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APPLICATION OF THE ELECTRE III METHOD FOR A SOLID WASTE MANAGEMENT SYSTEM

Aysun ÖZKAN [1], Müfide BANAR [1], Ilgın Poyraz ACAR [2], Aydın SİPAHİOĞLU [3]

ABSTRACT

In recent years, effective disposing of solid waste environmentally and economically has become mandatory due to the increase in environmental problems resulted by the solid waste. Furthermore, choosing a solid waste management system appears to be an important decision making problem. Hence, economical, social, cultural and technical factors in choosing thesolid waste management systems should be considered together. A solid waste management system may have different alternatives to be evaluated by considering several criteria.Hence, this type of problem is considered as Multi Criteria Decision Making problem. Therefore, in this study, there were five alternative system scenarios (MRF, recycling, composting, incinerating and landfilling processes) ranked by using ELECTRE III for Eskisehir city/Turkey.Eskisehir is one of the developing cities of Turkey where approximately 750 tons/day waste is generated in total. It is required to apply an effective MSW management system since the generated MSW is dumped in an unregulated dumping site that has no liner, no biogas capture, etc. Final ranking for scenarios was in the following order: S3>S2>S1>S4=S5. According to the comparisons and the sensitivity analysis, scenario S3 (15% recycling+77% composting + 8% landfilling) for MSW management system in Eskisehir should be preferred.

Keywords: Solid waste, Waste management, ELECTRE III, Multiple criteria decision making.

BİR KATI ATIK YÖNETİM SİSTEMİNDE ELECTRE III YÖNTEMİNİN UYGULAMASI

ÖZ

Son yıllarda, katı atıklardan kaynaklanan çevre sorunlarının artması nedeniyle katı atığın çevresel ve ekonomik açıdan etkin bir şekilde bertaraf edilmesi zorunlu hale gelmiştir. Dolayısıyla, önemli bir karar verme problem olan katı atık yönetim sisteminin seçiminde ekonomik, sosyal, kültürel ve teknik faktörlerin birlikte ele alınması gereklidir. Bir katı atık yönetim sisteminde çeşitli kriterlerin değerlendirildiği farklı alternatifler olabilir. Bu durumda problem bir Çok Ölçütlü Karar Verme problemi haline gelir. Nitekim bu çalışmada da Eskişehir için beş farklı sistem senaryosu (MRF, geri dönüşüm, kompostlama, insinerasyon ve düzenli depolama), ELECTRE III yöntemi kullanılarak sıralanmıştır. Bir günde 750 ton atığın çıktığı Eskişehir'de atıklar halen herhangi bir sızdırmazlık ve gaz toplama sisteminin olmadığı vahşi depolama sahasında depolanmaktadır. O nedenle etkin bir atık yönetim sisteminin kurulmasına ihtiyaç vardır. Çalışmada kurulan senaryolar S3>S2>S1>S4=S5 şeklinde sıralanmış olup, karşılaştırma ve hassasiyet analizi sonuçlarına göre Eskişehir için tercih edilmesi gereken senaryo S3 (15% geri dönüşüm+77% kompostlama+ 8% düzenli depolama) olarak belirlenmiştir.

Anahtar Kelimeler: Katı atık, Atık yönetimi, ELECTRE III, Çok ölçütlü karar verme.

[1], Anadolu University, Department of Environmental Engineering IkiEylül Campus 26555, Eskisehir, Turkey.
E-mail: aysunozkan@anadolu.edu.tr, mbanar@anadolu.edu.tr
Tel: +90 222 321 35 50/6400, Fax: +90 222 323 95 01
[2], Anadolu University, Department of Industrial Engineering IkiEylül Campus 26555, Eskisehir, Turkey.
e-mail: ipoyraz@anadolu.edu.tr
[3], Eskisehir Osmangazi University, Department of Industrial Engineering Meşelik 26120, Eskisehir, Turkey.
e-mail: asipahi@ogu.edu.tr

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1. INTRODUCTION

The waste management system may be a complex and an interdisciplinary problem that considers the technical, the social and the economical factors for recycling and sustainable development. Hence, different approaches can be used in this area. Studies about modeling the waste management systems started in the 1970s, and have accelerated the 1980s with the development of computer technology. While the models studied in the 1980's mostly included the economical dimension of the event (Gottinger 1988), it was started to develop models that included the recycling and the other waste management methods for the planning of municipal solid waste(MSW) management system (MacDonald 1996) in the 1990's. The models developed recently were constructed based on the waste management system integrated with MSW system and in these models environmental and economical evaluations were carried out. Linear programming with Excel-Visual Basic (AbouNajm et al., 2004), Decision Support Systems (Fiorucci et al., 2003; Haastrup et al., 1998), fuzzy logic (Chang et al., 1997) and Multi Criteria Decision Making (MCDM) methods (Hokkanen et al., 1997) were used in these models.

Multi-Criteria Decision Making (MCDM) system is a dynamically developing research area that utilizes several evaluation criteria in choosing, sorting and ranking of different alternatives (Vincke, 1992). MCDM allows particular selection of the most preferred choice according to several criteria. There are several methods used to solve the MCDM problems such as: Goal Programming, Analytic Network Process, PROMETHEE, TOPSIS and ELECTRE (I, II, III, IV, TRI) (Figueira et. al., 2005). These methods were used in several disciplines as well as in Environmental Engineering.ELECTRE (Elimination Et Choix Traduisant la REalité) carries out a choice among several discrete alternatives. Basic philosophy of ELECTRE is an outranking relation that points out the Decision Maker's (DM) strongly established preferences. The features of the outranking methods are (Vincke 1992): (a) the application of the outranking relation, (b) the concept of pseudo-criterion in the modeling of DM's preferences, (c) the acceptance of incomparability between alternatives, (d) the introduction of non-additive rule of criteria.

ELECTRE varies through a number of versions ranked as ELECTRE I, II, III IV and TRI. ELECTRE III, developed by Bernard Roy in 1968, is based on the outranking relation for modeling the DM's preferences. Comparison between alternatives proceeds on a pair wise basis with respect to each decision criterion and establishes the degree of dominance or outranking of one option over another (Rogers and Bruen 2000; Takeda 2001). The outranking relation in ELECTRE III is a fuzzy (imprecise and uncertain) binary relation (Roy 1991).

Among others, ELECTRE III is the most common method and widely used in various studies such as: the choice of route for Dublin port motorway (Rogers and Bruen 2000) and energy-planning problem (Georgopoulou and others 1997). ELECTRE III is also used for the environmental decision making problems such as: choosing a solid waste management system (Hokkanen and Salminen 1997), locating of waste treatment plants (Norese 2006) and evaluating the performance of construction plants (Tam et al., 2003).

ELECTRE III is based on the outranking relation. The method utilizes the extended model of DM's local preferences that includes: indifference, weak preference, strong preference and incomparability (Zak, 2005). The ELECTRE method algorithm is composed of 3 phases: construction of the evaluation matrix (alternatives and criteria), calculation of the outranking relation and exploitation of the outranking relation. AHP, another MCDM method, is based on the utility function that aggregates different criteria (points of view) into one global criterion. The difference between the AHP and ELECTRE is incomparability between alternative. Such as: AHP eliminates incomparability between alternatives while ELECTRE III takes into account the incomparability between alternatives. Hence, ELECTRE III was considered in this study.

In this study, ELECTRE III method was used to develop sustainable solid waste management system in Eskisehir city. Furthermore, five scenarios and twenty criteria under four groups were derived for Eskisehir city and these scenarios were evaluated according to these criteria by using ELECTRE III.

2. METHODOLOGY

The process in this study was considered in ten steps and showed in Figure 1.

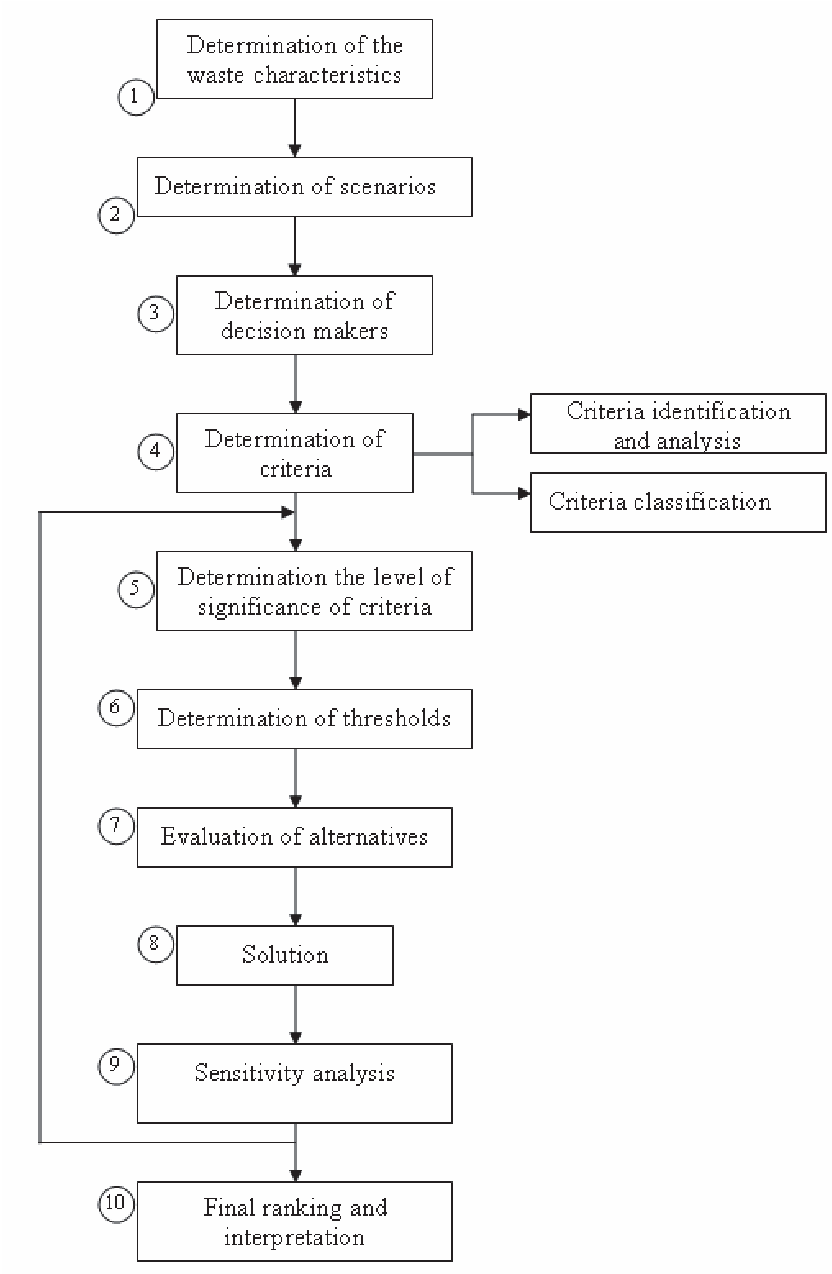

Figure 1. Flow diagram for improving a solid waste management system

Step 1: Determination of the waste characteristics

In order to developing and implementing the effective strategies to meet these targets, reliable information on the composition of all parts of the MSW stream is required. Generated composition of waste is extremely unsteady due to the seasonal variations, the population life-style, the demographic structure, the geographic conditions, and the legislation impacts.

So, the MSW production rate in Eskisehir is 750 tons/d. In addition, 805 tons of daily MSW are projected by the year 2030. An industrial waste quantity in Eskisehir is 231,000 ton per year (Ozkan, 2008). Vehicles of the two private companies employed by the two sub municipalities (Tepebasi and Odunpazari), are in charge of collecting the municipal solid wastes in plastic bags. These bags then are discarded and are piled up on the streets by the residents and these wastes are transported to the open dump site. The composition of the Eskisehir MSW according to the analysis results for 562 samples in a year is given in Table 1.

Table 1. Composition of the MSW in Eskisehir (Banar and Ozkan, 2008)

Component	*Composition (wt.%)*
Paper-cardboard	10.1
Metal[a]	1.3
Glass	2.5
Plastic	5.6
Food	67.0
Ash	3.9
Others[b]	9.7
Total	100.00
Moisture content (%)	37
Higher heating value (MJ/kg)	12.7

[a] It was assumed that all metals were aluminum cans.
[b] This component includes dominantly yard wastes.

This composition was determined before the removal of recyclables by scavengers from the MSW. Recyclables (paper/cardboard, glass and aluminum) were collected from curbside and they were separated by scavengers. These materials (2.04, 0.71 and 0.25% of paper/cardboard, glass and aluminum, respectively) were sent directly to the reprocessing facility. Rest of the waste (97%) was collected from curbside collection points and it was sent to the open dump site. This open dump site was an open area where the recyclable components of waste were partially separated (7%) under unhygienic conditionsmanually and they were piled up for recycling. Then, all of the recyclable materials were sent to the recycling facilities in other cities.

Step 2: Determination of the scenarios

According to the solid waste characteristics, waste management scenarios that include recycling, composting, incinerating and landfilling in various ratios should be described. These scenarios must be appropriate for the legal regulations and the efficiency of each process.

In this study, five alternative scenarios for the current waste management system were derived according to the MSW composition of Eskisehir. Flowcharts of the scenarios are given in the Figures 2-6 (Banar et al., 2009) where the percentages represent the proportion of the total municipal solid waste stream.

Scenario 1: This scenario was derived from current waste management system through some improvements (Figure 2). In this scenario, a Material Recovery Facility (MRF) and a landfill were added to the system. Percentages of recycling and landfill were same with the current waste management system. Recyclable fraction (3%) collected by scavengers was sent to the MRF. Rest of the recyclables was separated in the MRF. These two parts were processed separately since their recycling qualities were different. Recyclable materials were then sent to the recycling facilities in different cities. Recycling efficiencies for these materials which were brought by scavengers and separated in MRF, were 80% and 70%, respectively. The residuals after recycling process were landfilled in the city where the recycling was applied. Rest of the waste was landfilled with energy recovery in Eskisehir.

Scenario 2: In this scenario, a source separation system with 50% efficiency was added as an improvement to Scenario 2 (Figure 3). Recyclables obtained from the source separation (9.72%) were sent to the MRF and after processing they were sent to the recycling facilities in other cities to recycle with 92% efficiency. Recyclables, which were mixed in organic waste, were also processed and were sent to the recycling facility with 70% efficiency. After recycling process, residuals were sent to the landfills with energy recovery.

Scenario 3: This scenario emphasized the recovery of the biologically degradable fraction (Figure 4). The flow of the system was similar with Scenario 2 for recyclable materials. The organic fraction (76,7%) from the MRF was transported to the composting facility while the residue from the MRF was sent to the landfill with energy recovery.

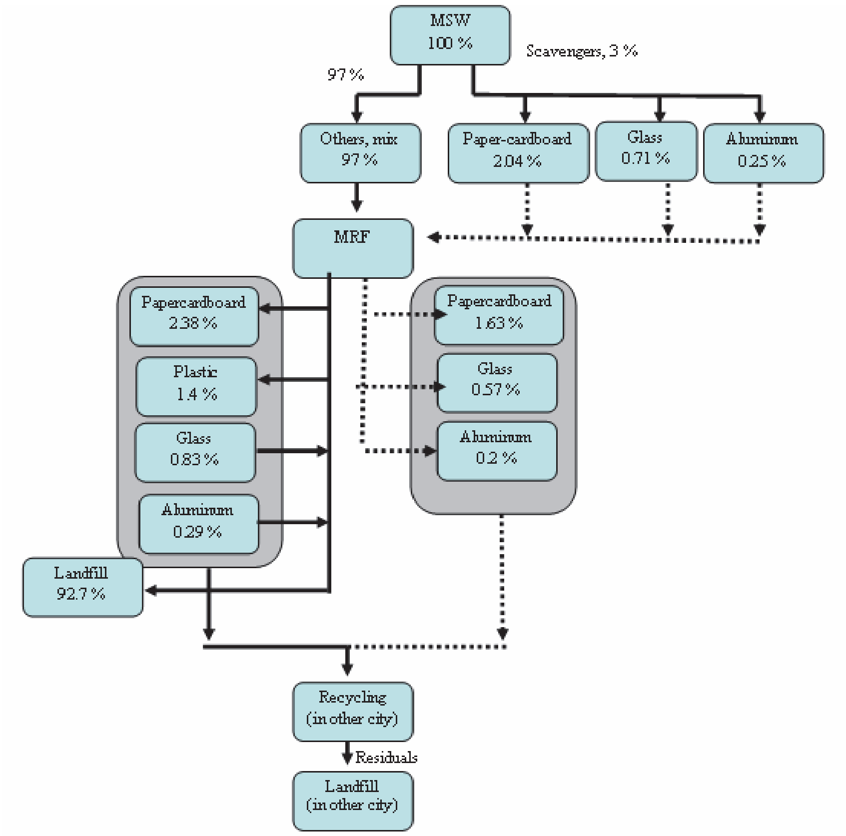

Figure 2. Flowcharts of the Scenario 1 (S1): 7.3% recycling+92.7% landfilling (Banar and others, 2009)

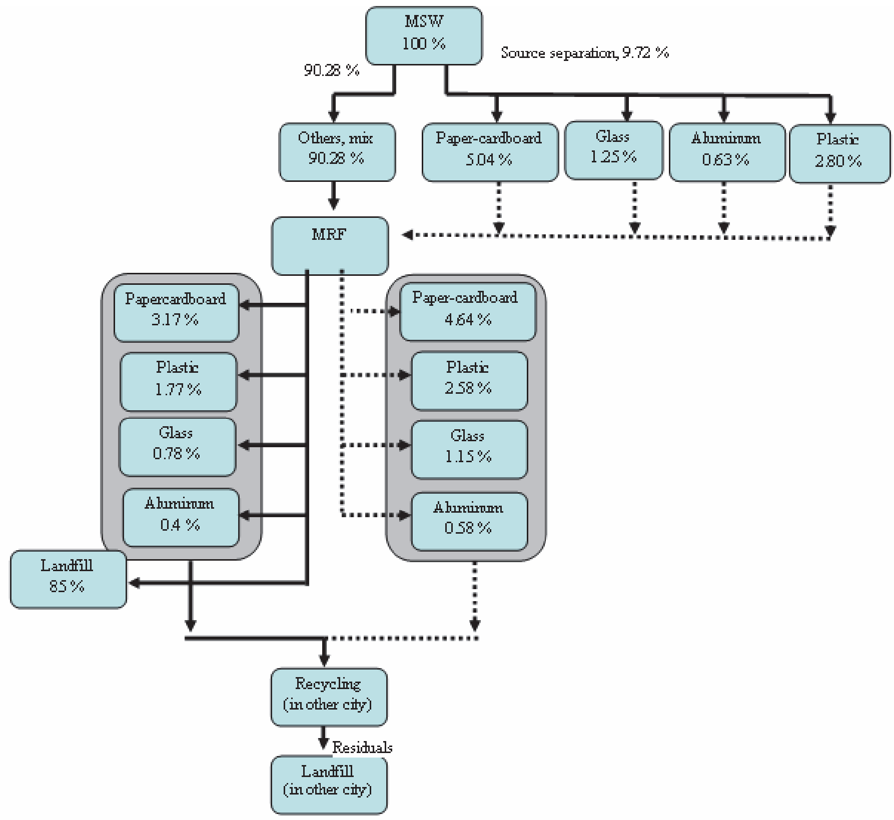

Figure 3. Flowcharts of the Scenario 2 (S2): 15% recycling+85% landfilling (Banar and others, 2009)

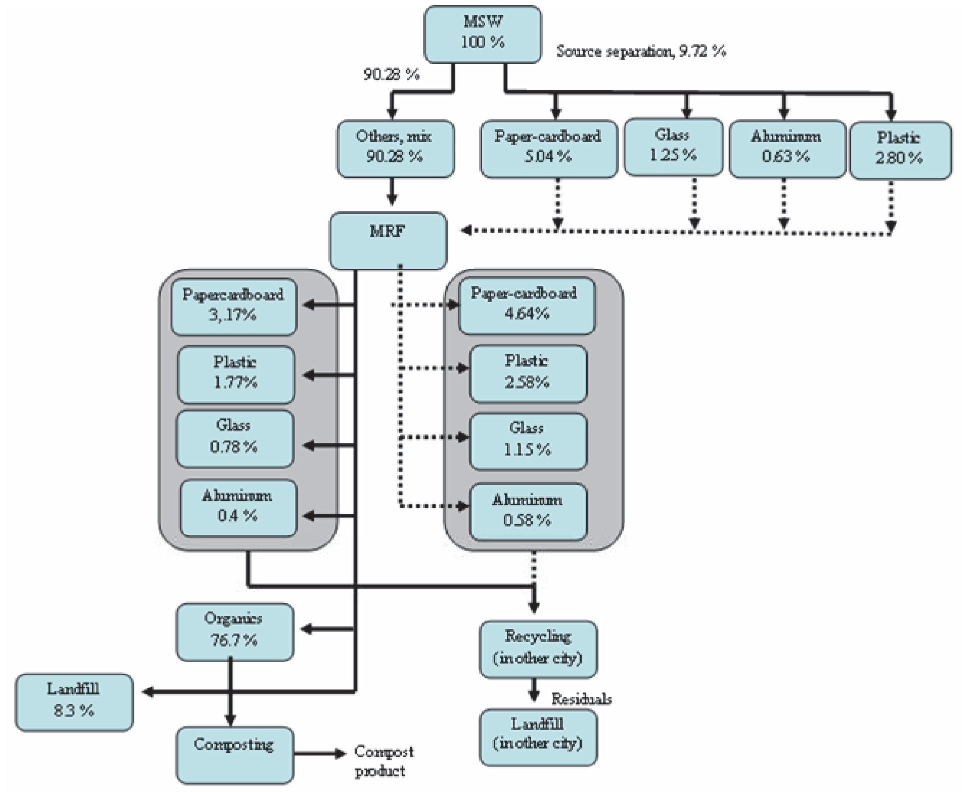

Figure 4. Flowcharts of the Scenario 3 (S3): 15% recycling+76.7% composting + 8.3% landfilling (Banar and others, 2009)

Scenario 4: In this scenario, an incineration process was added to the system instead of composting facility (Figure 5). In this case, all organic wastes and the wastes from the separated recyclables were transported to the incinerator (85%). It was considered that 10 % bottom ash in incinerating facilities (mass of input waste to incineration process) was occurred. The bottom ash was landfilled without energy recovery.

Scenario 5: In this scenario it was considered that all MSW was sent to the incineration processes (100%) (Figure 6). It was considered that 10 % bottom ash in incinerating facilities (mass of input waste to incineration process) was occurred. The bottom ash was landfilled without energy recovery.

- Mixed and separated recyclables (depending on the scenario) were sent to the MRF. It was considered that processes before recycling were carried out in three ways; by scavengers, by source separation and at MRF. In addition, different efficiencies that were used for different collection types were given as follows:
    - Source separation of recyclables: 50%
    - Separation of recyclables from mixed waste: 70%
    - Recycling of recyclables after source separation: 92%
    - Recycling of recyclables collected by scavengers: 80%
    - Recycling of recyclables after separation of recyclables from mixed waste: 70%
- Organic material obtained from the composting process was used as a soil conditioner where composting system was worked in aerobic conditions.
- It was considered that energy was recovered in incineration processes.

Step 3-8: Determination of the decision makers, criteria, level of significance of criteria, thresholds; evaluation of the alternatives and solution

A decision maker may be a person or a group of people (e.g., a committee), who carries out a final choice among the alternatives.

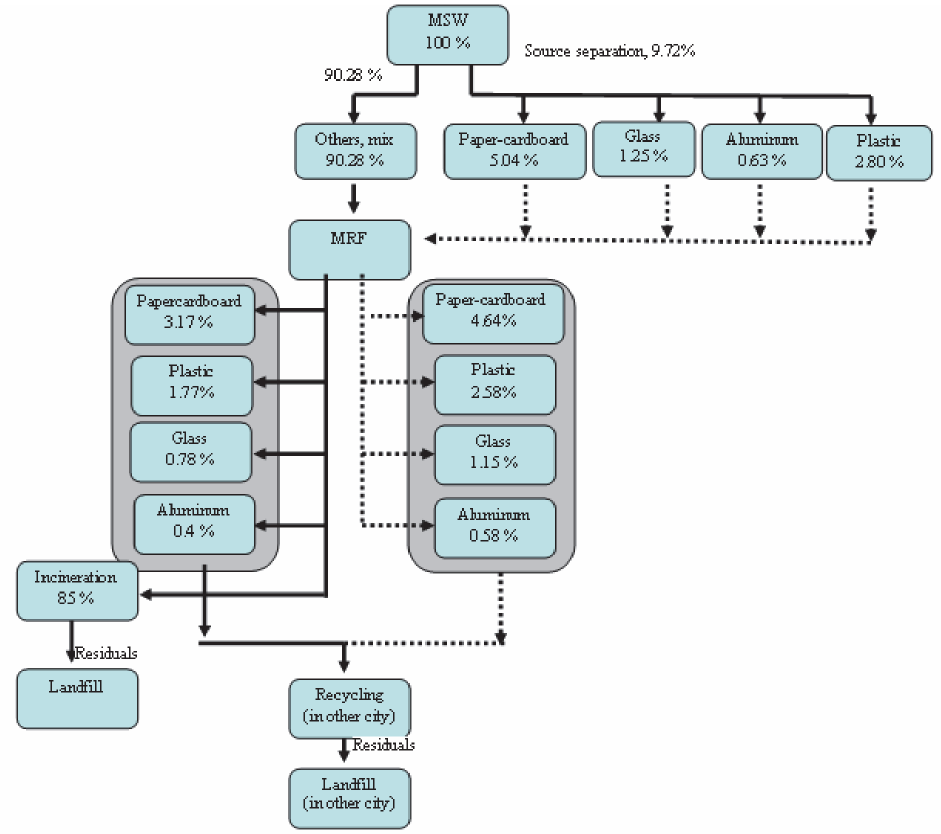

Figure 5. Flowcharts of the Scenario 4 (S4) : 15% recycling+85% incineration (Banar and others, 2009)

Figure 6. Flowcharts of the Scenario 5 (S5): 100% incineration (Banar and others, 2009)

Decision maker should have sufficient knowledge and experience to apply the decisions. In the determination of a solid waste management system, municipal authorities (waste collectors or officials from the office in charge, etc) and academic staff were considered as decision makers in this study.

In this study, decision maker, as a group, included the municipal authorities and the academic staff at the university. This group evaluated the means of ELECTRE III according to the criteria (Table 2). These criteria were considered as technical, environmental, economical and social/political criteria. Only useful life and rapid completion (based on year) among technical criteria were numerical values, other technical, environmental and social/political criteria were non numerical values. Hence, real values of waste per ton were used for economical criteria. Units and ascending orders of the criteria are showed in Table 2.

Comparison of the scenarios according to the costs was realized considering the data in Table 3. The data required for the calculation of the costs were taken from the literature.Performance values of criteria are given in Table 4. First, the ascending orders were considered for the evaluation of the criteria with non numerical values and the DMs were asked to assign first place to the least important criterion. Then the other importance values were assigned based on how many times more important they appeared than the least important criterion. Thus, if a criterion was considered, for example 3 times more important than the least important one, 3 was the value to be assigned to that criterion.The cost values were calculated by multiplying the costs per 1 ton waste and the percentage of waste management options (Figure 2-6).

In a case like the MSW management system problem, the number of DMs is often large and they do not give equal value to the individual weights. Thus, to give useful information on the importance of the various criteria, an inquiry needs to be carried out. Then the data need to be formulated in some sensible manner to obtain the overall weights of the group. First, the DMs were asked to assign the criteria weights. The final weights were determined on the basis of majority.

After a problem is formulated by determining criteria and alternatives, the weight for each criterion and each threshold are required for the implementation of the method. The DM must define the thresholds and weights. Thresholds must be set by means of the following formula:

$$p_j\,(g_j(a_i)) = \alpha_p g_j(a_i)+\beta_p \quad \text{and} \quad q_j\,(g_j(a_i)) = \alpha_q g_j(a_i)+\beta_q \qquad (1)$$

where α is a coefficient from 0 to 1. This coefficient is a percentage of the alternative's performance that the DM is willing to tolerate and β is a coefficient that can be interpreted as the amount that the DM is willing to tolerate in addition to the percentage. β is expressed in the same units as the performance scale.To determine the thresholds, all of the DMs might assume different thresholds according to the criteria values. In this case, average of these thresholds was used. The veto thresholds for all criteria were omitted. Using veto thresholds affects the final ranking. However, in this study, DM stated that there was not any alternative that could be vetoed. Hence, the veto threshold was not used in this study, and the discordance matrix was not considered. However, if needed, the spreadsheet tool developed for this study had the capability to incorporate the veto threshold. For indifference and preference thresholds, while α_q and α_p were given as zero, β_q and β_p values were assumed to be 1, 5, 1, 2, 1, 1, 2, 2, 3, 3, 2, 2, 2, 50, 20, 3, 1, 1, 1, 1 and 2, 10, 3, 1, 2, 3, 1, 1, 1, 1, 1, 1, 1, 30, 50, 2, 3, 2, 3, 2, respectivelyfor the criteria.

Step 9: Sensitivity Analysis

Nevertheless, the ranking of alternatives remains dependent on the values of the various thresholds and the weights of importance. A sensitivity analysis was recommended to highlight which priority order was convincingly justified by the model in spite of all the elements of inclusive arbitrariness. According to the results of the sensitivity analysis, steps 5-8 should be repeated.

Table 2. Criteria and Properties

Groups of criteria	Criteria no	Name of criteria	Unit Ascending order*	Explanations
Technical criteria	g1	Applicability of process	Score (1-9) Increasing	Obtaining of necessary conditions for effective process (heating value, humidity, waste composition etc.).
	g2	Useful life	Year Increasing	Maximum useful life
	g3	Adaptability to new applications	Score (1-9) Increasing	Adaptation to new demand through local/national/international regulations
	g4	Rapid completion	Year Decreasing	Minimum completion time in processes for decision makers.
	g5	Operation experience	Score (1-9) Increasing	Past experiences for operation of system.
	g6	Adaptation to changing in waste composition and waste quantity	Score (1-9) Increasing	Adaptation to differences in waste composition and waste quantity due to changing of consumption habits.

Table 2. (continued) Criteria and Properties

Environmental criteria	g7	Noise pollution	Score (1-9) Decreasing	Noise pollution by traffic and waste treatment/disposal facility.
	g8	Greenhouse gases	Score (1-9) Decreasing	Effect of greenhouse gases such as CO_2 and CH_4.
	g9	Acidic gases	Score (1-9) Decreasing	Effect of acidic gases such as SO_2 and NO_x
	g10	Emissions that are causing to health effects	Score (1-9) Decreasing	Effect of heavy metals such as Cd and Pb and organic compounds as PCDD and PCDF.
	g11	Soil pollution	Score (1-9) Decreasing	Soil pollution from processes.
	g12	Water pollution	Score (1-9) Decreasing	Ground and surface water pollution from processes.
	g13	Aesthetic and odor pollution	Score (1-9) Decreasing	Aesthetic and odor pollution caused of wastes, birds and trucks.
Economical criteria	g14	Investment and operation costs	US$/ton Decreasing	Investment and operation costs of facilities.
	g15	Energy and material incomes	US$/ton Increasing	Revenue of recyclable material/compost/energy obtained from treatment/disposal plants.
	g16	External costs	US$/ton Decreasing	Costs of pollution arisen from collection and transportation, accidents, leachate, greenhouse gases and conventional air pollutants.
Social/political criteria	g17	Public opinion	Score (1-9) Increasing	Recycling habits and opinion about treatment/disposal site.
	g18	Employment	Score (1-9) Increasing	Employment created all of the components in system.
	g19	Adaptation to environmental regulations	Score (1-9) Increasing	Adaptation to regulations in Turkey and EU.
	g20	Resource conservation	Score (1-9) Increasing	Conservation of natural resources and land due to recycled materials and energy.

*Non numerical values were scaled from 1 to 9 where Excellent=9; Very good=8; Good=7; More or less good=6; Indifferent=5; Somewhat bad=4; Bad=3; Very bad=2; Awful=1 for increasing ascending order and Excellent=1; Very good=2; Good=3; More or less good= 4; Indifferent=5; Somewhat bad= 6; Bad=7; Very bad=8; Awful=9 for descending order.

Table 3. Calculation of Costs

Cost type	**Explanation**
Investment costs	They were given as35 US$/ton for recycling, 40 US$/ton for composting, 180 US$/ton for incinerating, 25 US$/ton for landfilling with energy recovery and 20 US$/ton for landfilling without energy recovery (DHV Consultants 2006).
Operational costs	They were assumed as 20 US$/ton for recycling, 50 US$/ton for composting, 150 US$/ton for incinerating, 15 US$/ton for landfilling with energy recovery and 10 US$/ton for landfilling without energy recovery (DHV Consultants 2006).
Material revenues	They were given as 60 US$/ton for recycling material (Personnel communications with a recycling industry, 2007).
Energy revenues	They were calculated as following: it was assumed that electrical energy production from incineration is 600 kWh/ton waste (DHV Consultants 2006) and biogas production from landfill was 250 m^3/1 ton BVS (biodegradable volatile solids) (Bovea and Powell, 2006). In this case, it was given that amount of BVS in wastes is 60 %, amount of methane in biogas was 55 %, heating value of this methane was 37235 kJ/$m^3$and efficiency of electrical conversion was 35 %. In this way, amount of electrical energy obtained from biogas was determined as 300 kWh/ton. Also, it was considered that 1 kWh of electrical energy was 0.12 US$ (TEIAS, 2007).
External costs	They were included thatcosts of pollution arisen from collection and transportation, accidents, leachate, greenhouse gases and traditional air pollutants. External costs in England were used, because any external cost calculations were not found in Turkey. These costs were assumed as 0.92 US$/ton for recycling, 2.28 US$/ton for composting, 10.38 US$/ton for incinerating, 7 US$/ton for landfilling without energy recovery and 4.38 US$/ton landfilling with energy recovery (Pearce and Brisson 1995).

Table 4. Performance Values of Criteria

Criteria	w*	S1	S2	S3	S4	S5	Criteria	w*	S1	S2	S3	S4	S5
g1	5	6	6	7	2	7	**g11**	5	6	6	4	3	2
g2	5	10	12	20	25	25	**g12**	5	5	5	6	6	6
g3	5	3	4	7	8	3	**g13**	2.5	7	7	7	6	6
g4	5	1	3	3	3	2	**g14**	10	31.8	42.2	80.6	291	333
g5	5	7	6	5	2	2	**g15**	10	37.8	39.6	11.9	70.2	72
g6	5	7	7	4	3	4	**g16**	5	4.13	3.86	2.25	9.55	11.08
g7	2.5	8	8	5	8	8	**g17**	4	5	4	6	3	2
g8	5	7	7	6	5	5	**g18**	3	6	6	8	8	7
g9	5	3	3	3	8	9	**g19**	5	2	4	7	8	3
g10	5	3	3	3	8	9	**g20**	3	4	7	7	7	7

*The values showed that weight of the criteria where the sum of these values was 100.

Sensitivity analysis, which is the influence of the changes of values, consists of information about DM's preferences. The sensitivity analysis in this study could be done in three different ways. These are;

- Changes in point values of non numerical criteria,
- Changes in the weights of criteria,
- Changes in threshold (only in preference, only in indifference and in both of them). For the first type; three criteria were changed because of its high weights and it was seen that there was no change in the final ranking. In the second type, 100 points were distributed to 4 criteria groups (technical, environmental, economical, and social/political) for the determination of weights of criteria. According to this, it was assumed that weights of technical and environmental criteria were 30 points and weights of economical criteria were 25 points and weights of social/political criteria were 15 points. For the second type of sensitivity analysis, changes were considered in the weights of technical and environmental criteria that were 25 points and the weights of economical criteria were 30 points and the weights of social/political criteria were 20 points. In the last type, changes were done in three ways such as; changes only in preference thresholds; only in indifference threshold and in both of them. The changes are given in Table 5.

Table 5. Result of Sensitivity Analysis

Changed parameters	**Initial values**	**Final values**	**Changes in results**
Changes in point values of non numerical criteria			
operation experience (g_5)	7,6,5,2,2	8,7,6,4,3	No change in the final ranking.
noise pollution (g_7)	8,8,5,8,8	6,6,7,8,8	
employment (g_{18})	8,8,5,8,8	4,5,8,7,6	
Changes in the weights of criteria			
weights of criteria	5; 5; 5; 5; 5; 5; 2,5; 5; 5; 5; 5; 5; 2,5; 10; 10; 5; 4; 3; 5;3	5; 4; 4; 4; 4; 4; 2,5; 4; 4; 4; 4; 4; 2,5; 12; 12; 6; 5; 5; 5; 5	No change in the final ranking although credibility and concordance matrix were changed in small amounts.
Changes in threshold			
only in preference thresholds	2, 10, 3, 1, 2, 3, 1, 1, 1, 1, 1, 1, 1, 30, 50, 2, 3, 2, 3, 2	4, 15, 3, 1, 3, 3, 1, 1, 3, 3, 1, 1, 1, 30, 40, 2, 3, 2, 3, 3	no change in final ranking
only in indifference threshold	1, 5, 1, 2, 1, 1, 2, 2, 3, 3, 2, 2, 2, 50, 20, 3, 1, 1, 1, 1	1, 2, 1, 2, 2, 1, 3, 2, 5, 5, 3, 2, 2, 100, 20, 4, 1, 1, 1, 1	final ranking is S3>S2>S1=S4=S5
changes in preference and indifference thresholds	2, 10, 3, 1, 2, 3, 1, 1, 1, 1, 1, 1, 1, 30, 50, 2, 3, 2, 3, 2 for p_j 1, 5, 1, 2, 1, 1, 2, 2, 3, 3, 2, 2, 2, 50, 20, 3, 1, 1, 1, 1 for q_j	4, 15, 3, 1, 3, 3, 1, 1, 3, 3, 1, 1, 1, 30, 40, 2, 3, 2, 3, 3 for p_j 1, 2, 1, 2, 2, 1, 3, 2, 5, 5, 3, 2, 2, 100, 20, 4, 1, 1, 1, 1 for q_j	final ranking is S3>S2>S1=S4=S5

3. RESULTS AND CONCLUSION

In this study, there were five alternative system scenarios (MRF, recycling, composting, incinerating and landfilling processes) ranked by using ELECTRE III for Eskisehir city/Turkey. All data were evaluated and the concordance index and the credibility matrix were composed by using Excel Worksheet, which was developed for similar MCDM problems. Finally, the distillation procedure that gives the ranking order is given in Table 6 a, b. Since veto threshold was not used in this study, discordance matrix was not calculated. The credibility matrix that gave the outranking degree was equal to the concordance matrix if the discordance matrix was not used. The value approaches to 1 gives the most preferable alternative. More detail was given in the study of Tam (2003).

Final ranking for scenarios was in the following order: S3>S2>S1>S4=S5. According to this result, S3 scenario (15% recycling+77% composting + 8% landfilling) for MSW management system in Eskisehir should be preferred. It was also shown that the scenario including landfill was one of the worst scenarios. However, scenario 5 including the incineration was the worst scenario due to the negative environmental effects and the high costs. In respect of the sensitivity analysis results, it was stated that there was no change in the final ranking for the changes in point values of non numerical criteria, weights of criteria and preferences threshold. However, in terms of the changes only in the indifference threshold and both in the preference and the indifference thresholds, the final ranking was S3>S2>S1=S4=S5. For the future studies, the problem could be reconsidered with the veto thresholds determined by DM and it would be examined whether any change occur in final ranking when new criteria and veto threshold were added to the problem.

Consequently, a model consisted integrated managerial approach regarding the solid wastes for our country, Turkey. Hence, there are many legal regulations and applications on the agenda due to EU adaptation process. In this manner, an approach based on landfilling that is tried to be applied in Turkey will not be sufficient.

Table 6a. Concordance Matrix

	S1	S2	S3	S4	S5
S1	1	0.9	0.7	0.6	0.8
S2	1	1	0.8	0.7	0.8
S3	0.8	0.9	1	0.9	0.9
S4	0.7	0.6	0.6	1	0.9
S5	0.7	0.6	0.5	0.9	1

Table 6b Credibility Matrix

	S1	S2	S3	S4	S5
S1	1	0.9	0.7	0.6	0.8
S2	1	1	0.8	0.7	0.8
S3	0.8	0.9	1	0.9	0.9
S4	0.7	0.6	0.6	1	0.9
S5	0.7	0.6	0.5	0.9	1

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