Global Journal of Pollution and Hazardous Waste management

ISSN: xxxx-xxxx Vol. 1 (1), pp. 071-084, November, 2013. © Global Science Research Journals

Full Length Research Paper

Sustainable management of municipal solid waste in Morocco: Application of PROMETHEE method for choosing the optimal management scheme

Makan A and Mountadar M

Water and Environment Laboratory, Chemistry Department, Faculty of Science, University ChouaibDoukkali El Jadida, Morocco.

Accepted 6 August, 2013

In this paper, alternate schemes are examined and analysed aiming at the improvement of MSW management in small urban municipalities in Morocco. These schemes are estimated by developing and applying the PROMETHEE method consisting in a multi-criteria analysis of the parameters and the constraints bound to the financial, technical, environmental and social-institutional aspects. Thus, 10 alternate management schemes were compared and ranked according to their performance and their efficiency. The obtained results will certainly help the decision-makers to make a decision for the best management scheme which hold in account particularities of every region, commune or municipality in Morocco.

Key words: Municipal solid waste, sustainable management, promethee, alternate scheme, multi-criteria analysis.

INTRODUCTION

Morocco has an area just under 712,550 km^2, a population of nearly 32 million of which 51% is urban with a growing rate of 2.85% per year. The total amount of solid waste generated daily in Morocco is approximately 11,000 tonnes with an average annual growth rate of 4.5% while the per capita rate of production is around 0.75 kg/capita/day which fluctuate significantly from urban to rural areas (D.E, 2006). Therefore Morocco is characterized by high urbanization and increased population growth which affects the generation rate of MSW especially in urban areas creating serious environmental challenges.

Municipal solid wastes are partly collected in many urban areas and are generally deposited on unorganized wild dump sites without sanitary measures, resulting in serious environmental and potential health problems. In urban areas, an average of 83% of MSW is collected while only 6.3% of it disposed in sanitary landfills (D.E., 2006). Waste management in Morocco is characterized by poor collection practices, mainly performed by private sector, and the presence of uncontrolled landfills within residential areas and peripheral districts which adversely affects the development of economic activities, tourism and the quality of life generally. The estimated cost arising from the unsustainable and inefficient MSW management in Morocco is estimated at 0.5% of the Gross domestic product (GDP) of the country which is considered as one of the highest levels among Middle East and North African region.

According to EU an efficient waste management system plan must include the following aspects:

- Enacting a coherent and comprehensive MSW legal framework.
- Steering of waste streams.
- Making sufficient recovery and disposal capacities available.
- Ensuring the efficient use of existing financial resources.

The main challenges that the Moroccan authorities should prioritize in order to tackle the immense environmental social and economic problem of MSW management can be categorized as follows:

i. Enhancing the MSW legal, regulatory and institutional framework for an effective governance of MSW.

ii. Short medium and especially long term cost-effectiveness of the MWM services.

iii. Introducing social and environmental guidelines with

*Corresponding author. **E-mail**:abdelhadi.makan@gmail.com
Tel: (+212) 669 12 41 53

respect to planning, implementation and operation of MSW systems and services.

In order to reform the MSW management sector the Moroccan government has recently taken two major initiatives towards this target. The first one is the enactment of the first solid waste law 28-00 and the second one is the development of a 15-year national solid waste program (NSWP). Law 28-00 sets the fundamental principles and rules governing the MSW management in Morocco. Among the main issues that it addresses are:

i. The initiation and establishment of the institutional framework for MSW.
ii. The development of MSW master plans at national, regional and municipal level.
iii. The establishment of cost recovery principles (e.g. “polluter pays” principle and user fees).
iv. The introduction of sanitary landfill as the established method for the final disposal of MSW and the requirement for landfill norms and specifications.
v. The introduction of hazardous waste management regulations.
vi. Development of a monitoring and evaluation system for the compliance with the law.

The NSWP is a 15-year, 3-phase program that has been initiated by the Moroccan government while the World Bank has granted a loan ($132.7 million) to implement and support this program. The objective of the program is to reform the MSW management through specific actions on MSW sector governance, on enhancing sustainability and on mainstreaming environmental and social dimensions into the planning, implementation, and operations of solid waste services and investments. It includes specific targets related to MSW management sector among which are: service and disposal standards for urban areas; quantitative goals for collection coverage (from 70% to 90% by 2021); introduction of sanitary landfills (100% of urban areas equipped by 2021); closure and rehabilitation of 300 existing open dumps, and the promotion of solid waste reduction, and recovery (sorting 20% of recyclable material).

The aim of this study is to choose the best system for the effective management of the MSW generated in the Moroccan small urban municipalities taking into account the technical characteristics of each alternative treatment system. This choice was based on the Multi-criteria analysis approach which takes into consideration the Moroccan social-institutional, environmental, financial and technical characteristics.

Multi-criteria analysis methods are used among others, for solving environmental problems related mainly to waste management. Indicatively, they were applied as a decision supporting tool for: (i) The selection of the most appropriate technology for cleaning polluting soil (Hokkanen andSalminen, 1997); (ii) the assessment and selection of waste treatment/management technologies (Hokkanen andSalminen, 1997; Kokot et al., 1998; Visual Decision, 1999) and (iii) the site allocation of waste management plants and landfill sites (Makan et al., 2012; Calijuri et al., 2004; DulminandMininno, 2003; Keller et al., 1991).

ECONOMIC DATA

This section presents an overview of the MSW managements technologies cost for MSW processing. With respect to the composting of the biodegradable organic waste, windrow composting systems are the simplest, most common, and least expensive systems. It has the lowest capital cost while labour is required occasionally during the process. The main drawback of such systems in relation to the cost is the extensive space requirements for processing large volumes of organic waste as well as the processing time in comparison to in-vessel systems. According to Diaz et al. (2002) the capital cost per tonne of organic waste treated for windrow composting systems (static and turned) with a capacity of 10 to 800 Tonnes Per Day (TPD), ranges from 33.5 to 88.7 $/tonne while the Operation and Maintenance (O&M) cost for a system acquiring a capacity of 10 to 600 TPD, ranges from 24 to 71 $/tonne (Diaz et al., 2002). Similar O&M costs have been reported by other studies according to which the O&M cost for open windrow systems is 32-79 $/tonne (Mavropoulos, 2008; World Bank, 2008).

In-vessel composting is by far the most costly and capital intensive composting option but it also requires the least amount of space and processing time. According to World Bank, The capital cost for the development of an in-vessel system with a capacity of 500 TPD is 46-72 M$ while the operation and maintenance cost is 32-52 $/tonne. Mavropoulos (2008) states that an estimated capital investment cost of closed composting facilities (including in-vessel technology) ranges from 236 $/tonne (capacity equal to 330 TPD) to 789 $/tonne (capacity lower than 330 TPD) while the O&M is 157 $/tonne and 39 $/tonne respectively.

The cost of anaerobic digestion systems varies from one category to another as well as from one country to another since there is a large number of different technologies involved with anaerobic digestion in the market worldwide and there still room for technological maturation. According to World Bank data, anaerobic digestion systems with a capacity of 300 tonnes/day acquire a capital cost around 19-72 M$, while the O&M cost ranges from 52-131 $/tonne (World Bank, 2008). Other studies suggest a capital of 197 to 328 $/tonne and O&M cost at 46- 105 $/tonne (Mavropoulos, 2008).

With respect to the Mechanical-Biological Treatment (MBT) facilities cost, it must be considered that they employ different set of MSW management technologies. Therefore the range of costs presents increased fluctuation in comparison to alternative MSW treatment technologies. According to a recent review on the cost of commercial MBT facilities performed by Archer et al.

(2005), an MBT facility acquiring a capacity which ranges from 71-685 TPD the capital cost is 2.8- 87.3 M$ while the O&M costs vary from 60-77 $/tonne of treated MSW.

With respect to the cost of Incineration facilities, the capital cost of a MSW incinerator with a capacity of 1,300 TPD is 26-157 $/tonne, while the O&M cost is 72-105 $/tonne (World Bank, 2008). It is assumed that the incineration facility is operating on a full capacity for 260 days per annum while parameters such as (a) turnovers from surplus electric energy produced (approximately 450 kWh/tonne MSW) and (b) cost for residues disposal (14$/tonne MSW) are not incorporated within the total cost.

The capital cost of a Gasification system with a capacity of 70-270 TPD is 300-600 $/tonne, while the O&M cost is 72-131 $/tonne (World Bank, 2008; Mavropoulos, 2008). The capital cost of a Pyrolysis system ranges from 700 to 950€ per MSW tonne treated, while the O&M cost is 105-157 $/tonne (Mavropoulos, 2008). With respect to the O&M cost the World Bank has reported similar values (105-197 $/tonne). However, gasification and pyrolysis technologies are not included in this study because they are too expensive. They are beyond the capacity of Moroccan communities, then they will not also include in the PROMETHEE ranking with other technologies.

Finally, the Sanitary landfill (capacity of 500 TPD) has a capital cost which ranges from 5 to 10 M$ and O&M cost which varies from 10 to 20 MUS dollars.

Land filling capital costs are difficult to come by, because construction often continues throughout the life of the landfill instead of being completed at the beginning of operations. An estimation of the startup costs of sanitary landfill that meets all EU regulations ranges from 13 to 20 MUS dollars (Loizidou, 2008).

METHODOLOGY FOR THE EXAMINATION OF ALTERNATIVE MSW MANAGEMENT SCHEMES

The development of the alternative management systems was based on state-of-the-art technology as well as on the experience gained from applications at European and international level. Then, reference was made to the specific characteristics of the country (e.g. annual generated quantities of MSW, existing infrastructures and relative market) that are necessary for the determination of the most suitable management schemes for possible implementation in Moroccan small urban municipalities. In total, 10 alternative schemes were examined which are briefly described below.

Scheme 1 (Landfill): It regards the collection of waste and their depositions to land fill. Under no circumstances this scheme is suggested. It is used as benchmark in order to evaluate the performance of other alternative management schemes as well as because it is used as management scheme in lots of countries.

Scheme 2: Collection in one bin of recyclable materials that are transferred to Mechanical Recovery Facility (recovery of glass, paper, plastics, Fe and non Fe metals) and in another bin the remaining waste that is transferred to landfill.

Scheme 3: Collection in one bin of recyclable materials that are transferred to Mechanical Recovery Facility (recovery of glass, paper, plastics, Fe and non Fe metals) and in another bin the biodegradable stream that is transferred to Composting Plant. The residues are collected using another bin and then transferred to landfill.

Scheme 4: Collection of mixed waste that is transferred to Mechanical Sorting Plant (recovery of glass, paper, plastics, Fe and non Fe metals) and the remaining waste is disposed to landfill.

Scheme 5a: Collection of mixed waste which is transferred to Mechanical - Biological Treatment Plant: Mechanical sorting where glass, Fe and non Fe metals are sorted and recovered as well as paper and plastics which are forwarded to end users, Biological treatment where the biodegradable fraction is subjected to composting. The residues from both the processes are disposed to landfill.

Scheme 5b: Collection of mixed waste which is transferred to Mechanical - Biological Treatment Plant: Mechanical Sorting where glass, Fe and non Fe metals are sorted and recovered as well as paper and plastics. The recovered combustible material is transferred to thermal treatment Plant for energy recovery. Biological treatment in where the biodegradable fraction is subjected to composting. The residues from both the processes are disposed to landfill.

Scheme 6a: Collection of mixed waste which is transferred to Mechanical - Biological Treatment Plant: Mechanical sorting where glass, Fe and non Fe metals are sorted and recovered as well as paper and plastics which are forwarded to end users, Biological treatment where the biodegradable fraction is subjected to anaerobic digestion. The residues from both the processes are disposed to landfill.

Scheme 6b: Collection of mixed waste which is transferred to Mechanical - Biological Treatment Plant: Mechanical Sorting where glass, Fe and non Fe metals are sorted and recovered as well as paper and plastics. The recovered combustible material is transferred to thermal treatment Plant for energy recovery. Biological treatment in where the biodegradable fraction is subjected to anaerobic digestion. The residues from both the processes are disposed to landfill.

Scheme 7: Collection of mixed waste that is subjected to Incineration treatment. The residues are transferred to landfill.

Scheme 8: Collection of mixed waste that is subjected to primary Mechanical Sorting (recovery of Fe and non Fe metals). The remaining combustible materials are subjected to incineration. The residues are transferred to

Table 1. Groups of criteria and individual criteria that was examined and calibrated.

Social - Institutional	Environmental	Financial	Technical
(S1) Harmonization with the legislative framework (S2) Application of priorities of legislation (S3) Social acceptance (S4) Possibility of creation of new jobs	(E1) Level of potential effects to the environment (E2) Air emissions (E3) Generation of wastewater (E4) Generation of solid waste – residues (E5) Noise pollution (E6) Visual nuisance	(F1) Investment cost (F2) Operational and maintenance costs (F3) Land use requirement (F4) Production of secondary materials	(T1) Functionality (T2) Existing experience – reliability (T3) Adaptability to local conditions (T4) Flexibility

Table2. Calibration of criteria (1–10) scale.

Criterion	Description	Score
S_1	Complete harmonization	10
	Partial harmonization	5
	No harmonization	1
S_2	Complete application	10
	Partial application	5
	Application in low level	3
	Opposition with the guidelines	1
S_3	Complete social acceptance after informing	10
	Partial social acceptance	5
	Social acceptance because of a lack of informing	3
	No social acceptance because of a lack of informing	3
	No social acceptance after informing	1
S_4	Creation of new job positions to a great extent	10
	Creation of new job positions to a significant extent	7
	Creation of new job positions to a limited extent	4
	No creation of new job positions	1
E_1	Environmental impacts to an insignificant extent	8
	Environmental impacts to a limited extent	4
	Environmental impacts to a great extent	1
E_2	Significant air emissions and odors (controlled)	3
	Limited air emissions and odors (controlled)	6
	Insignificant (minimum) air emissions and odors (controlled)	8
E_3	Significant production of wastewater (controlled)	3
	Limited production of wastewater (controlled)	6
	Insignificant (minimum) production of wastewater (controlled)	9
E_4	Significant production of solid waste-residues (controlled)	1
	Limited production of solid waste-residues (controlled)	5
	Insignificant (minimum) production of solid waste-residues (controlled)	9
E_5	Minimum noise pollution	9
	Limited noise pollution	7
	Relatively high noise pollution	4
	Extreme noise pollution	1
E_6	Low visual nuisance	9
	Relatively low visual nuisance	7
	Moderate visual nuisance	4
	High visual nuisance	1
F_1	Low total investment cost (covered by others)	10
	Moderate total investment cost (covered by others)	6

	High total investment cost (covered by others)	2
F_2	Low operation-maintenance cost	9
	Moderate operation-maintenance cost	7
	Relatively high operation-maintenance cost	4
	High operation-maintenance cost	1
F_3	High land cost	1
	Relatively high land cost	3
	Lack of land	1
	Moderate land cost	7
	Low land cost	9
F_4	Low production of useful secondary materials	1
	Moderate production of useful secondary materials	4
	Relatively high production of useful secondary materials	7
	High production of useful secondary materials	10
T_1	High functionality	9
	Relatively high functionality	7
	Moderate functionality	5
	Low functionality	3
	Very low functionality	1
T_2	High existing experience	10
	Relatively high existing experience	7
	Moderate existing experience	5
	Low existing experience	3
	Very low existing experience	1
T_3	High adaptability	10
	Relatively high adaptability	7
	Moderate adaptability	5
	Low adaptability	3
	Very low adaptability	1
T_4	High flexibility	10
	Relatively high flexibility	7
	Moderate flexibility	5
	Low flexibility	3
	Very low flexibility	1

Table 3. Estimation of criteria final weights.

Criteria	Group weights %	Criteria description	Criterion weights %	Final weights %
Social -Institutional	10.00%	Harmonization with the legislative framework (S_1)	30.00%	3.00%
		Application of priorities of legislation (S_2)	30.00%	3.00%
		Social acceptance (S_3)	25.00%	2.50%
		Possibilities of new jobs (S_4)	15.00%	1.50%
		Subtotal	100.00%	10.00%
Environmental	25.00%	Level of possible effects to the environment (E_1)	25.00%	6.25%
		Air emissions (E_2)	20.00%	5.00%
		Generation of wastewater (E_3)	20.00%	5.00%
		Generation of solid waste (E_4)	20.00%	5.00%
		Noise pollution (E_5)	10.00%	2.50%
		Visual nuisance (E_6)	5.00%	1.25%
		Subtotal	100.00%	25.00%
Financial	35.00%	Investment cost (F_1)	35.00%	12.25%
		Operation and maintenance cost (F_2)	30.00%	10.50%
		Land use requirement (F_3)	15.00%	5.25%
		Production of secondary materials (F_4)	20.00%	7.00%
		Subtotal	100.00%	35.00%
Technical	30.00%	Functionality (T_1)	25.00%	7.50%
		Existing experience-reliability (T_2)	30.00%	9.00%
		Adaptability to local conditions (T_3)	25.00%	7.50%
		Flexibility (T_4)	20.00%	6.00%
		Subtotal	100.00%	30.00%
		Total		100.00%

Table 4. Performances of management schemes in social, environmental, financial and technical criteria.

Management Schemes	Social				Environmental						Financial				Technical			
	S_1	S_2	S_3	S_4	E_1	E_2	E_3	E_4	E_5	E_6	F_1	F_2	F_3	F_4	T_1	T_2	T_3	T_4
Scheme 1	1	1	1	2	2	3	4	1	8	1	9	9	3	1	9	10	9	9
Scheme 2	5	5	5	4	4	4	4	4	7	5	8	8	7	6	8	9	8	8
Scheme 3	9	9	10	7	7	6	7	9	7	8	7	8	6	9	8	9	8	7
Scheme 4	4	4	4	6	4	5	4	3	7	4	8	6	5	4	7	8	7	8
Scheme 5a	7	7	9	8	7	7	7	7	7	7	6	7	4	7	6	7	7	7
Scheme 5b	8	8	8	9	5	5	6	6	5	5	4	6	3	7	5	6	6	6
Scheme 6a	7	7	7	8	7	8	6	6	7	6	5	6	5	7	6	7	7	6
Scheme 6b	8	8	6	9	5	6	5	5	5	4	3	5	4	7	5	6	6	5
Scheme 7	5	5	4	6	4	4	7	4	7	2	7	6	7	3	7	9	8	8
Scheme 8	8	6	6	8	6	5	8	6	6	4	4	7	6	5	8	9	7	8

Table 5. Indifference and preference thresholds of criteria.

Criteria	Indifference threshold (q)	Preference threshold (p)
S_1	0.8	2.4
S_2	0.8	2.4
S_3	0.9	2.7
S_4	0.7	2.1
E_1	0.5	1.5
E_2	0.5	1.5
E_3	0.4	1.2
E_4	0.8	2.4
E_5	0.3	0.9
E_6	0.7	2.1
F_1	0.7	2.1
F_2	0.4	1.2
F_3	0.4	1.2
F_4	0.8	2.4
T_1	0.4	1.2
T_2	0.4	1.2
T_3	0.3	0.9
T_4	0.3	0.9

landfill.

The list of these systems was prepared in two stages:

- Brainstorming between members of the National Technics University of Athens, Greece (NTUA) and the Faculty of Science of El Jadida, Morocco (FSJ) in order to formulate a list of possible MSW management schemes and
- Thorough consultation of various actors at the local and governmental level which is involved in the MSW management sector which resulted in the screening of the initial list based on the characteristics and needs of Morocco.

The multi-criteria analysis method was specifically designed in order to evaluate the 10 suggested management schemes. This analysis involves three main phases (a) the setting and calibration of criteria, (b) the weighting of criteria according to their significance and (c) the ranking of the alternative MSW treatment schemes (Araz et al., 2007; Diakoulaki and Karangelis, 2007; Wang and Yang, 2007). A brief description of the analysis performed is presented below.

Setting and Calibration of Criteria

The criteria that have been selected are classified into four major groups incorporating social-institutional, environmental, financial and technical parameters. Table 1 presents the groups of criteria and their individual criteria (sub-criteria) that were examined and calibrated. The criteria used are described analytically while their calibration,in a scale of 1–10 are given according to their characteristics (Table 2). The groups of criteria and the sub-criteria were set specifically for the purposes of the project, since they focus on the examination and evaluation of alternative systems for the effective management of MSW (adaptation of the multi-criteria method to the subject under examination).

Weighing of Criteria

The most important step in Multi-criteria evaluation methods is the assignment of weights, since weights reflect the relative importance of the various impacts considered. PROMETHEE does not provide specific guidelines for determining these weights, but assumes that the Decision Maker (DM) is able to weigh the criteria appropriately, at least when the number of criteria is not too large. In this research, firstly, weights are defined for each group of criteria and secondarily weights are defined for every criterion in the group. The final weights are arisen after the multiplication of every criterion weight with the group weight that it belongs. Table 3 presents the weights of the criteria group, the weights of every single criterion in the group as well as the final weights.

The determination of the criteria weight coefficients was based on the suggestions of all the Moroccan decision makers involved in the field such as Ministries (Ministry of Regional Planning, Water and Environment of Morocco, Ministry of Higher Education, Executive Training and Scientific Research, Ministry of Health-Delegation of El Jadida Province), companies, associations (Associations of self- employment ANNAMAE, the National Association

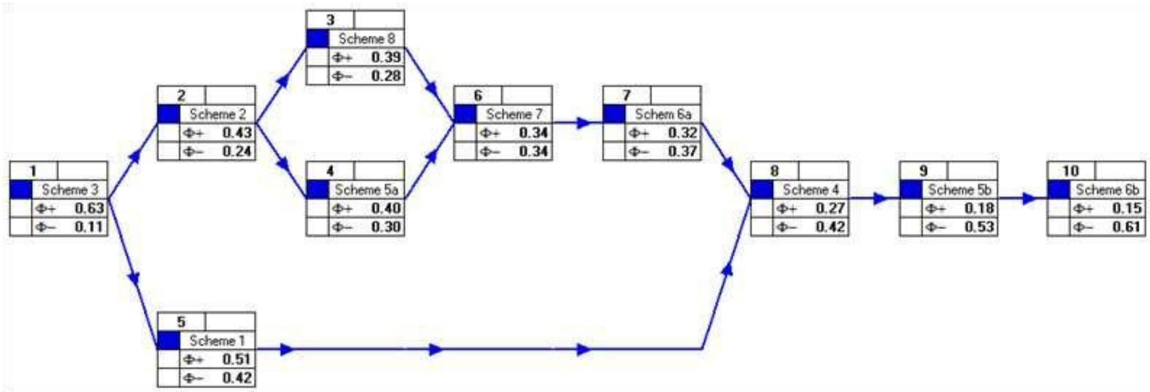

Figure 1. PROMETHEE I partial ranking of the alternative candidate management schemes for the treatment of MSW in Morocco with the utilization of linear function.

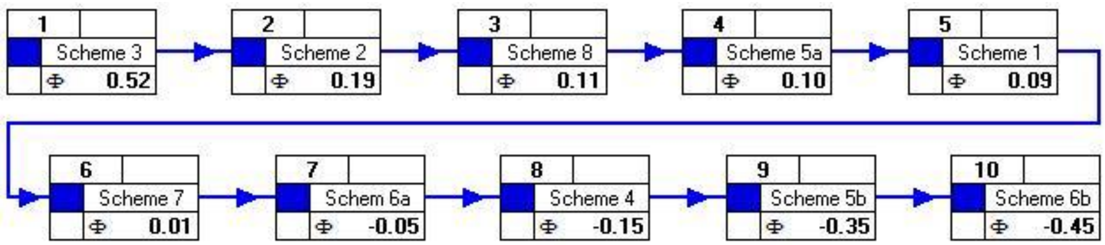

Figure 2. Ranking of the alternative management schemes for the treatment of MSW in Morocco (schemes are ranked from the most preferred on the extreme left hand side to the least preferred on the extreme right hand).

of Environment and of Sustainable Development), Regional Office of Agricultural Development of Doukkala and local Authorities. The authors visited the premises of all Moroccan authorities involved in the field, had discussions with them and asked them to complete a questionnaire that was distributed together with appropriate informative material. After 2 months, the working group visited again the premises of the Moroccan authorities and actors and collected the completed questionnaires.

RANKING OF THE ALTERNATIVE MSW SCHEMES

Performance of Alternative Management Schemes

In this section the performance of alternative management schemes is presented. This performance is an extremely difficult and strenuous task as a wrong estimation will result in false results as well as in disorientation from the best compromise management option. Each criterion was quantified according to its performance for each alternative scenario and in specific, its actual performance was compared to the criterion's calibration set, scale form 1 (the most unfavorable) to 10 (the most favorable cases). The quantification of the criteria was finalized by the same actors that had contribution in the weighing of criteria (Table 4). Thus, a second questionnaire was specially prepared and distributed on these actors. After 2 months, completed questionnaires were collected and the averages are calculated.

Indifference and Preference Thresholds

The use of thresholds of indifference and preference facilitates the DM to express his preferences without the need for determination of value interrelations. The type and the prices of thresholds depend on the nature of the criterion, the dissemination of records of choices, the objective uncertainty and the subjective hesitations of the DM on small differences of records. Usually, the threshold of indifference, q, is estimated not to exceed 5–15 %, and the threshold of preference, p, is estimated not to exceed 10-30% of this difference (Rousis et al., 2008). In this particular case, the indifference threshold is set at 10% of the difference between the highest and lowest score while the preference threshold is set at 30% of the

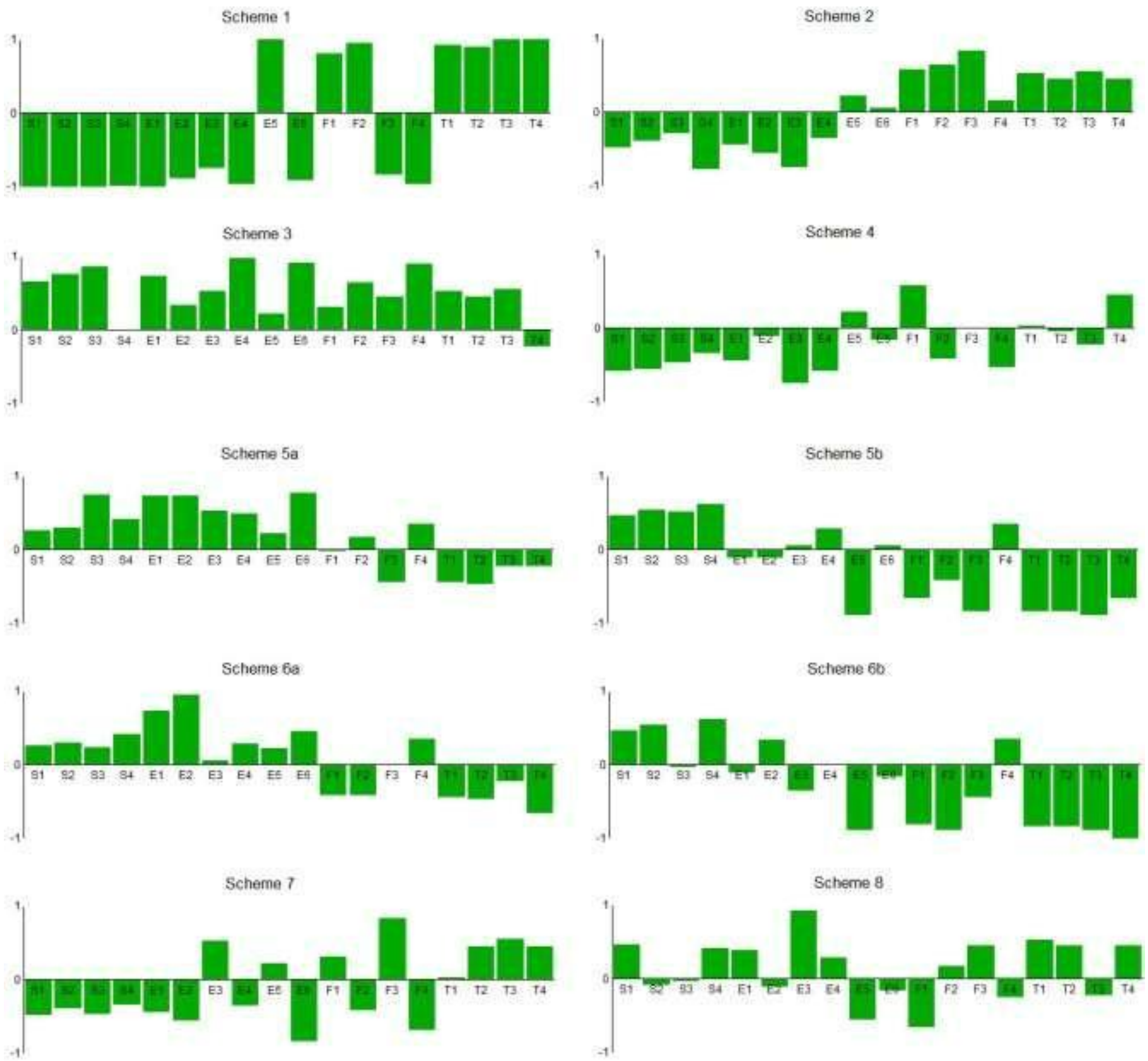

Figure 3. Comparison of the ten candidate management schemes preference in proportion of different criteria.

same difference. The indifference threshold denotes that if the difference in the performance of two scenarios a and b in a criterion is lower than this threshold, these are considered as equivalent (p(a,b)=0). The preference threshold denotes that strict preference (p(a,b)=1) of system, a, over system, b, holds only if the difference in their performance of scenario is higher than this threshold. Table 5 summarizes the criteria indifference and preference thresholds.

Promethee Ranking of Alternative Management Schemes

All the potential alternative management schemes and technologies presented in section 3 were examined and ranked according to their efficiency and performance through the use of PROMETHEE II multi-criteria method. Figure 1 presents the partial ranking, while Figure 2 illustrates the complete ranking of the alternative schemes from best to worst in terms of their net flow with the utilization of linear function.

The indices shown in Figure 2 quantify the degree to which each system outranks (positive value) or is outranked (negative value) by the others and sum up to zero. The optimal balance among the social-institutional, environmental, financial and technical criteria is achieved by the candidate management scheme 3. More specifically, the priorities for the treatment of MSW are in

Table 6. Stability intervals for linear function.

Criteria	Coefficient Weight	Allowed Limits		Coefficient Weight (%)	Allowed Limits (%)	
		min	max		min	max
Harmonization with the legislative framework (S_1)	0.0300	0.0245	0.1088	3.00%	2.47%	10.08%
Application of priorities of legislation (S_2)	0.0300	0.0246	0.0652	3.00%	2.48%	6.30%
Social acceptance (S_3)	0.0250	0.0210	0.0420	2.50%	2.11%	4.13%
Possibilities of new job (S_4)	0.0150	0.0100	0.0818	1.50%	1.01%	7.67%
Level of possible environmental impacts (E_1)	0.0625	0.0585	0.1021	6.25%	5.87%	9.82%
Air emissions (E_2)	0.0500	0.0457	0.0659	5.00%	4.59%	6.48%
Generation of wastewater (E_3)	0.0500	0.0446	0.0971	5.00%	4.48%	9.27%
Generation of solid waste (E_4)	0.0500	0.0453	0.1134	5.00%	4.55%	10.67%
Noise pollution (E_5)	0.0250	0.0000	0.0339	2.50%	0.00%	3.36%
Visual nuisance (E_6)	0.0125	0.0084	0.0269	1.25%	0.84%	2.65%
Investment cost (F_1)	0.1225	0.0587	0.1308	12.25%	6.27%	12.97%
Operation and maintenance cost (F_2)	0.1050	0.0421	0.1139	10.50%	4.49%	11.29%
Land use requirement (F_3)	0.0525	0.0376	0.1039	5.25%	3.82%	9.88%
Production of secondary materials (F_4)	0.0700	0.0648	0.0921	7.00%	6.51%	9.01%
Functionality (T_1)	0.0750	0.0614	0.0801	7.50%	6.23%	7.97%
Existing experience-reliability (T_2)	0.0900	0.0756	0.0951	9.00%	7.67%	9.46%
Adaptability to local conditions (T_3)	0.0750	0.0000	0.0807	7.50%	0.00%	8.02%
Flexibility (T_4)	0.0600	0.0402	0.0657	6.00%	4.10%	6.53%

Table 7. PROMETHEE II complete ranking by the variation of specific financial criteria weights.

Variation of criteria weights	PROMETHEE II complete ranking of candidate management schemes
Complete ranking of management schemes prior the variation of specific criteria weights	3→2→8→5a→1→7→6a→4→5b→6b
Total investment cost (F_1)	
12.25%→2%	3→2→8→5a→1→7→6a→4→5b→6b
12.25%→7%	3→2→8→5a→1→7→6a→4→5b→6b
12.25%→12%	3→2→8→5a→1→7→6a→4→5b→6b
12.25%→17%	3→2→1→5a→8→7→6a→4→5b→6b
Operation and maintenance cost (F_2)	
10.5%→2%	3→2→8→5a→7→6a→1→4→5b→6b
10.5%→5%	3→2→8→5a→1→7→6a→4→5b→6b
10.5%→12%	3→2→8→5a→1→7→6a→4→5b→6b
10.5%→15%	3→2→1→8→5a→7→6a→4→5b→6b
Production of secondary materials (F_4)	
7%→2%	3→2→1→8→5a→7→6a→4→5b→6b
7%→12%	3→2→5a→8→1→6a→7→4→5b→6b

Table 8. PROMETHEE II completes ranking by the variation of specific criteria weights.

Variation of criteria weights	PROMETHEE II complete ranking of candidate management schemes
Complete ranking of management schemes prior the variation of specific criteria weights	3→2→8→5a→1→7→6a→4→5b→6b
Social acceptance (S_3)	
2.5%→5%	3→2→5a→8→1→7→6a→4→5b→6b
2.5%→10%	3→2→5a→8→1→6a→7→4→5b→6b
Level of possible environmental impacts (E_1)	
6.25%→1%	3→2→1→8→5a→7→6a→4→5b→6b
6.25%→11%	3→2→5a→8→1→6a→7→4→5b→6b
Flexibility (T_4)	
6%→1%	3→2→5a→8→1→7→6a→4→5b→6b
6%→11%	3→2→1→8→5a→7→6a→4→5b→6b

the following order: scheme 3, scheme 2, scheme 8, scheme 5a, scheme 1, scheme 7, scheme 6a, scheme 4, scheme 5b and scheme 6b.

Scheme 3 which is the most favorable includes:

i. Collection of recyclable materials in one bin which then are transferred to Mechanical Recovery Facility for recovery of glass, paper, plastics, Fe and non Fe metals;

ii. Collection of the biodegradable sub stream in another bin which then is subjected to Composting;

iii. Residues and non-recovered materials are disposed to sanitary landfill.

Scheme 2 which is the second most favorable scenario includes:

i. Collection of mixed waste that is transferred to MBT Plant. At MBT plant, mechanical sorting process is applied for recovery of glass, Fe and non Fe metals as well as paper and plastics that are forwarded to the end users;

ii. The biodegradable portion of the mixed waste is recovered and subjected to composting;

iii. Residues of the processes are disposed to sanitary landfill. Scheme 8 is the third most preferable scenario and including primary mechanical sorting for metal recovery while the remaining combustible materials are subjected to thermal treatment (Incineration) for energy recovery. Figure 3 is provided by the profile option of the Decision LAB software and presents the comparison of the ten candidate management schemes preference in proportion of different criteria. The scores are between +1 (being the best) and -1 (being the worst). With these evaluations the strong and the weak sides of each management scheme are known in advance.

Sensitivity Analysis

The software tool that was applied for the purposes of the Multi-criteria analysis provides the possibility of the processing of the results, through changing the weights of the criteria. Therefore this option is appropriate for analyzing the sensitivity of the decision problem with respect to the weights of the criteria.

In general, sensitivity analysis provides information on how variations in the input change the output of a model (French and Papamichail, 2003). The output must be interpreted with great care whenever it varies significantly for input fluctuations that are within the realm of error or-perhaps more appropriate- within the realm of confidence in their values (French and Geldermann, 2005).

Firstly, with sensitivity analysis, the importance of broad uncertainties in data and models is assessed by the DMs. Furthermore, they can judge whether the analysis is necessary or whether they need to gather more data to allow a more sophisticated analysis (French and Rios Insua, 2000). Secondly, it can help build consensus among the DMs (Renn et al., 1995).

Table 6 illustrates for each criterion the limits within 'weight values' which could be varied without changing the PROMETHEE II complete ranking with utilization of linear function.

From the data of Table 6 it is concluded that the variation of specific criteria weights such as Harmonization with the legislative framework (S1), Social acceptance (S3), Investment cost (F1), Operation and maintenance cost (F2), Functionality (T1) and Flexibility (T4) have the greatest impact on the complete ranking.

In Table 7, analytical information concerning the alteration of the PROMETHEE II complete ranking by the variation of specific financial criteria weights is presented, with the utilization of linear function:

1. Investment cost (F1)
2. Operation and maintenance cost (F2)
3. Production of secondary materials (F4)

Table 8comprises analytical information concerning the alteration of the PROMETHEE II complete ranking by the variation of the specific criteria weights (with the utilization of linear function):

1. Social acceptance (S3)
2. Level of possible effects to the environment (E1)
3. Flexibility (T4)

Tables 7,8 indicates the variation of the coefficient weights in the chosen criteria doesn't vary in the ranking of the schemes of the first two positions. More specially scheme 3 seems to be the best compromise scheme while scheme 2 possesses the second position. The latest tree positions were also invariable; scheme 4, 5b and 6b respectively.

On the contrary, significant variations are observed with the increase or the decrease of the specific criteria as regards the Third, fourth and the fifth position. For instance, as shown in Table 7 the increase of the coefficient weight in the criterion that regards Investment cost from 12.25% to 12%, the third position is possessed by scheme 8 while the variation from 12.25% to 17% the same position is possessed by scheme 1.

However, it must be mentioned that some of these variations correspond to the most unfavorable conditions as in this way the significance of the rest examining criteria is underrated.

CONCLUSION

The present paper was based on the development and application of a specific MCDA approach and more specially the PROMETHEE method in order to select the best systems for the MSW management in Morocco.

This selection was based on the comparisons of alternatives according to their performances with respect to relevant social - Institutional, environmental, financial and technical criteria. In most of the examined schemes, the first stage regards to the mechanical sorting of waste while the second one includes the application of biological or thermal treatment.

Also, in almost all the alternative management schemes, recovery of ferrous and non-ferrous metals, glass, paper-plastics is achieved. The obtained results show that scheme 3 was presented as the most favorable solution in the case of Morocco. Scheme 3 suggests the collection of recyclable materials in one bin which, then, are transferred to Mechanical Recovery Facility for the recovery of glass, paper- plastics, Fe and non Fe metals and in another bin the biodegradable organics that are subjected to Composting while the residues are disposed to Landfill.

Scheme 2 and scheme 8 are ranked as the second and third preferable solutions, respectively. Schemes 5a, 1, 7 and 6a follow, presenting lower positive efficiency level, while the most unfavorable management schemes refer to the schemes 4, 5b and 6b.

REFERENCES

Araz C, Ozfirat P, Ozkarahan I (2007). An integrated multicriteria decision-making methodology for outsourcing management. Computers and Operations Research. 34: Pp. 3738-3756.

Archer E, Klein A, Whiting K (2005). Mechanical-biological treatment: A guide for decision maker's process, Policies & Markets – Juniper Consultancy Services Ltd., Sheppards Mill, Uley, UK.

CalijuriML,Marques ET, Lorentz JF, Azevedo RF, Carvalho CA (2004). Multi-criteria analysis for the identification of waste disposal areas. Geotechnical and Geological Engineering. 22. 2: Pp. 299-312.

DE (2006). Rapport sur l'état de l'environnement du Maroc. Département de l'Environnement, Morocco.

Diakoulaki D, Karangelis F (2007). Multi-criteria decision analysis and cost-benefit analysis of alternative scenarios for the power generation sector in Greece. Renewable and Sustainable Energy. 11, 4: Pp. 716-727.

Diaz LF,Savage, GM, Golueke CG (2002). Handbook of Solid Waste Management 2nd edition, in Tchobanoglous, G. and Keith, R., Ed., McGraw-Hill, New York.Pp. 30.

Dulmin R, Mininno V (2003). Supplier selection using a multi-criteria decision aid method. Purchasing and Supply Management. 9: Pp.177-187.

French S, Geldermann J (2005). The varied contexts of environmental decision problems and their implications for decision support. Environ. Sci. Policy. 8: Pp. 378–391.

French S, Papamichail N (2003). Decision Behavior Analysis and Support-Decision-Making And How Computers And Analysis Bay Support This, Manchester Business School (MBS), Manchester.

French S, Rios Insua D (2000). Statistical Decision Theory, Edward Arnold, London, UK.

Hokkanen J, Salminen P (1997). Choosing a solid waste management system using multi-criteria analysis. Operational Research. 98, 1:Pp.19-36.

Keller HR, Massart DL, Brans JP (1991). Multicriteria decision making: a case study. Chemo metrics and Intelligent Laboratory Systems. 11(2): Pp. 175-189.

Kokot S, Grigg M, Panayiotou H, Dong Phuong T (1998). Data Interpretation by some common Chemo metrics methods. Electroanalysis, 10: p.1081.

Loizidou M (2008). National Technical University of Athens Chemical engineering department, Lecture Notes.

Makan A, Malamis D, Assobhei O, Loizidou M, Mountadar M (2012). Multi-criteria decision analysis for the selection of the most suitable landfill site: case of Azemmour, Morocco. Int. J.Manag. Sci. Eng. Manag. 7, 2: Pp. 96-109.

Mavropoulos A (2008). Waste Treatment Technologies, United Association of Waste Management of Crete.

Renn O, Webler T, Wiedermann P (1995). Fairness and Competence in Citizen Participation: Evaluating Models and Environmental Discourse, Springer. Pp. 381.

Rousis K, Moustakas K, Malamis S, Papadopoulos A, Loizidou M, (2008). Multi-criteria analysis for the determination of the best WEEE management scenario in Cyprus. Waste Management. 28: Pp. 1941–1954.

Visual Decision Inc., Getting Started Guide, Decision Lab

2000, Visual Decision Inc., Montreal, Quebec, Canada, (1999.

Wang JJ, Yang DL (2007). Using a hybrid multi-criteria decision aid method for information systems outsourcing. Computers and Operations Research, 34: Pp. 3691-3700.

World Bank (2008). Municipal Solid Waste Treatment Technologies and Carbon Finance, Thailand, Bangkok.