Managing The Solid Waste: Recycling In Subang Jaya

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EXECUTIVE SUMMARY

Recycling is a relatively new exercise in Malaysia. Even though recycling has been introduced years back, lack of public awareness caused a slowdown in the progress of recycling exercise. Lack of sufficient recycling facilities or inappropriateness of the facilities' location contributed further to the slowdown. Presently, about 19,000 tonnes (approaching 20,000 tonnes) of solid waste are being discarded daily. The Ministry of Housing and Local Government set a recycling goal to be 22% by 2020. In Malaysia, research is being done vastly on recycling but very few related to multicriteria.

The objective of the paper is to study the status and the successfulness of recycling exercise in Subang Jaya, Malaysia. With an estimated area 161.8km² and an immense figure of 500,000 of people living in the vicinity of Subang Jaya City Council (SJCC), an estimated count of 350 tons of waste is produced on daily basis with each person contributing around 0.7kg waste per day, in accordance to a current study. Thus it demands a high management cost, with a staggering 50% out of the total tax collected by SJMC had to be allocated for the abovementioned matter. The present recycling rate of Subang Jaya is less than 1%.

In this paper, we study ways to achieve the national recycling target by the year 2020. To this end, formulation and analysis of various strategies to raise the recycling rate are done. The evaluation of various strategies involves inherently qualitative criteria and imprecise data. Therefore, the outranking analysis which has been frequently used in such situations is employed. For ranking strategies, a new exploitation procedure based on eigenvector in a PROMETHEE context is proposed to evaluate the overall performance of recycling facilities in Subang Jaya.

Analytic Hierarchy Process (AHP) is used to determine the weights based on the local officer and then various stakeholders in the decision process. Then, a generalized procedure in PROMETHEE analysis, a modified approach, is used to rank the alternatives to get an insight on recycling strategies. We proposed a new preference ranking procedure based on eigenvector using the "weighted" in- and out- preference flows of each alternative in the outranking analysis. The basic idea of the procedure proposed here is that it should be better to outrank a "strong" alternative than a "weak" one and, conversely, it is less serious to be outranked by a "strong" alternative than by "weak" one in a PROMETHEE context. It has a completely different interpretation with the AHP since the components of the valued outranking relation matrix are neither ratios nor reciprocal as in the AHP.

A total of ten (10) strategies were formulated focusing on two main streams, namely, awareness creation and increasing recycling facilities. Results of our study show that both awareness creation and sufficient recycling facilities are necessary to increase the recycling rate in Subang Jaya. In order to achieve the national recycling target of 22% by the year 2020, intensive awareness creation programs are needed to create awareness among the residents of Subang Jaya. This has to be complemented with sufficient recycling facilities.

Keywords: recycling, multicriteria, preference, outranking analysis

INTRODUCTION

The increasing number of residents in developing cities has also meant a steady growth of waste quantity. One such city is Subang Jaya; a city located in the state of Selangor, Malaysia under the governance of Subang Jaya Municipal Council (SJMC). With an estimated area 161.8km² and an immense figure of 500,000 of people living in the vicinity of SJMC, an estimated count of 350 tones of waste is produced on daily basis with each person contributing around 0.7kg waste per day, in accordance to a current study. Thus, the whole ordeal demands a high management cost. In accordance to the national recycling program, all local authorities were instructed to implement recycling programs in order to achieve government recycling target of 22% by the year 2020. At present, recycling practice is less than 10%. This paper evaluates the overall performance of recycling exercise in Subang Jaya (SJ) and gets insight into strategies to increase the recycling activity.

MUNICIPAL SOLID WASTE (MSW) AND RECYCLING IN SUBANG JAYA

There are three (3) area under the governance of SJMC, namely Seri Kembangan, Puchong and Subang Jaya. Our focus is on Subang Jaya with total population of 257,288 accounting for 57% of the total population of SJMC (MPSJ, 2005). The area of Subang Jaya is divided into 9 zones.

Recycling Efficiency in Subang Jaya

Presently, Subang Jaya's recycling facilities consist of recycling centre (RC), recycling bin, Siverbox (recycling box at the pedestrian walk) and recycling vans (Chenayah and Takeda, 2006). In this section, we determine the efficiency of recycling in Subang Jaya based on the available data. There are a total of 67 sets of bins located at various locations in Subang Jaya. Out of 9 recycling centre, 7 are located in the vicinity of Subang Jaya. All Silverboxes are located in Subang Jaya. The recycling van makes 7 visits to different locations in Subang Jaya, totaling to 84 visits per year. Table 1 show data on the amount recycled according to the recycling facilities available in Subang Jaya.

Based on the number of units/sets/visits, we calculated the efficiency per unit/set/visit and the efficiency rate. Recycling centre recorded the highest efficiency rate of 78.9%, followed by bins, 13.7%, Van 7% and Silverboxes 0.4%. From Table 1, efficiency per unit of the ecycling bin is 504.7kg. Efficiency of each recycling centre is 48869.4kg; efficiency per unit of Silverbox is 1053kg and efficiency per visit of the van being 126kg.

Table 1 Recycling data for area under SJMC governance

	All area under SJMC				**Subang Jaya**	
Recycling facilities	**Recycled**	**No**	**Efficiency per unit**	**Efficiency Rate**	**No**	**Recycled** *(estimation)*
Bin	76203.92	151 sets	504.6617	0.137	67	33812.34
Recycling Centre	439824.9	9 unit	48869.43	0.789	7	342086
Silverbox	2106	2 unit	1053	0.004	2	2106
Van	39540.61	312 visit	126.7327	0.07	84	10645.55
Total Recycled	**557675.43**					**388649.9**
Total Waste	**157567210**					

From the efficiency per unit calculated in Table 1 above, we computed the recycling amount for Subang Jaya based on various facilities as given in last column of Table 1. The reason for using this calculation method is due to lack of information on recycling in Subang Jaya. Total amount recycled by SJMC in the year 2004 is 557.67tons (MPSJ, 2004a). We estimated that SJ contributed more than half to this figure, this is about 389tons. The reason is that SJ has more recycling facilities compared to Puchong or Seri Kembangan.

Waste growth using the Logistic Curve

Given insufficient information on the waste growth of the area under the governance of SJMC, we used the 'logistic growth model' to estimate the municipal (household) solid waste growth. This rationale stems from the growth of population with the increase in recyclables. In our studies, we denote by $W(t)$ the total municipal solid waste for Subang Jaya. Using the logistic equation,

$$W(t) = \frac{K_{TWSJ}}{1 + me^{-rt}} \qquad (1)$$

As a first step in the waste estimation, we determined the value of K_{TWSJ} (*multiplication of total waste of Subang Jaya and population ratio*, m ([(K_{TWSJ} / *waste in year 0)-1*]) and r for the area of SJMC using the data in Table 1. Total waste of all area under SJMC are 132,454.40 (2002), 142,586.56 (2003) and 157,567.21 (2004) (MPSJ, 2004b). From these figures, waste ratio is calculated.

Our research focuses on Subang Jaya. However, there were no data on the amount of waste collected by each zone under SJMC. Therefore, we used the population ratio and estimated the total waste collected by Subang Jaya. Population of Subang Jaya comprises 57% of the total population of area under SJMC. Therefore, the estimated total waste of Subang Jaya is given is Table 2. Using the values, a logistic curve is fitted to calculate the projected growth of waste in Subang Jaya. The parameters are given: m=10.13, K_{TWSJ}=1,000,000, r=0.098.

Table 2 Estimated total waste and Logistic curve for Subang Jaya area

	2002 (t=-2)	**2003 (t=-1)**	**2004 (t=0)**	**2020 (t=16)**
Estimated total waste	75499	81274	89813	----
Logistic curve	**75038**	**82123**	**89813**	**320997**

As we noted before, at present, the collection rate in SJMC area is 0.35% and is estimated 0.43% in Subang Jaya. Thus, this small collection rate is considered to be due to the small quantity of recyclables items brought by the residents and the small number of residents accessible to the facilities. The former is improved by awareness creation and the latter by increase in number of facilities.

As the recycling facilities increases, there may be substitutes among facilities. We assume that facilities are not so much as they significantly substitutes among them and that therefore, the effect is additive. Thus, in our study, we assumed the total waste collected for, denoted by $WC(t)$, which are assumed to be expedited by awareness and facilities. Amount collected for recycling in Subang Jaya (K_{RWSJ}) is assumed to be β=0.3 of the estimated total waste of Subang Jaya (K_{TWSJ}) which will be achieved over a long time period with the assumption of the status quo, where β=0.3 is some collection rate in advanced countries in recycling as stated in the executive summary of EPA (US EPA, 1995). That is, the collection rate for recycling in Subang Jaya will catch up with advanced countries in recycling over a long time period with the assumption of the status quo.

$$WC(t) = \frac{\beta K_{TWSJ}}{1 + me^{-rt}} \qquad (2)$$

However, awareness creation activities and the increase in recycling facilities expedite it. We assume that the awareness expedites the achievement by $(r + \alpha)$ and recycling facilities effect on the collection

$$(\sum_i n_i p_i) WC(t) \qquad (3)$$

where n_i is the number of i- th facility. With the parameters given: m=10.13, K_{TWSJ} =1,000,000, r=0.098, we calculated K_{RWSJ} =0.3 X K_{TWSJ} = 300000. Using the values, a simulation is run and the projected growth of the total amount recyclable in Subang Jaya is calculated.

With the assumption of status quo, recycling is estimated to increase to 0.578% of the total waste of Subang Jaya by 2020. With only 0.43% in year 2004, question arises on the capability of SJ under SJMC to achieve the national recycling target. From this preliminary work, we move into formulating some strategies to assist SJMC in achieving the government recycling target. Assuming β=0.3 (US EPA, 1995), recycling is estimated to increase to 0.58% by 2020 and 0.88% by 2030 with the assumption of the status quo. We have formulated ten (10) strategies to look at the feasibility of achieving the targeted recycling goal by the year 2020 and beyond.

Recycling Strategies and Simulation

Formulation of Strategies (alternatives)

We formulated 10 strategies to increase the recycling in SJ by 2020. In our earlier study (Chenayah and Takeda, 2006), we concluded that awareness creation is as important as providing sufficient recycling facilities. Therefore, the strategies focus on these two main streams, namely awareness creation and increasing the recycling facilities. Strategies 1, 2 and 3 focus on the effect of awareness creation without any changes in the status of the recycling facilities. Strategies 4 onward look into the effect of both awareness creation and changes in recycling facilities on the projected collection rate.

Strategies 1 to 3

Effect of awareness creation (α): low = 10%, medium = 15% and high = 20%

$r^* = r + \alpha$, where $r = 0.098$

Recycling facilities: status quo

Strategy 4

Effect of awareness creation: status quo

Recycling facilities: increase recycling facilities in 2-phase; year 2010 and year 2015.

Under Strategy 4, a two-phase increase in the number of recycling facilities is proposed, the first increase in 2010 and the second in 2015 (see Table 3).

Strategy 5, 6 and 7

Effect of awareness creation: low=10% (Strategy 5), medium = 15% (Strategy 6), high = 20% (Strategy 7).

Recycling facilities: increase recycling facilities in 2-phase; year 2010 and year 2015 as given in Strategy 4.

Strategy 8, 9 and 10

Effect of awareness creation: low=10% (Strategy 8), medium = 15% (Strategy 9), high =

20% (Strategy 10). Recycling facilities: Increase of recycling facilities in 2012.
Table 4 presents a one-phase increase in recycling facilities in 2012

Table 3 A two-phase increase in the number of recycling facilities

Facilities	**Increase in 2010 (%)**	**Increase in 2015 (%)**	**2004**	**Increase by**	**2015**
Recycling Centre	0%	100%	7	7	**14 unit**
Recycling Bin	100%	50%	67	101	**168 sets**
Recycling Van	600%	0%	7	42	**49 visits/month (3 unit of van)**
Silverbox	**300%**	**0%**	**2**	**6**	**8 unit**

Table 4 A one-phase increase in the number of recycling facilities

Facilities	**Increase in %**	**2004**	**Increase by**	**2012**
Recycling Centre	150%	7	11	**18 unit**
Recycling Bin	500%	67	335	**402sets**
Recycling Van	800%	7	56	**63 visits/month**
Silverbox	**800%**	**2**	**16**	**18 unit**

Simulation results for recycling strategies in Subang Jaya

Simulation was done to look at the estimated growth of recyclable collection, to see how it expedites with the effect of awareness creation.

MULTICRITERIA MODELLING IN EVALUATING RECYCLING STRATEGIES IN SUBANG JAYA

Criteria for Consideration

Five criteria for evaluation were considered:

1. Recycling rate (c_1)

   Increase in recycling rate will have positive impact on the environment by reducing the generation of solid waste, the waste that end at landfill and the number of landfill needed. The main objective is to achieve the government recycling target of 22% by 2020.

2. Construction cost (c_2)

   From the interview with experts at the Ministry of Housing and Local Authority and SJMC, the cost to set up each facility is as given in Table 5.

   Cost of various programs to create awareness (MYR 100,000 – 250,000/ year)

   i) With status quo, the cost for awareness creation is MYR100,000

ii) With awareness, the cost for awareness creation is more than MYR 150,000

- Awareness 10% = MYR150,000, awareness 15% = MYR200,000 and awareness 20% = MYR250,000

Table 5 presents the calculation of construction cost of recycling facilities and awareness program.

Table 5 Calculation of Construction Cost for Strategy 4 - 10

	Cost per unit	**Two-phase increase in 2010, 2015**	**One-phase increase in 2012**	**Total Cost [Strategy 4, 5, 6 and 7] (TC1)**	**Total Cost [Strategy 8, 9 and 10] (TC2)**
Recycling centre	70000	14	**18**	**490000**	**770000**
Recycling Bin	1500	168	**402**	**151500**	**502500**
Recycling Van	70000	49	**63**	**140000***	**140000***
Silverbox	5000	8	**18**	**30000**	**80000**
Total Cost of increase in RC facilities				**811,500**	**1,492,500**
Total Cost without awareness two-phase increase (*one-phase)*				**911,500**	***1,592,500***
Total cost with awareness Strategy 5 *(8)*				**961,500**	***1,642,500***
Total cost with awareness Strategy 6 *(9)*				**1,011,500**	***1,692,500***
Total cost with awareness Strategy 7 *(10)*				**1,061500**	***1,742,500***

a. TC1: Cost for Recycling van is MYR140,000 with the purchase of 2 new vans

b. Total cost in *italic* for Strategy 8, 9 and 10

3. Operating/ maintenance cost (c_3)

   This operating cost consists of:

   i) the cost of carrying out various awareness program to ensure continuous increase in awareness and to create civic mindedness among the residents

   ii) maintaining various recycling facilities (collection from various spots, cleaning the facilities and administration cost)

   As the number of recycling facilities increases, the maintenance cost increases as well; more man power needed for collection, cleaning and replacing the bins. Operating/ maintenance cost is given using score from 1 to 5. Score '1' indicates high maintenance and score '5' indicates low maintenance. Higher score is desirable

4. Social impact (employment, economic benefits to the residents) (c_4)

   We analyze the social impact to the residents in the creation of job and benefit from recycling (in the form of souvenirs, coupons, payments). Higher awareness and increase in the number of recycling facilities will have higher social impact on the residents. This criterion is described using scores 1 to 5. Score '1' indicates low impact, whilst score '5' indicates high impact. Higher score is desirable.

5. Convenience for the residents (accessibility) (c_5)
   We analyze the convenience of the recycling facilities (accessibility). Presently, the recycling facilities are not sufficient. Therefore, it is difficult to encourage the residents to recycle in cases where the facilities are out of the reach. Increasing the recycling facilities increases the accessibility to the residents. We use scores 1 to 5, with score '1' indicating low accessibility and score '5' indicating high accessibility. Higher score is desirable.

Construction of the Outranking Relation

Setting weights

We constructed the reciprocal matrix and derived the priority vector:
(0.470, 0.144, 0.079, 0.045, 0.262).

From this priority vector, we find that the recycling rate (c_1) is more important, followed by the accessibility criteria (c_5), construction cost (c_2), operation cost (c_3) and social impact (c_4). With lambda max = 5.314, Concentration Index (C.I.) =0.0784, thus, a consistency ratio (C.R.) of 0.070 (≤ 0.1) is considered acceptable.

We employ the outranking ELECTRE III method. Therefore, it is important to determine the preference (P), indifference (Q) and veto (V) thresholds.

1. For recycling rate, the values are; P = 3, Q = 0.5 and V = 10.
2. For construction costs, it is set, P = 200000, Q = 100000 and V = 100000000.
3. For maintenance costs, the thresholds are as follow: P = 3, Q = 1 and V = 5.
4. For the social impact criteria, P = 3, Q = 1 and V = 5.
5. For convenience for the residents criteria, P = 3, Q = 1 and V = 5.

Tables 6, summarize the alternatives (Strategies 1-10) and criteria for consideration. Using the values in Table 6, outranking relation matrices were constructed.

Exploitation from outranking relation

PROMETHEE (Preference Ranking Organization METHod for Enriching Evaluations) has been widely used to deal with the complex decisions involving quasi-criterion and pseudo-criterion (Bana e Costa, 1982; Brans et al., 1986). We employed an exploitation procedure based on eigenvector in a PROMETHEE context (Chenayah and Takeda, 2008).

Table 7 Summary of alternatives and criteria

	c_1	c_2	c_3	c_4	c_5
p	1	100000	1	1	1
q	0.5	10000	0	0	0
v	5	1000000	2	2	2
a_1	2.79	150,000	5	1	1
a_2	5.997	200,000	4	2	1
a_3	12.37	250,000	4	3	1
a_4	3.06	911,500	3	2	3
a_5	6.56	961,500	3	2	3
a_6	13.48	1,011,500	2	3	3
a_7	25.63	1,061500	2	4	3
a_8	9.14	1,642,500	3	3	5
a_9	18.33	1,692,500	2	4	5
a_{10}	33.39	1,742,500	1	5	5
weight	0.47	0.144	0.079	0.045	0.262

From the eigenvector procedure using weighted preference flows:

$\Psi^{+} = (0.0020 \quad 0.0033 \quad 0.0085 \quad 0.0309 \quad 0.0544 \quad 0.1255 \quad 0.3258 \quad 0.1832 \quad 0.2293 \quad 1.0000)$

$\Psi^{-} = (1.0000 \quad 0.6799 \quad 0.0007 \quad 0.1027 \quad 0.0602 \quad 0.0025 \quad 0.0007 \quad 0.0007 \quad 0.0003 \quad 0.0003)$

the value of lambda; $\lambda_{\max} = 1.627, \quad (\varepsilon = 0.0001)$

And the ranking in descending and ascending order are as shown below.

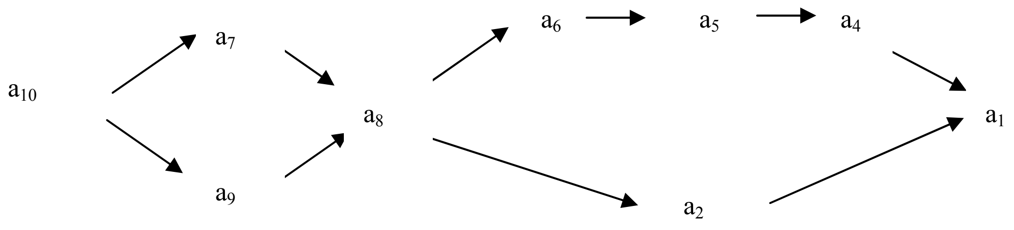
Descending order:

$a_{10} \rightarrow a_7 \rightarrow a_9 \rightarrow a_8 \rightarrow a_6 \rightarrow a_5 \rightarrow a_4 \rightarrow a_3 \rightarrow a_2 \rightarrow a_1$

Ascending order:

$\{a_{10}, a_9\} \leftarrow \{a_7, a_8, a_3\} \leftarrow a_6 \leftarrow a_5 \leftarrow a_4 \leftarrow a_2 \leftarrow a_1$

and the final ranking:



From the final ranking, Strategy 10 was ranked first, followed by Strategies 7 and 9. Strategy 7 and 9 are not comparable and emerged as the second best alternatives. Strategy 10 was ranked first even though construction cost is very high compared to other strategies. Under

Strategy 10, facilities were increased in 2012 by a larger percentage compared to strategies 4, 5, 6 and 7 and awareness creation was at highest rate of 20%.

Visually, Strategy 10 seems to be the best alternative with collection rate projected to increase up to 33.4%, social impact is the highest to society and easily accessible. However, the construction cost and maintenance cost is the highest. Criteria 1 (projected collection rate) carries the most weight. Therefore, Strategy 10 emerged as the best alternative. Under this strategy, social impact to the society and accessibility to the residents is highest. Outranking takes into account multi-criteria simultaneously, hence this emerging as the best alternative despite the high cost. This is because all five criteria were simultaneously taken into consideration in the ranking of alternatives. Strategy 7 was preferred to Strategy 8 even though under strategy 8 percentage increase in the number of facilities is higher. This could be due to high awareness creation (20%) compared to strategy 8 (10%). In all cases, the projected collection rate of recyclables is higher when increase in recycling facilities is complemented by awareness creation.

Sensitivity analysis

Since the outranking analysis involves several parameters, we performed a sensitivity analysis. We examined the sensitivity of the final ranking with respect to threshold values. We have done two cases. In case 1, veto thresholds of c_3, c_4, c_5 are all relaxed into 3 from 2.

$$p_1 = 1, \quad q_1 = 0.5, \quad v_1 = 5$$
$$p_2 = 100000, \quad q_2 = 10000, \quad v_2 = 1000000$$
$$p_i = 1, \quad q_i = 0, \quad v_i = 3, \qquad (i = 3,4,5).$$

Case 2;

$$p_1 = 5, \quad q_1 = 1, \quad v_1 = 10$$
$$p_2 = 50000, \quad q_2 = 5000, \quad v_2 = 500000$$
$$p_i = 1, \quad q_i = 0, \quad v_i = 3, \qquad (i = 3,4,5).$$

In both cases, Strategy 10 again was the best ranked. Either Strategy 9 or 7 emerged as second best alternative. In both cases, Strategy 1 is the least preferred. Even by relaxing the properties of criteria 3, 4 and 5, holding the equal weights fixed, we can find that the final ranking is sufficiently robust for threshold values.

CONCLUSION

The evaluation of various strategies involves inherently qualitative criteria and imprecise data. The outranking analysis which has been frequently used in such situations were employed. A non-additive aggregation (fuzzy integral) to evaluate the overall performance of recycling facilities in Subang Jaya is used. For ranking strategies, an exploitation procedure based on eigenvector in a PROMETHEE context is proposed.

From the analysis, awareness is most important to make recycling a success. Even with the necessary facilities, the success of recycling cannot be ensured. Therefore, educating the public, as what is being done now by SJMC should continue. SJMC has placed bins at kiosks and petrol stations. This is a way to encourage people to recycle more.

It is rationale that the results from the outranking analysis using eigenvector clearly states that in order to increase recycling rate to 22% by 2020, SJMC should focus not only on increasing the facilities but on awareness creation too. In fact awareness creation should be given utmost attention in order to create the civic-mindedness among the residents. From our study, it can be seen that awareness creation on itself can increase the recycling rate of SJMC. Rationale is to increase both facilities and awareness simultaneously.

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