conceptual framework, Environ. Dev. Sustain. 25 (1) (2023) 734–810.
[19] F.M. Tsai, et al., A performance assessment approach for integrated solid waste management using a sustainable balanced scorecard approach, J. Clean. Prod. 251 (2020) 119740.
[20] L. Corominas, et al., The application of life cycle assessment (LCA) to wastewater treatment: a best practice guide and critical review, Water Res. 184 (2020) 116058.
[21] S. Suriyanti, Planning strategy of operation business and maintenance by analytical hierarchy process and strength, weakness, opportunity, and threat integration for energy sustainability, Int. J. Energy Econ. Pol. 10 (4) (2020) 221–228.
[22] H. Gonzalez-Urango, E. Mu, M. García-Melón, Stakeholder engagement and ANP best research practices in sustainable territorial and urban strategic planning, in: Multiple Criteria Decision Making for Sustainable Development: Pursuing Economic Growth, Environmental Protection and Social Cohesion, Springer, 2022, pp. 93–130.
[23] J. Gutierrez-Lopez, et al., Decision support frameworks in solid waste management: a systematic review of multi-criteria decision-making with sustainability and social indicators, Sustainability 15 (18) (2023) 13316.
[24] S.M. Darmian, S. Moazzeni, L.M. Hvattum, Multi-objective sustainable location-districting for the collection of municipal solid waste: two case studies, Comput. Ind. Eng. 150 (2020) 106965.
[25] M. Giampietro, Implications of Complexity Theory, 2021.
[26] A.E. Torkayesh, H.R. Vandchali, E.B. Tirkolaee, Multi-objective optimization for healthcare waste management network design with sustainability perspective, Sustainability 13 (15) (2021) 8279.
[27] J.M. Torrente-Velásquez, et al., Robust information for effective municipal solid waste policies: identifying behaviour of waste generation across spatial levels of organization, Waste Manag. 103 (2020) 208–217.
[28] M.S. Allahyari, et al., Effects of COVID-19 pandemic on household food waste behaviour in Iran, Heliyon 8 (11) (2022) e11337.
[29] A. Youngman, Recycling in the garden: reusing everyday items, Recycling in the Garden (2023) 1–160.
[30] A. Golzary, H. Nematollahi, M. Tuysserkani, Assessment and pathways for improving municipal solid waste management in rapidly urbanizing Tehran, Iran, Clean Technol. Environ. Policy (2023) 1–17.
[31] D.N. Anayo, C. Nwankwo, P. Abude, Investigating university students' environmental knowledge and waste disposal behaviour in enugu state, Nigeria: a critical analysis, Caritas Journal of Management Social Sciences and Humanities 3 (1) (2024).
[32] T. Ramayah, J.W.C. Lee, S. Lim, Sustaining the environment through recycling: an empirical study, J. Environ. Manag. 102 (2012) 141–147.
[33] K. Holmberg, S. Persson, Keep plastics on a tight leash: Swedish public opinion on plastic policies, Environ. Sci. Pol. 141 (2023) 109–116.
[34] S.J.M. Al-Neyazy, The use of a multinomial logistic regression model in analyzing the characteristics of married women using family planning methods in Iraq 2018, Turkish Journal of Computer and Mathematics Education (TURCOMAT) 12 (12) (2021) 4723–4742.
[35] F.L. Huang, Alternatives to logistic regression models when analyzing cluster randomized trials with binary outcomes, Prev. Sci. 24 (3) (2023) 398–407.
[36] T. Malmir, Y. Tojo, Municipal solid waste management in Tehran: changes during the last 5 years, Waste Manag. Res. 34 (5) (2016) 449–456.
[37] Z. Golhosseini, M.J. Ghazizade, Municipal solid waste status in Iran: from generation to disposal, Environmental Protection Research (2024) 16–29.
[38] Y. Dhokhikah, Y. Trihadiningrum, Solid waste management in Asian developing countries: challenges and opportunities, Journal of Applied Environmental and Biological Sciences 2 (7) (2012) 329–335.
[39] L. Veselá, et al., Beyond the bin: dissecting factors and barriers in food waste sorting among Czech households, in: WASTE, 2023.
[40] P.K. Sarangi, et al., Municipal-based biowaste conversion for developing and promoting renewable energy in smart cities, Sustainability 15 (17) (2023) 12737.
[41] M. Meena, et al., Municipal solid waste: opportunities, challenges and management policies in India: a review, Waste Management Bulletin 1 (1) (2023) 4–18.
[42] Y. Ma, Y. Shen, Y. Liu, State of the art of straw treatment technology: challenges and solutions forward, Bioresour. Technol. 313 (2020) 123656.
[43] N. Nahar, Z. Hossain, S. Mahiuddin, Assessment of the environmental perceptions, attitudes, and awareness of city dwellers regarding sustainable urban

environmental management: a case study of Dhaka, Bangladesh, Environ. Dev. Sustain. 25 (8) (2023) 7503–7531.
[44] W. Fadhullah, et al., Household solid waste management practices and perceptions among residents in the East Coast of Malaysia, BMC Publ. Health 22 (2022) 1–20.
[45] N. Purbasari, Community empowerment through recycling plastic waste (Case study on waste bank community housing poklili in Perumahan Griya Lembah Depok, Sukmajaya Subdistricts, Depok city). Social Science Education Department, Faulty of Tarbiyah and Education, Syrif Hidayatullah State Islamic, University, Jakarta, Indonesia, 2014. Unpublished Thesis.
[46] F.B. Awino, S.E. Apitz, Solid waste management in the context of the waste hierarchy and circular economy frameworks: an international critical review, Integrated Environ. Assess. Manag. 20 (1) (2024) 9–35.
[47] Y. Hotta, C. Aoki-Suzuki, Waste reduction and recycling initiatives in Japanese cities: lessons from Yokohama and Kamakura, Waste Manag. Res. 32 (9) (2014) 857–866.
[48] I.R. Abubakar, et al., Environmental sustainability impacts of solid waste management practices in the global South, Int. J. Environ. Res. Publ. Health 19 (19) (2022) 12717.

Nomenclature

Notation

N: Total Population
n: Number of Samples
d: Error margin
X1: Gender
X2: Age
X3: Education Background
X4: Family Income
X5: Family Income
X6: Media-obtained Information
X7: Reduction Training
X8: Environmental Cadre in the Region
X9: Availability of Waste Processing Plant
Y1: Sorting Activity
Y2: Recycling Engagement
Y3: Composting Participation
β_0: Parameter Vector
β_p: Coefficient
X_p: Predictor Vector
P_x: Conditional Mean

Subscript

0: standard condition

Acronyms

MSW: Municipal Solid Waste
3R: Reduce, Reuse and Recycle
MuSIASEM: Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism
MSWMS: Municipal Solid Waste Management System
PET: Polyethylene Terephthalate
RT: Reduction Training
Inf: Information from Media
EC: Environemntal Cadre