Evaluating Sustainable Waste Management(Household Waste) in Tehran, Iran

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Abstract: The aim of this study is to identify the most fitting scenarios of waste source separation in the integrated waste management scheme in Tehran, Iran by examining the key factors by applying multi-criteria decision-making method (MCDM).This paper emulates four different scenarios involving various separation methods including buyback centres, door-to-door services and kerbside. These scenarios were assembled from environmental source consumption, economic and social perspectives and then ranked on the basis of MCDM method. The information gathering was based on foreground data and not on background data. This study has taken in to account only the source with no engrossment of environmental emissions, economic and social aspects of the source separation programs. The results of this study showed that a fourth scenario with buyback centre + door-to-door service with 8-litter bin+ kerbside with blue container is the best scenario for managing waste source separation in Tehran because of the highest level of public acceptability, with lowest risk and low cost in door-to-door service and with reduced collection frequency. The selection of this method proved that the costs can be reduced without having a huge impact upon recovery.

Key words: Sustainability, Household waste, Source separation, Iran, Developing countries
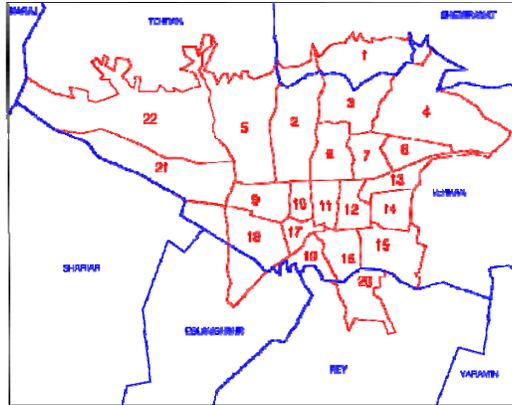
INTRODUCTION

The Integrated Solid Waste Management (ISWM) is defined as a comprehensive waste prevention, recycling, composting, and disposal concept. ISWM planners should focus on institutional, social, financial, economic, technical, and environmental factors (EPA, 2002). ISWM also provides new opportunities for selecting and combining the most appropriate waste management scheme to meet the local needs and prevailing conditions (Wilson, 2007). Thus the success of a waste management strategy in a community depends on its environmental, economic and social impacts (Daly and Farley, 2004).

The success of a source separation program depends on public participation and remuneration. (Noehammer *et al.* 1997). Recently several researchers have studied source separation awareness, interest, participation, economic incentives and cultural factors. It was found out that economic, social, environmental, and legal factors affect ISWM and thus there is no single solution or alternative to establish a source separation collection method. (White *et al*, 1995, Wang *et al*, 1997, Gallardo., 2000, Martin *et al* 2006, Shaw *et al*, 2006, Dahlén*et al*.2007). As a follow up other influencing factors such as demographic, logistic and economic factors were studied to understand participation, quantitative analysis, and waste generation (Daskalopoulos*et al*. 1998, Emery *et al*., 2003, González-Torre &Adenso-Díaz, 2005).

The socio-economic factors in the drop-off points indicated that there will be increased participation along the higher socio-economic levels (Gandy, 1994, Belton *et al*. 1994). However Lobber (1996) disregard socio-economic as a significant factor in the degree of participation.

Integrated solid waste management in source separation is influenced by facilities and type of household storage and collection as well. Temporary containers, such as cardboard boxes, plastic bags and a range of different types of alternative containers have been found to be effective in reducing the costs (UN, 2010). Deposit Points, time of collection and type of collection are other factors influencing the source separation. Deposit points are on the kerbside, buyback centres, organizations and schools, household, chain stores etc.

In 2010, Tehran separated 4.8E+08 kg per capita per year of waste, 200 kg/householder/year. Household waste represented 3E+06Mt (85.30%) of MSW, of which only 2E+05Mt (12.40%) were recycled or composted despite over two-thirds of the contents of the average dustbin being recyclable or compost able. Most of the 3E+08 Kg (57%) recycled materials were collected from door-to-door services, and 34% of households served by kerbside sorting collection schemes and 9% by buyback centres. There was a wide variation in household-recycling rates among the 22 local authorities (LAs) in Tehran, where the majority (nearly 50%) failed to recycle or compost more than 12% of MSW (TWMO, 2009).

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Fig. 1: Twenty two regions of Tehran's municipality

The development of recycling programs across Tehran is based on sustainable principles. Many successful municipal programs were performed with commingled collection. A survey conducted in 1995 in Tehran found that participation in new programs averaged about 55% compared with 34% in previous years but it was not successful unless there was public participation through buy back centres, home containers and an extensive effort to provide public education.

This paper focuses only upon source separation management with attention to factors of integrated solid waste management. The aim of this study was to compare different scenarios of waste source separation in Tehran, according to the criteria of cost, risk, social acceptability, resource consumption to select the best scenario with multi-criteria decision-making approach.

MATERIAL AND METHOD

In Tehran, an average of 7,000 metric tons of waste are generated per day by each of the municipal regions (Fig. 1). Currently, more than two and a half million tons of waste is generated annually in Tehran. According to the waste analysis, 32% of dry material is recyclable. The choice of wheeled container or plastic bags depends on the collection method (separated collection or commingled collection). In the 22 regions of Tehran buyback centres and kerbside containers are provided free of charge. Tehran municipality uses plastic bags, so that recyclables can be easily transferred by hand. There are several levels of storage, depending on the distance travelled by the citizen to the deposit point: The first method is the door-to-door method using plastic bags that are located at each door in the residual area. The distance to deposit point is minimal. The second method is the kerbside method with deposit points located at a distance of 50-60m, a suitable way for highly populated areas. The third method is the drop-off points (buyback centres) that are approximately at a distance of 100-300m in residential area.

Data for this paper was collected in a survey carried out by questionnaire and examination of other relevant documents in Tehran during the year 2010.Material and energy data for the types of storage equipment and collection method were supplied by the Tehran municipality, the Iran Small Industries and Industrial Parks Organization, the Industrial Advisers Databank of the Ministry of Industries and Mines (ISIPO, 2010),and Iran Police Electronic Information Services (NAJI Research and Development Corporation,2009).

With attention to the main factors in the integrated waste source separation management, the criteria for the study included the environmental sources consumption, the revenue from the sale of dry recyclable materials, social acceptability, waste separation rate and the risk of the process. In order to select the combination of a waste separation collection method that best suits its needs, it is necessary to define some indicators including the following:

The first set of criteria studied included the revenue calculation. Iran's expense for waste source separation is 45-60 Euros per ton of separated materials. Cost-benefit assessment was used in calculating the revenue .The net profit of operations of the waste source separation should be more than the cost of recovery based on the formula (Eq.1):

$$P > C \qquad P = R - C \qquad\qquad (1)$$

P =Net profit
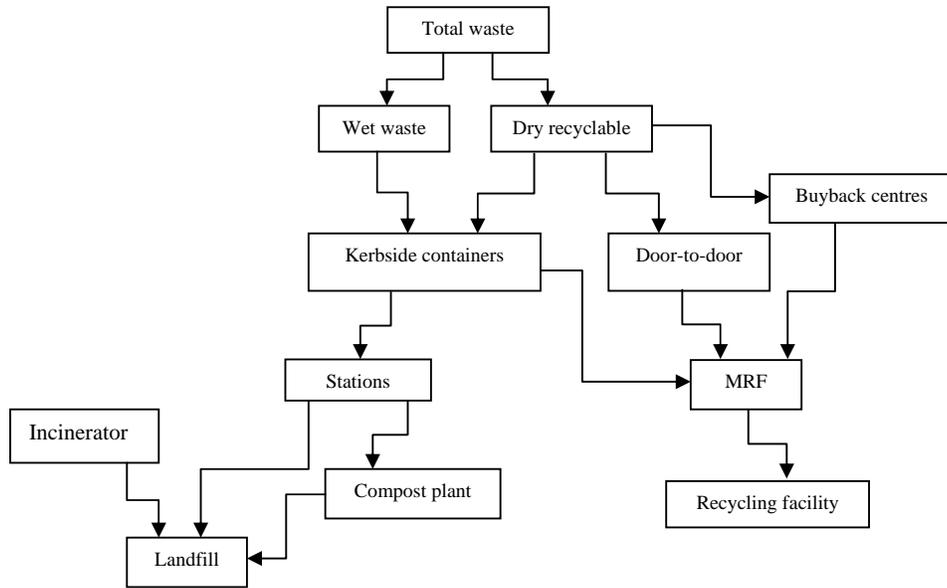C =Cost Recovery
R =Revenue

Fig. 2: Solid waste management in Tehran

The second set of criteria covered the risk processes. The risk assessment mechanism used was based on the composition of the error analysis method and its effects (Failure Mode & Effect Analysis) or briefly FMEA using the logic "what if" and has been integrated and calculated to understand the exposure hazards, consequential risk and accidents(Stamatis, 2003).The formula is (Eq.2):

The consequence rate(C) × risk exposure hazard rate (E) × probability incident cerate (P) = risk score (RC)   (2)

The third set of criteria studied included public acceptability. The success of a chosen method in a society can be evaluated by attitudes and opinions of citizens. With this in mind the questionnaire was prepared with a survey on the attitude and opinion of Tehran citizens on source separation of domestic waste, waste recovery and the waste collection service. It included indicators for determining public acceptability of the type of deposit points, the types of location, spent time, the kinds of houses, money, encouragement of their children, concern about sorting the waste, environmental protection. For determining public acceptability the questionnaire had 20 questions. χ^2 Test (Chi-square) was developed using the following equation (Eq.3):

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} (O_{ij} - E_{ij}) / E_{ij}$$

(3)

The fourth set of criteria that was studied included separation rate (SR_i). The ratio between the amounts by weight of raw material separated and the total amount of material in the urban waste (Eq.4).

$$SR = \frac{\text{Gross amount of waste collected in container for i}}{\text{Total amount of I waste generated}} . 100(\%)$$

(4)

The fifth set of criteria that was studied included environmental source consumption. It calculated energy usage as MJ-kg^{-1} for collecting dry recyclable materials.

In this paper, the waste source separation scenarios with different components of the process have been studied. For managing waste source separation in Tehran a total of four scenarios have been considered and are

ranked by MCDM method (Carlsson.*et.al*, 1995). Processes include kerbside sorting, door-to-door service, buyback centres and kerbside using blue containers.

Description Of Scenarios:

This paper is based on an assumptions scenario proposed by the contractors. The scenario details the problems that contractor is having at work and is considered to find new approach. The paper outlines as a result some of the major assumptions that was made in these scenarios and proposes how to decrees negative points, discusses some other alternatives. All scenarios are investigated in the same situation. Assumptions in the four scenarios including:

a.   Scenarios efficiency in blue and black bins programmes is assumed to be the same
b.   Scenarios efficiency in plastic bag and HDPE bins programmes is assumed to be the same
c.   Waste collected and population is assumed to be constant overall 5 years
d.   Based on estimated kilometres and the number of vehicles was estimated fuel consumption
e.   The number of vehicles was estimated based on the volume of collected waste and vehicle capacity

Results:

Based on the influencing factors in ISWM, each community has a different challenge in combing waste source separation methods. Each of these methods in each stage has different impacts on source consumption, efficiency, revenue and risks. Each of these activities influences the ISWM through one or more of the following ways:

Source Consumption:

The amount of source consumption varies based on the type of collection vehicle and its fuel consumption. Tehran municipality calculates the energy consumption based on local trips and the distance travelled (kilometres). In this study, the overall mean score for the source consumption was 4.00, one of the lowest. It was found out that the highest energy consumption belonged to kerbside collection method using a truck collecting plastic bags or 8-litter HDPE bin from door-to-door, followed by kerbside collection with three wheeled vehicles and then buyback centres.

Efficiency Indicators:

Separation rate is a necessary tool for evaluating and implementing the source separation method sit provides direct information on the quantity recovered in each method. The separation rate will indicate the level of public participation, the overall performance and the quality of the recovered items in a method. The Tehran recycling rate for household waste stood at 15% in 2010; this figure has been growing as a result of initiatives by local authorities such as the establishment of practical waste source separation schemes. However, it is still inadequate in comparison to the European Union (EU) countries and in terms of reaching the national target of 25% by 2012. In this study, the overall mean score for the efficiency was 3.00. It is interesting to note that the highest efficiency was achieved in door-to-door collection method with plastic bags or 8-litter HDPE bins from the kerbside with three wheeled trucks; and then the buyback centres.

Cost-Benefit:

In order to calculate the initial costs of an operation and the other recurring costs, a cost-benefit analysis was carried out. Benefit and costs were expressed in money terms, so that the cost of each method was expressed as "net present value' and the income of each method was derived from the income of recyclable materials. Ranking of collection methods was based on the ratio of the revenue of each method to. Generally, the various strategies for source separation activities were evaluated.

The overall mean score for the net profit (P) was 3.00. It was found out that the highest net profit was achieved in door-to-door service collection method with plastic bags or 8-litter HDPE bins; then kerbside collection method using a three wheeled vehicles or truck; and then the buyback centres. The overall mean score for the cost of recovery (C) was 4.00. In this calculation the highest cost belonged to the door-to-door service collection method with plastic bags. The second was the kerbside collection method using a truck; the third was the kerbside collection method with a three wheeled vehicle and the fourth was the door-to-door service collection method with 8-litter HDPE bins. In this study, the overall mean score for revenue (R) was 3.00. It was also found that the highest revenue belonged to the door-to-door service collection method with plastic bags or 8-litter HDPE bins; the second was the kerbside collection method with a three wheeled motor vehicle or truck and the third was the buyback centres.

Public Acceptability:

In this study, the overall mean score for public acceptability was 4.00. It was found out that the highest public acceptability belonged to the door-to-door service collection method with plastic bags or 8-lit HDPE bins

and the second was the kerbside collection method using a truck. The buyback centres and kerbside sorting doesn't find public acceptability.

Risk Assessment:

High level of contamination in some methods affect sorting the dry recyclable material of mixed waste and the quantity of material collected and its market price. The input of contamination may come from the most common dry material in the container, middle stations, compost plant and landfill. To improve the quality of recovered materials, the design method, education and social awareness may help. In this study, the overall mean score for the risk was 1.00. It was also found out that the highest risk belonged to the kerbside sorting collection method by three wheeled motor vehicle and other methods did not have any significant collection risk. According to the above review criteria, each of the indicators has a positive or negative effect on the chosen method that helps to rank them.

To select the best scenario of source separation in addition to existing scenarios two other parameters were also investigated. Thus door-to-door collection using 8-litter HDPE bin and kerbside using 660-litterblue container are included though they are assumptive.

The door-to-door method with 8-litter HDPE bins had a total score of 83.33; which is related to the indicators of risk reduction, efficiency and revenue. Door-to-door methods with plastic garbage bags with a total score of 78.33, was the second in place, which is related to the indicators of efficiency and risk reduction. The kerbside collection method using trucks had a total score of 61.67; which is related to the indicators of risk reduction and public acceptance. The buyback centre method with a total score of 60 came next, which is related to the indicators of resource consumption, public acceptance and the risk reduction process. The kerbside collection method using three-wheeled motor vehicles had a total of 20; which is related to the indicators of net profit and efficiency.

Buyback centres (S1) collected commingled recyclable materials. This is a good way for providing a product with low risk of contamination. Consumption of energy is shown in Table 1 referring to per kilogram per segregated recyclable materials .The majority of people selected buyback centres because of their proximity to their home and those who did little separation were most motivated by money and preferred this method than other methods. This method is preferred than other methods with attention to lower process risk and collection of clean product. This method was established in order to reduce management costs. Revenue of sale of recyclable materials from this method is shown in Table 3.

Table 1: Average waste collected in various source separation programs

Waste collection methods	Average weight(kg)	Average weight(%wt)
Kerbside sorting using black 660-litter container	2E+08	%34
Kerbside sorting using blue 660-litter container	2E+08	-
Buyback centre	4E+07	%9
Door-to-door services using plastic bag	3E+08	%57
Door-to-door services using 8-litter HDPE bin	3E+08	-

Door-to-door service (S2) with plastic bags has also been used to collected recyclable materials as a commingled. This is a good way for clean reduction and providing a produce with low risk and contamination. The weight of plastic bags used in the door-to-door service is about 43 tons per year. Consumption of energy in this method was about 2.3E+9 MJ-L^{-1}, with attention to kilogram segregated recyclable materials. This is shown in Table 2. The majority of people tended to spend less than five minutes in delivering their separated waste. This method is preferred to the door-to-door service with 8-litter HDPE bins with lower environmental impacts. The revenue from the sale of recyclable materials from this method is shown in Table 3.

Table 2: Average energy consumption in various source separations

| Waste collection methods	Average energy consumption MJ-L^{-1}	Average energy (%)
Kerbside sorting using black 660-litter bin	8E+08	%22
Kerbside sorting using blue 660-litter bin	3E+09	-
Buyback centre	3E+08	%9
Door-to-door services using plastic bag	2E+09	69%
Door-to-door services using 8-litter HDPE bin	2E+09	-

Door-to-door service with 8-litter HDPE bin (S3) was used to collect recyclable materials as commingled .This is a good way for providing a produce with low risk and contamination. Consumption of energy is about 2.3E+9 MJ-L^{-1} with attention to kilogram segregated recyclable materials. This is shown in Table 2. The majority of the respondents tended to spend less than five minutes delivering their separated waste. This method is preferred to door-to-door service with plastic bags with lower costs during 5 years of useful life time. Revenue from the sale of recyclable materials from this method is shown in Table 3.

Kerbside sorting with 660-litter black containers (S4) is collected as co-mingled recyclable materials. This is a good way for reduction of waste volume for transfer and land filling, and the resulting compost is useful for agriculture. Consumption of energy is about 7.54E+8 MJ-L^{-1}, with attention to kilogram segregated recyclable materials. This is shown in Table 2.Three-wheeled vehicles are used to transport recyclable materials to MRF plants. Most of those who carried out waste separation were concerned about sorting and separating the waste. This method is the method that has a higher process risk and collection of polluted product. Revenue of sale of recyclable materials from this method is shown in Table 3.

Table 3: Average revenue in various source separation methods in 5 years

Waste collection methods	Average revenue $/kg year^{-1}	Average revenue (%)
Kerbside sorting using black 660-litter bin	9E+07	%39
Kerbside sorting using blue 660-litter bin	9E+07	-
Buyback centre	2E+07	%11
Door-to-door services using plastic bag	1E+08	%50
Door-to-door services using -8litter HDPE bin	2E+08	-

Kerbside with 660-litter blue containers (S5) was used to collect recyclable materials as commingled. This is a good way for reduction of waste volume for transfer and land filling, and the resulting compost is very desirable. Consumption of energy is about 2.54E+9 MJ-L^{-1}, with attention to kilogram segregated recyclable materials. This is shown in Table 2. A truck is used to transport recyclable materials to the MRF plant. The majority of people tend to spend less than five minutes to deliver their separated waste and most respondents preferred to take the waste to the kerbside rather than going from door-to-door. This method is preferred to other methods with lower process risk and collection of a clean product. This method is preferred to 8- litter HDPE bin and door-to-door service with plastic bags having lower costs during 5 years of useful life time. The revenue from the sale of recyclable materials from this method is shown in Table 3.
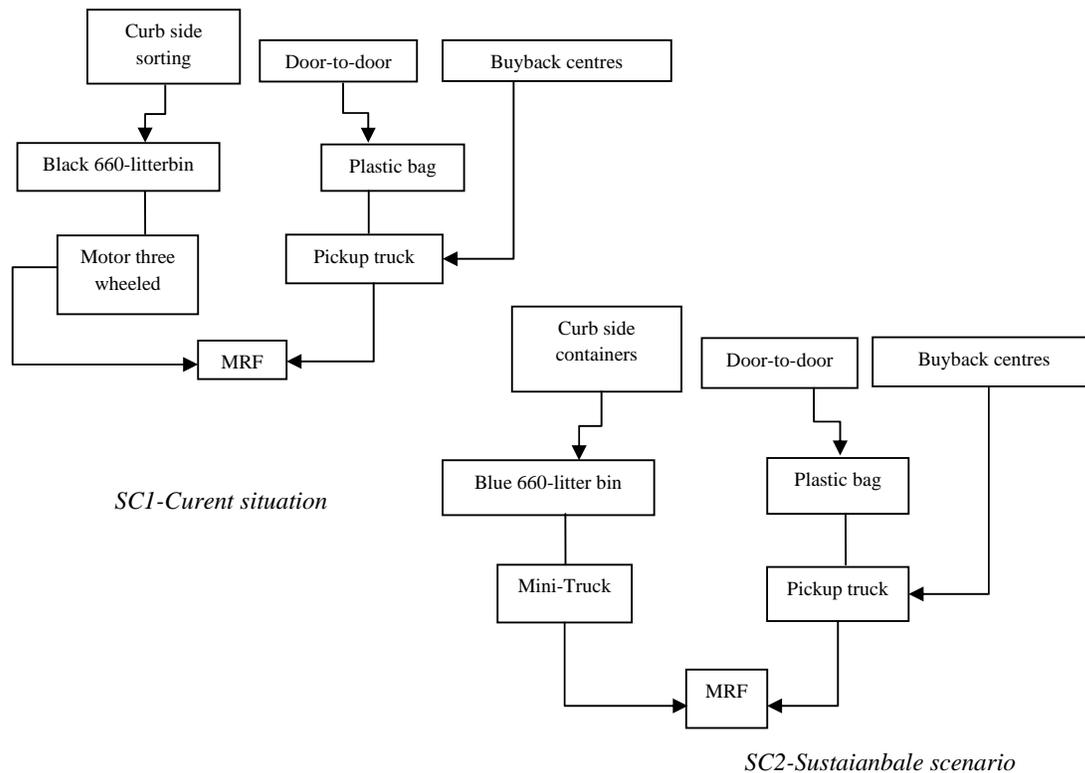
Fig. 3: SC1 and SC2 scenarios source separation examined

SC3- Scenario with more cost and risk

SC4-Clean scenario but with more cost
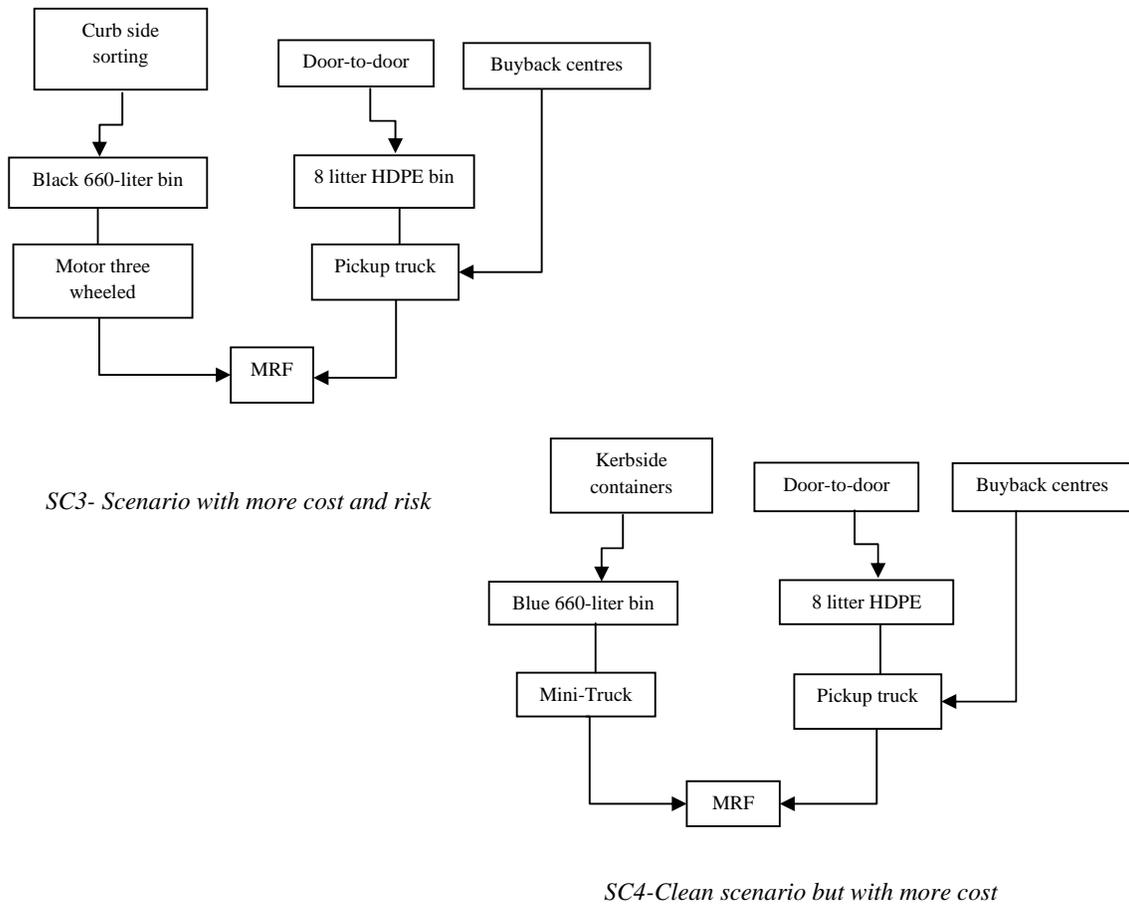
Fig. 4: SC3 and SC4 scenarios source separation examined

Discussion:

A combination of various processes as shown before can be selected for the four scenarios that are described below. Clearly, each process has an effect on every scenario that may be positive or negative. The following examines the positive and negative effects of various scenarios and the best scenario is proposed. This study was conducted to determine the most feasible recyclable materials management method in terms of its critical effects for Tehran. In all the cases, citizens and city services personnel must be educated in this regard. This was accomplished by using the several tools of comparison of different management methods of recyclable materials with several options. The results of the study were supported with economic and social factors. They indicated that:

SC1:

Buyback centre + Kerbside sorting using a three-wheeled motor vehicle + Door-to-door service using plastic bags

This is ranked 4th with a weakness caused by the method of reclaiming from the curb-side sorting. It separates the recyclable method with wet waste. The separated material influences both the price and the quality of recyclable material. Though this scheme is proved to be with the lowest risk, unfortunately it is not the public's favourite. It uses the reduction method with door-to-door collection which utilizes plastic bags and pick-up, together with buy-back centre using pick up. The citizen keeps the recyclable materials in blue plastic bags and hand them to contractors or buyback centres.

SC2:

Buyback centre + Kerbside using a truck + Door-to-door service using plastic bags

It is clearly a scheme that the people are fond of but with difference in social taste due to the manner in which the dry recyclable materials are collected. However, it involves the highest door-to-door cost. The combination reduction method via curb-side method, door-to-door method by plastic bags together with

buy-back centre trucks stand second in rank in critical values. The scenario is that the citizens keep their recyclable materials in regular home plastic bags and place them on the curb-side. One vital thing to look upon is that wet waste contractors and city services personnel must be acknowledged on the matter and avoid mixing the wet waste together with recyclable material.

SC3:

    Buyback centre + Kerbside sorting using a three-wheeled motor vehicle+ Door-to-door service with 8-litter HDPE bin

Ranked in third, this scheme receives the lowest acceptability due to usage of a three-wheeled motor vehicle to collect door-to-door with 8-litterHDPE bins. It uses the combination reduction method via curb-side sorting method, door-to-door by 8-litterbins along with buy-back centre pickup trucks. The citizens store their recyclable materials in home garbage bins or bins provided by the municipality. They separate the wet waste on the curb-side for betterment. The weakness of the scheme is that both citizens and scavengers separate wet waste and recyclable material that leads to health problems.

SC4:

    Buyback centre + Kerbside using a truck + Door-to-door service with 8-litter HDPE bin

This is the people's most fond scenario with the lowest cost in door-to-door service with 8-litterHDPE bin. Naturally, this has the highest ranking and placed first. This is a combination of reduction method via curb-side collection with 8-litterbins along with buy-back centre trucks. A better scenario would be if the citizens store recyclable materials in home garbage bins or bins provided by the municipality, placing them apart from wet waste on the curb-side. Tehran citizens found to store their recyclable materials in the aforesaid bins provided by the municipality, apart from wet waste on the curb-side.

Conclusion:

The ISWM plan will help to guide the implementation process. After developing and writing the solid waste management plan, the Tehran Municipal Authority began to implement the various components of waste management. Implementing the ISWM plan is an ongoing process, so it is expected that it will be necessary to make adjustments to the plan along the way. Once the evaluation of the methods takes place, inefficiencies will be discovered and the solid waste management service (EPA, 2002) will be informed.

The critical point is waste material reduction and reuse by the consumer. Reduction includes kerbside sorting and delivery to buyback centre.

Reuse method is the most preferred in reduction system. Both show equal critical values in certain scenarios but indicate that reduction method is of higher risk in product and process. Hence the equipment for source separation influences the costs.

These findings suggest an apparent need for a new separation management method in Tehran with focus on source consumption which alters the type of vehicle in collecting dry recyclable materials. The government has developed strategies to help with municipality in deriving a good policy for waste management.

ACKNOWLEDGEMENTS

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