Performance Evaluation of the Proposed and Existing Waste Management System: Economic Analysis

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Abstract

The increasing generation of municipal solid waste (MSW) is a major problem particularly in large metropolitan cities with inadequate landfill capacities and ineffective waste management systems. Therefore, a sustainable and effective waste management strategy is needed to reduce the heavy reliance in landfill that can minimize the system operating cost and resolved the maximum amount of waste. Recently, a lot of research have been done on this topic. The authors have used different optimization techniques to reduce waste management cost. These techniques are likely to improve the waste management system and solve different problems that occur during the process. However, a cost effective analysis is essential for real life implementation of these schemes. This paper reports a performance evolutionary comparison of the proposed and existing waste management system. The objective function describes the total investment and maintenance costs, collection cost, transportation cost, processing cost and disposal cost. The benefit from recyclable materials, finished compost and from energy generation are also incorporated in the objective function. The problem was formulated as a multi-objective mixed integer linear programming model to maximize the profit of the integrated municipal solid waste management system. The multi-objective optimization scheme would simulate the real data that can be used for proposing optimal cost effective solution for the municipal solid waste management system. The proposed scheme has been applied to the Kolkata Metropolitan city so as to consider the integration of MSW from different municipalities. The results show that an optimal utilization of MSW can provide economic and environmental benefits.

Keywords
Optimal planning; collection; transportation; treatment; economic analysis.

1. Introduction
Recently, municipal solid waste management is a challenging issue for developed and emerging countries. The issue is difficult to deal with backward technology, low consciousness and irrational institutions. It has caused severe water, air and soil pollution problems, land consumption, and human health problems in urbanized areas (Hu et al., 1998; Manaf et al., 2009). One of the important problem is that the municipal solid waste (MSW) is mixed (i.e. biodegradable, combustible, inert and recyclable materials) and they require to be separated for further processing and treatment, which increases the separation cost (Aguilar et al., 2013). This is common in developing countries, where most of the people do not segregate the wastes, which results in very significant increases of total wastes volume and weight, besides the fact that the facilities are not adequate to store these residues. These make more difficult and expensive waste management system (Guerrero et al., 2013). In this case the application of social, environmental, institutional, financial and economic tools to guarantee a sustainable waste management is required.

It is important to note that the action that have been implemented to solve this problem are focused only on one particular type of waste, without taking into account the interaction between the waste consumption and distribution, and without considering the entire supply chain optimization as well as economies of scale (Beigl et al., 2008). The distribution of wastes, products and the design and selection of processing facilities are crucial in yielding an adequate solution for the entire problem (Kollikkathara et al., 2010). Therefore, this paper proposes a general scheme for the optimal planning of municipal solid waste management system and the economic analysis has been done based on quantity of municipal solid waste generation rate and treatment facilities. The proposed scheme is based on mixed integer linear programming approach formulation for the optimal planning of the reuse of municipal solid waste to maximize the economic benefits while accounting for social and environmental aspects. The optimization scheme is capable of reduced the total waste management cost.

The aim of the proposed scheme is to maximize the overall operating profits of the MSW management system, in which segregation process of waste materials has been done at sources and the technologies considered for processing of waste materials based on characteristics of segregated waste materials. In this proposed scheme the objective function to be minimized is the sum of the annualized capital investment and annual operating cost that includes waste collection, transfer and transportation costs, capital costs for treatment facilities, final disposal costs and the maintenance costs. The profit function considers all of the possible income from the sale of the products, i.e., revenue from recyclable material sales, revenue from compost product sales and the revenue from electricity sales.

The paper is organized as follows. Section 2 discusses the literature survey. In Section 3, the problem is formulated. In section 4, we provide the formulation of the proposed scheme. We also discuss the fair solution in this section. Section 5 contains our empirical results; namely an economic analysis of proposed scheme versus the regional MSW management system. Finally, we conclude the paper in section 6.

2. Literature Survey

This section briefly reviews the literature on municipal solid waste management system related to this work. Generation of MSW increases with the rapid urbanization and the accelerated economic development within the rapidly growing advanced technological societies. The sources of MSW are broadly classified as residential, industrial, commercial, institutional, construction, demolition and agricultural types (Khajuria et al., 2010). Accurate forecasting of MSW generation is crucial and fundamental to the planning, operation and optimization of any MSW management system (Xu et al., 2013). To determine the most sustainable MSW management strategy for cities, it is first necessary to identify the nature and composition of the urban waste. The MSW composition varied considerably depending on many factors such as seasons, cultural activities, food habits and socioeconomic condition (Gomez et al., 2009; Kumar et al. 2009). The household solid waste can be converted from burden to resource through segregation at the sources (Sujauddin et al., 2008). As per the characteristics of the waste materials the segregation can be done in four categories such as recyclable, compostable, combustible and inert materials. As the collection of MSW, takes up the largest percentage of MSW management budget, however, one of the most difficult operational problems improving is important. The optimization of MSW collection, through source separation, is compulsory where a landfill based management must be overcome (Faccio et al., 2011; Rada et al., 2013). The transportation of the MSW from transfer station to treatment facilities/ landfill site is one of the most widely studied problems in the optimization of MSW management. The optimization of the garbage transportation vehicle tour for developing countries can be described as follows. The garbage is located in collection centre/transfer station along the streets and they must be collected by a fleet of vehicles whose capacity cannot the exceeded. Each vehicle can service several such sites before going to the treatment facility site or landfill site for unloading (Nuortio et al., 2006; Amponsah et al., 2008). The treatment of MSW is needed due to a number of factors, including continuous increasing quantity of waste, environmental impact, the political demand for efficient utilization of wastes and minimize the quantity of waste disposal for limited landfill site (Emery et al., 2007; Juul et al., 2013). The waste treatment facilities have been developed with respect to waste characteristics. The well-known waste treatment facilities are recyclable waste treatment at recycling industries, MSW degradation under control composting condition, inert material utilization at brick factories or road construction and incineration or gasification (waste to energy) process (Moy et al. 2008; Weng et al., 2011). Municipal solid waste disposal has been one of the most important environmental problems for all the developing countries (Magrinho et al., 2006). The most appropriate site selection for disposal of residues from treatment plants (recycling, composting and waste to energy) is a problematic issue for reducing the environmental pollution, soil pollution and ground water pollution (Cossu 2013; Ritzkowski et al., 2013).

3. Problem Formulation

The MSW management system consists of a number of nodes. The nodes may be the sources, collection centres, transfer stations, treatment facilities or potential disposal facilities. The nodes are connected to each other by means of transportation routes. The wastes generated at sources must be segregated and then must be carried out the transportation steps (i. Sources to collection centres; ii. Collection centres to transfer stations; iii. Transfer station to categorized treatment facilities). The treated waste residues are then transferred to a disposal facility. The activities of segregation, collection, transfer, transportation, treatment and disposal involved costs. Thus, the problem is to select an optimal configuration of facilities for segregation, collection, transfer, transportation, treatment and disposal so that the MSW is managed with minimum cost and minimum risk to the environment. The formulation of mathematical expressions for various objectives and constraints are as follows.

The first objective function is to minimize the total net cost of MSW management for n number of sources.

$$Minimize\ W_{managenent}Cost = \sum_{i=1}^{n} C^s + \sum_{i=1}^{n} C^c + \sum_{i=1}^{n} C^t + \sum_{i=1}^{n} C^p + \sum_{i=1}^{k} C^d + C \quad (1)$$

Where, C^s is the segregation cost, C^c is the collection cost, C^t is the transfer and transportation costs, C^p is the processing costs, C^d is the disposal costs for k number of residues generated from processing plants and C is the uncertain event cost.

The second objective function is to maximize the total revenue gain by the n number of sources.

$$Maximize\ W_{managenent}Revenue = \sum_{i=1}^{n} R^r + \sum_{i=1}^{n} R^c + \sum_{i=1}^{n} R^e \quad (2)$$

Where, R^r is the selling price of recyclable materials, R^c is the selling price of compost product and R^e is the selling price of electricity. In waste management technology always try to develop a technique that increases the $W_{management}$ *(profit)*. Therefore, the objective of any waste management scheme is how to reduce waste management costs. In this paper, we increase the $W_{management}$ *(profit)* to reduce $W_{management}$ *(costs)*.

$$Maximize\ W_{management}(profit) = \sum_{i=1}^{n} W_{managenent}Revenue - \sum_{i=1}^{n} W_{managenent}Cost \quad (3)$$

This work design an optimized waste management scheme for a city. This SWM management scheme collects waste from different sources then transfer and process them in categorized treatment facilities. Finally disposes the residue to sanitary landfill sites with minimum costs.

4. Proposed Scheme

The optimization scheme developed in this work aims to obtain least-cost MSW management strategies covering the management, segregation, collection, transfer, transportation, processing and disposal. The architectural view of economic planning for integrated MSW management system is shown in Figure 1.

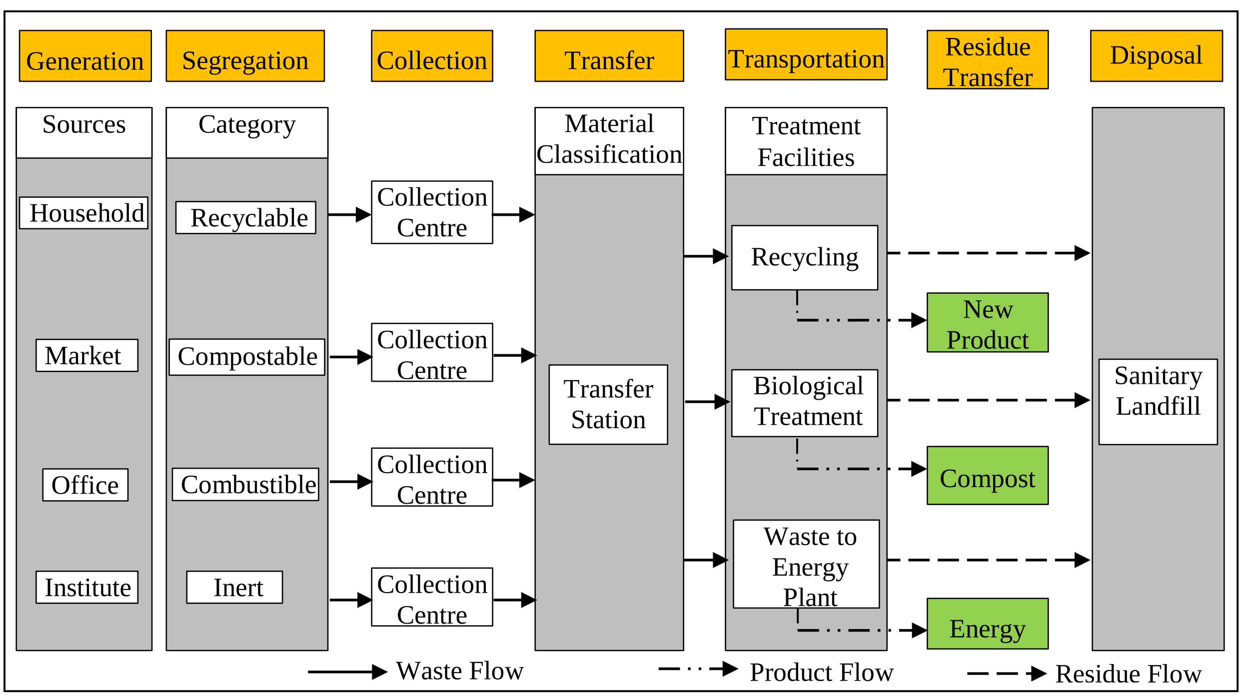

Figure 1: Architectural view of economic planning for integrated MSW management system

The proposed scheme is a mixed-integer linear programming model considering multiple objectives with respect to economic, technical and environmental issues. The symbols used for the formulation of the scheme are given in Table 1.

4.1 Municipal Solid Waste Generation

The estimation of MSW generation rate is a major factor, which decide technology to be used for processing and disposal. On the basis of waste quantity, the variable operational cost and infrastructure requirement waste being treated can be estimated. This data will also serve as a basis for up gradation or switching over to better treatment or disposal option. Equation (4) shows the estimation of municipal solid waste generation on the basis of number of sources and waste generation rate or capacity.

$$G_{MSW} = \sum_{i_1=1}^{n_1} \sum_{\alpha_1=1}^{a} WH_{i_1\alpha_1} + \sum_{j=1}^{b} \sum_{\alpha_2=1}^{c} WM_{j\alpha_2} + \sum_{l=1}^{d} \sum_{\alpha_3=1}^{e} WR_{l\alpha_3} + \sum_{m=1}^{f} \sum_{\alpha_4=1}^{g} WI_{m\alpha_4} \quad (4)$$

4.2 Waste Segregation Cost (C^s)

The segregation of wastes is one of the most important and expensive activities in integrated MSW management system; however, if we separate the wastes at sources, it will reduce the segregation cost tremendously. Therefore, the segregation cost is dependent on the cost for providing the separate waste bins at sources and cost per unit quantity of recyclable items at transfer stations. The segregation cost of MSW is shown in equation (5).

$$C^s = \sum_{i=1}^{n} \sum_{\beta=1}^{h} iB_\beta + \sum_{i=1}^{n} QR_i \, SCUQ \quad (5)$$

4.3 Waste Collection Cost (C^c)

The important activity is the collection of wastes from sources and bringing them to collection centres; this activity has an associated cost, which consider the unitary collection cost of MSW. The unitary collection cost has units of money per unit quantity and distance. The equation (6) gives the calculation of the collection cost of wastes from sources to collection centres is given as follows:

$$C^c = \sum_{\epsilon=1}^{o} \sum_{\theta=1}^{p} G_{MSW_{\epsilon\theta}} \, D_{\epsilon\theta} \, CUC \quad (6)$$

4.4 Waste Transportation Cost (C^t)

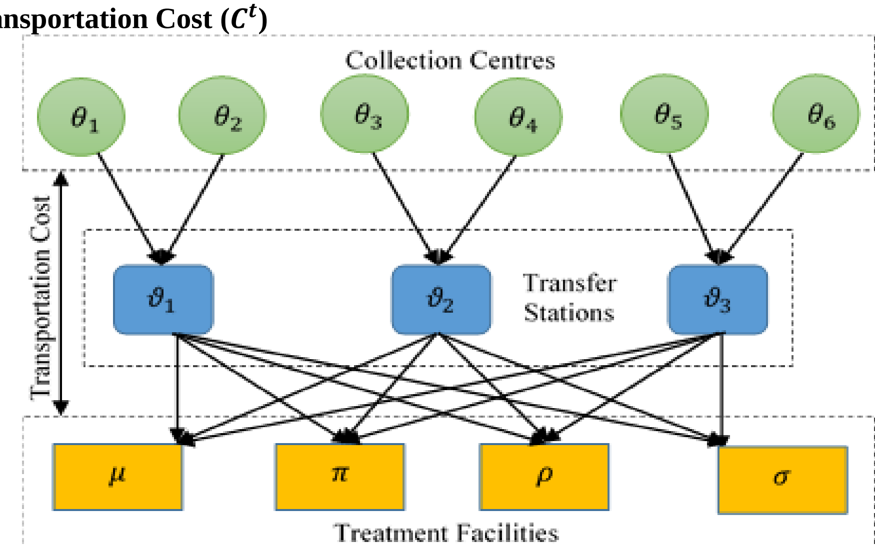

Figure 2: Representation of treatment facility based transportation cost calculation

Table 1: List of symbols used in the model

Parameters	Description
C^s	Waste segregation cost
C^c	Waste collection cost
C^t	Waste transportation cost
C^p	Waste processing cost
C^d	Residues disposal cost
C	Constant cost that are dependent on uncertain event
n	Number of sources
k	Number of residues generated from processing plants
R^r	Selling price of recyclable materials
R^c	Selling price of compost product
R^e	Selling price of electricity
G_{MSW}	Municipal solid waste generation
$WH_{i_1\alpha_1}$	Waste generation from $i_1$number of household at the generation rate of $\propto_1$
$WM_{j\alpha_2}$	Waste generation from j number of market at the generation rate of $\propto_2$
$WR_{l\alpha_3}$	Waste generation from l length of road sweeping at the generation rate of $\propto_3$
$WI_{m\alpha_4}$	Waste generation from m number of office or institute at the generation rate of $\propto_4$
iB_β	Segregation costs for B category of wastes at the bins purchasing rate of β
SCUQ	Segregation cost per unit quantity of recyclable materials
$G_{MSW_{\epsilon\theta}}$	Generated waste collection from location of sources ∈ to location of collection centres θ
$D_{\epsilon\theta}$	Distance from sources ∈ to collection centres θ
CUC	Cost per unit quantity collection
$G_{MSW_{\theta\vartheta}}$	Generated waste transfer from collection centres location θ to transfer stations location ϑ
$D_{\theta\vartheta}$	Distance from collection centres θ to transfer stations ϑ
CUQ	Cost per unit quantity
$QR_{\vartheta\mu}$	Quantity of recyclable materials transport from location of transfer stations ϑ to recycling industry μ
$D_{\vartheta\mu}$	Distance from transfer stations ϑ to recycling industry μ
$QC_{\vartheta\pi}$	Quantity of compostable materials transport from location of transfer stations ϑ to composting facilities π
$D_{\vartheta\pi}$	Distance from transfer stations ϑ to composting facilities π
$QB_{\vartheta\rho}$	Quantity of combustible materials transport from location of transfer stations ϑ to waste to energy plants ρ
$D_{\vartheta\rho}$	Distance from transfer stations ϑ to waste to energy plants ρ
$QI_{\vartheta\sigma}$	Quantity of inert materials transport from location of transfer stations ϑ to landfill sites σ
$D_{\vartheta\sigma}$	Distance from transfer stations ϑ to landfill site σ
C_r^p	Processing cost for recycling
F_C^r	Fixed capital cost for recycling
$QR_{\tau_1\tau_2}$	Recyclable materials quantity (materials categoryτ_2), processed at technology τ_1
$RR_{\tau_1\tau_2}$	Ratio of recyclable materials category
$CTRR_{\tau_2}$	Cost for treatment of recyclable materials category τ_2
C_c^p	Processing cost for composting facilities
F_C^c	Fixed capital cost for composting
$QC_{\gamma_1\gamma_2}$	Treatment cost of compostable waste of facility $\gamma_1$at site γ_2
UCC	Unit composting cost
C_e^p	Processing cost for waste to energy generation
F_C^e	Fixed capital cost for waste to energy generation
$QB_{\delta_1\delta_2}$	Treatment cost of combustible waste of facility $\delta_1$at site δ_2
UTC	Unit treatment cost
$RS_{\mu\sigma}$	Quantity of residues transfer from recycling industry μ to landfill site σ
$D_{\mu\sigma}$	Distance from recycling industry μ to landfill site σ
$RC_{\pi\sigma}$	Quantity of residues transfer from composting facilities π to landfill site σ
$D_{\pi\sigma}$	Distance from composting facilities π to landfill site σ
$RFB_{\rho\sigma}$	Residues of fly ash and bottom ash transfer from waste to energy plants ρ to landfill site σ
$D_{\rho\sigma}$	Distance from waste to energy plants ρ to landfill site σ
R_ε^{total}	Total quantity of residues from treatment facilities
ULC	Unit levelling and covering cost
$RRSP_{\tau_2}$	Selling price of recyclable materials category τ_2
$COMP_{G_{\gamma_1\gamma_2}}$	Compost product generation at each facility $\gamma_1$at site γ_2
$COMPSP_{\gamma_2}$	Selling price of compost product at site γ_2
$QB_{n\omega_1}$	Quantity of combustible waste from n number of sources at flow rate ω_1
$WTETC_{\omega_1\omega_2}$	Waste to energy transfer co-efficient with of electricity generation at ratio ω_2
ESP_{ω_2}	Selling price of electricity at ratio ω_2

Transportation is an important activity in MSW management system for transporting the wastes from collection centres to processing plants or treatment facilities. The transportation cost is the function of the waste quantity being transported, distance between the nodes (collection centres and treatment facilities) and the unit cost of transportation. In this waste management scheme, transportation activity has been completed in two phases (Figure 2), due to narrow road width in municipality. In first phase, wastes is transported from collection centres to transfer stations using small vehicles and in second phase, wastes is transported from transfer stations to treatment facilities using heavy vehicles. Therefore, the total transportation cost will be the cost of two phases, which has been calculated in equation (7).

$$\boldsymbol{C^t} = \left[\sum_{\theta=1}^{p}\sum_{\vartheta=1}^{q} G_{MSW_{\theta\vartheta}} D_{\theta\vartheta}\, CUQ\right] + \left[\sum_{\vartheta=1}^{q}\sum_{\mu=1}^{u_1} QR_{\vartheta\mu} D_{\vartheta\mu}\, CUQ + \sum_{\vartheta=1}^{q}\sum_{\pi=1}^{u_2} QC_{\vartheta\pi} D_{\vartheta\pi}\, CUQ + \sum_{\vartheta=1}^{q}\sum_{\rho=1}^{u_3} QB_{\vartheta\rho} D_{\vartheta\rho}\, CUQ + \sum_{\vartheta=1}^{q}\sum_{\sigma=1}^{u_4} QI_{\vartheta\sigma} D_{\vartheta\sigma}\, CUQ\right] \quad (\mathbf{7})$$

Equation (7) shows the separate transportation cost for recyclable waste, compostable waste, combustible waste and inert materials.

4.5 Waste Processing Cost (C^p)

The wastes in the processing plants are distributed to different processing technologies as per characteristics of wastes, and depending on the selected technology it is possible to produce several products. For each technology the processing cost is taken into account, which is divided in two phases. The first one consists of a capital cost (depending upon the capacity) for installing the facility. The capital cost is a function of the capacity of the processing facilities. To calculate the total capital cost, the individual capital costs for the units considered are obtained. The second one consists of variable operational cost depending upon the quantity of the waste being treated.

$$C_r^p = F_C^r + \sum_{\tau_1=1}^{v_1}\sum_{\tau_2=1}^{v_2} QR_{\tau_1\tau_2} RR_{\tau_1\tau_2} CTRR_{\tau_2} \quad (8)$$

$$C_c^p = F_C^c + \sum_{\gamma_1=1}^{w_1}\sum_{\gamma_2=1}^{w_2} QC_{\gamma_1\gamma_2}\, UCC \quad (9)$$

$$C_e^p = F_C^e + \sum_{\delta_1=1}^{x_1}\sum_{\delta_2=1}^{x_2} QB_{\delta_1\delta_2}\, UTC \quad (10)$$

$$C^p = \quad C_r^p + C_c^p + C_e^p \quad (11)$$

Equation (8), equation (9) and equation (10) show the cost for recycling, cost for composting and cost for waste to energy generation, respectively. Equation (11) is used to define the total processing cost, which depends on the processing plant, technology used, wastes characteristics and quantity of waste.

4.6 Waste Disposal Cost (C^d)

The final phase of the MSW management system is the disposal of residues generated from various processing plants. The disposal cost is associated with quantity of residues, distance between the treatment facilities and landfill site and unit disposal cost (levelling and covering the landfill site). The equation to calculate the total disposal cost of residues is given as follows:

$$C^d = \left[\sum_{\mu=1}^{u_1}\sum_{\sigma=1}^{u_4} RS_{\mu\sigma}\, D_{\mu\sigma}\, CUQ + \sum_{\pi=1}^{u_2}\sum_{\sigma=1}^{u_4} RC_{\pi\sigma}\, D_{\pi\sigma}\, CUQ + \sum_{\rho=1}^{u_3}\sum_{\sigma=1}^{u_4} RFB_{\rho\sigma}\, D_{\rho\sigma}\, CUQ\right] + \sum_{\varepsilon=1}^{y} R_\varepsilon^{total}\, ULC \quad (12)$$

Where, $R_\epsilon^{total} = RS_{\mu\sigma} + RC_{\pi\sigma} + RFB_{\rho\sigma}$

4.7 Revenue from Selling of Product

When the raw materials are converted, the products can be sold from the processing plants to product selling agency. Each product has a unitary price, which depends on the type of product and the city where it is sold. The price changes with respect to the city because each city has product demands. The profit from the sold products is the sum of the amount of products sold to the different agencies multiplied by the corresponding unitary cost. The revenue comes from basically three category of product. First one is the selling price of recyclable materials. The recyclable materials can be sold from transfer stations to the respective industry. The selling price is dependent upon the recyclable materials category τ_2 (INR/ton). Second one is the revenue from selling of compost. This revenue is dependent upon the compost generation rate at each compost facility and the selling price of compost at each compost facility (INR/ton). The third one is the selling price of electricity. That is depend upon the waste of electricity transfer coefficient (KWh/ton) and the selling price of electricity (INR/KWh).

$$\sum_{i=1}^{n} R^r = \sum_{\tau_1=1}^{v_1} \sum_{\tau_2=1}^{v_2} QR_{\tau_1\tau_2} RR_{\tau_1\tau_2} RRSP_{\tau_2} \tag{13}$$

$$\sum_{i=1}^{n} R^c = \sum_{\gamma_1=1}^{w_1} \sum_{\gamma_2=1}^{w_2} COMP_{G_{\gamma_1\gamma_2}} COMPSP_{\gamma_2} \tag{14}$$

$$\sum_{i=1}^{n} R^e = \sum_{i=1}^{n} \sum_{\omega_1=1}^{x_1} \sum_{\omega_2}^{x_2} QB_{n\omega_1} WTETC_{\omega_1\omega_2} ESP_{\omega_2} \tag{15}$$

Equation (13) shows the revenue from recyclable materials, equation (14) shows the revenue from compost plant and finally revenue from waste to energy plant is shown in equation (15).

5. Economic Analysis

Performances of the proposed waste management system is evaluated, in term of total waste management cost and total revenue from ultimate utilization of waste. A case study is presented to show the applicability of the proposed scheme. This case study corresponds to the optimal management of the municipal solid waste for the region located in Kolkata metropolitan city with respect to the profit as economic objective and the percentage of utilized waste as environmental objective, where several municipalities and markets have been considered. The city had 4.5 million sources of waste generation. The total municipal solid waste generated by 14.12 people living in the metropolitan areas was 4837 metric ton per day in 2013 (Das and Bhattacharyya, 2014).

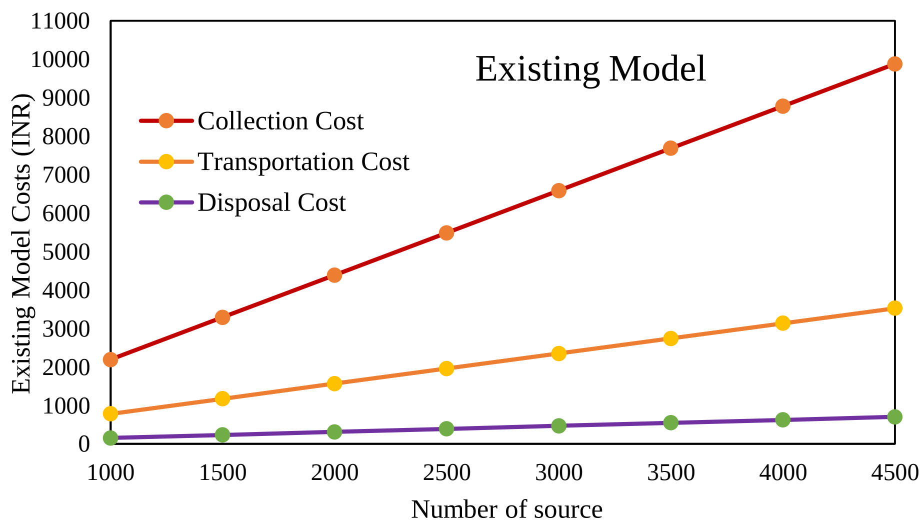

Figure 3: Cost analysis of the existing model

The cost analysis of the existing model for the Kolkata metropolitan city has been presented in Figure 3. Three major activity covering the existing solid waste management system: (i) collection of waste has been done without segregation; (ii) transportation of waste and (iii) disposal of waste without any treatment. The total collection cost of the waste depends on the number of sources and distance between the sources. The total transportation cost depend upon the quantity of waste and the distance between collection centres and disposal sites. The disposal cost is fully dependent upon the quantity of waste. Form the analysis of the Fig. 4 we can find out the cost of each activity with respect to number of source. The results shows that 70% of the total budget of MSW is spent only for collection of waste. Where 25% of the budget is spent for transportation and only 5% of the budget is spent for final disposal of MSW.

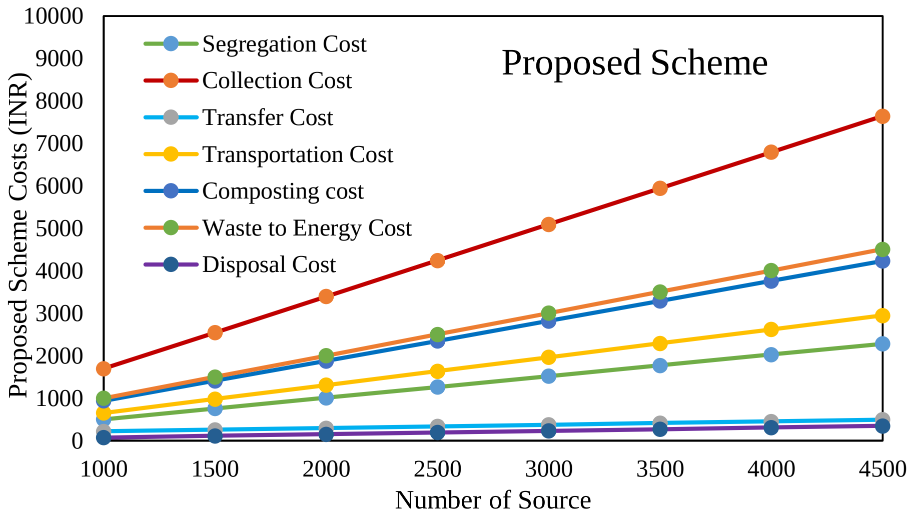

Figure 4: Cost analysis of the proposed scheme

The total cost for the proposed scheme is depicted in Figure 4. All the activity's cost has been calculated through standard optimized method. The processing cost has been calculated as per standard respective treatment technique. The total collection cost in this proposed scheme is less compared to the existing method. In this proposed scheme, we search optimal waste collection path between the different numbers of source through the standard optimization method that decreases 23% of existing collection cost of the waste. Fig. 5 also shows that in higher numbers of source our proposed scheme reduces much of the collection cost compared to the existing method.

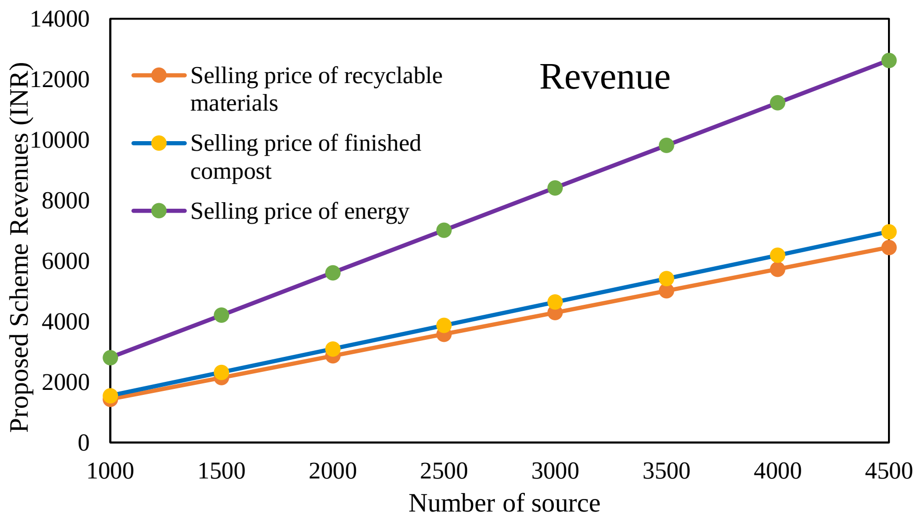

Figure 5: Revenues from reusable wastes

In case of transportation cost comparison between the proposed scheme transportation cost and existing method transportation cost for different number of source, shows that if the number of source increases, transportation cost linearly increases in the existing method that have been used by the Kolkata SWM department. However, in our proposed scheme transportation cost also increases linearly with respect to number of source increases but the rate of increment is less compared to the existing method. It is because the proposed scheme identifies optimal route between the transfer stations and treatment plants. The optimal path of waste transportation decreases total transportation cost of the system. Fig. 5 also depicts that if number of source is increased then our proposed scheme shows better performance in term of transportation cost compared to the existing method.

Disposal is an important factor in a waste management system cost and environmental issues. The comparison of cost of solid waste disposal between the proposed scheme and existing method that have been shown in Figure 4 and Figure 3 for different number of source. The proposed scheme reduces disposal cost of the proposed waste management system through maximum quantity of waste reuse. In the existing method of the Kolkata SWM department, the total generated waste is going to the disposal site, therefore disposal cost of the existing method is very high. However, in our proposed system maximum amount of waste is reused through the different product, rest of the waste is transported to the disposal site through the optimal path that reduces disposal cost of the proposed scheme.

The revenue analysis for the proposed solution are summarized in Figure 5. The revenues are mainly achieved from the sale of recycled materials, finished compost and electricity. The recovered percentages of segregated materials are recyclable 15%, compostable 40% and combustible 37%. The recyclable materials are directly sold to the respective recycling industry. The compostable wastes are used in windrow composting process that produced finished compost, 30% of the original wastes. The finished compost are supplied to the authorized dealers. Another major source of income for the MSW management system is converting waste to energy. In this case the segregated combustible wastes are used as a fuel in combined cycled based power generation plant, resulting in generate the electricity. These electricity are supplied to the grid.

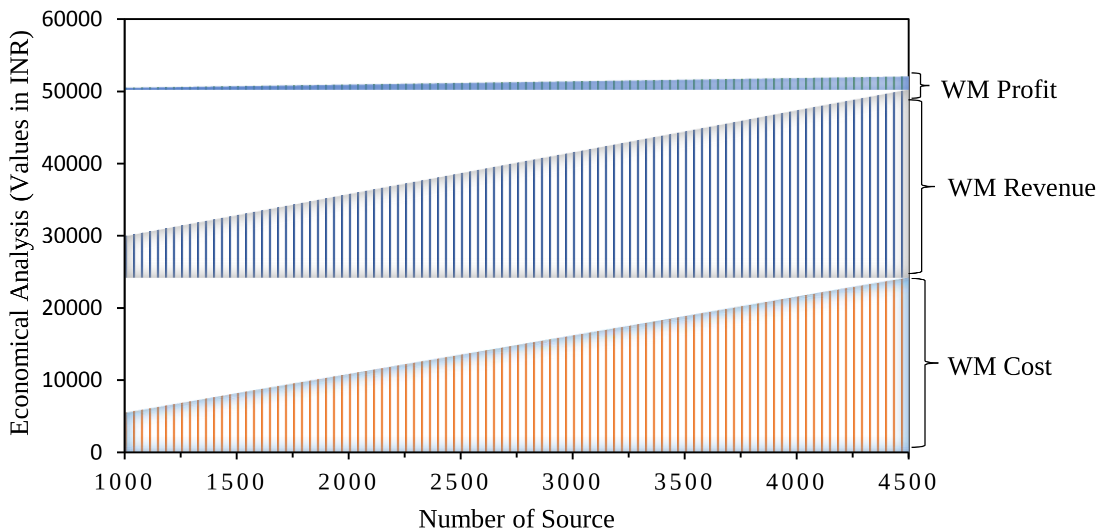

Figure 6: Economic analysis of the proposed scheme's

The economic analysis of the proposed scheme is shown in Figure 6. Here the total costs for the MSW management, as well as the revenue from the proposed scheme are shown. From the analysis of the figure, the profit can be easily found out. The proposed scheme gives the 5% profit of the total investment cost of MSW management.

6. Conclusions

This paper evaluates the performance of proposed scheme and existing model while considering the economic, technical and environmental aspects. The problem has been mathematically formulated as a multi-objective mixed integer linear programming problem. The application of the proposed scheme has been illustrated through a case study of Kolkata metropolitan city. The results show that the proposed scheme not only recover the total waste management cost but also is able to provide the profit from the system. In this regards, the scheme can be useful to consider the waste management in regions where the waste management has not been developed or there is not an established way to control wastes.

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Biography

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