Policy Model for Management of Urban Waste

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The disposal of wastes is a very crucial problem to the modern urban societies in third world countries claiming the major share in the total expenditure allotted for all urban services. The existing system of disposal through land filling and reusing a part is inadequate and leaves behind a large volume of garbage accumulating over time. In this study, an attempt has been made to formulate a suitable policy model for solving the problem of disposal of this remaining part through productive use. Two alternative approaches are suggested. To maximize the net return from this product, the first model deals with the method of finding out the price policy regarding the product, and the second model is for the determination of the optimal amount of wastes to be disposed of within a period of time. An empirical exercise has been done using the first model. The results show that a net profit can be earned if the appropriate price is chosen for this product. Taking a particular time period within which total loss should be compensated by total revenue, a suitable price policy can also be determined.

1. INTRODUCTION

Solid waste is one of the residuals generated by economic activities. In modern urban societies, generation of waste always increases with the increase in population as well as with the increase in amenities and living condition due to increasing income and technological advancement. At present, the problem of disposal of this ever-increasing volume of garbage has become critical. However, this problem is more crucial in developing countries, mainly in tropical countries like India, compared to developed countries. A significant portion of wastes in developed countries contains biodegradable elements, and reduction of which through incineration is not possible in developing countries. Therefore, more land is required for dumping it. And of all the basic urban

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services, management of solid wastes claims the highest per capita expenditure.

A high rate of growth of population is the characteristic of the Indian cities; Calcutta is no exception. The population in Calcutta, according to the 1991 census, was around 4.4 million and has increased considerably since then. The increase in population is accompanied by an increase in the volume of garbage accumulated here, causing a serious disposal problem.

Since its inception, the system of garbage disposal followed in the city was simply dumping. Even now this system is being followed in the low lying areas in the eastern part of the city. The rate of dumping is so high that it has covered almost all the area allocated for it. Thus, further dumping will continually encroach on all the valuable urban land and will require more land to be requisitioned. This process is also polluting the atmosphere.

Urban waste contains a number of materials that are actually taken out by pickers for processing and used in various forms. This system of recycling obviously solves a part of the dump clearing problem. Another part of the remaining undesirable wastes is used for land fill. But this accounts for only approximately one-third of the total garbage; the remaining part is deposited at the dumping ground. But due to insufficient supply and the high cost of land as well as limited scope of land-fill, the cost of disposal is increasing rapidly. There is a need for change in the traditional practice of solid waste management for the city with specific suggestions for its recycling or reuse toward achieving the goal. In fact, any sustainable growth of the economy should depend on the ability to recycle and regenerate its resources and turn the apparent liabilities into productive assets.

In this study our objective is to formulate a model for determining the policies for the management of urban wastes through productive use. The plan of this article is as follows: section 2 presents the model, section 3 analyzes the results, and section 4 presents concluding remarks.

2. MODEL

Unlike in developed countries, the bulk of the urban refuse in the cities of a tropical country contains wastes from agricultural and animal products, which are usually amenable to composting when confined over a reasonable period. Mechanical processes are also available for transforming garbage into compost. Such composts are not only rich in nutrient contents like nitrogen, potash, and phosphatic elements, ingredients of chemical fertilizers; they have additional elements like carbon and humus and other organic substances essential for restoring the structure of soils that are affected by the repeated use of chemical fertilizers in cultivation.

It is easy to appreciate that the compost from the garbage will raise the productivity of agricultural land. At the same time, every ton of garbage removed from the urban area relieves the pressure on urban land, which remains limited and continues to rise in value over time. Generation of gas, a by-product of compost production, can partially solve the problem of fuel and power.

The objective of finding a suitable policy for disposal of garbage through the productive uses can be analytically worked out with the help of a model following Hotelling (Hotelling, 1931). The formulation of such a model may have the basic objective of maximizing the net return from the removal of garbage over a period of time (Bose, 1975). A number of studies have been conducted to find ways to solve the problem of garbage disposal. Most of them have the objective to reduce the volume as a solution to garbage disposal and examine imposition of fees based on the volume of disposal by households as a means of bringing about the efficient level of disposal (Morris and Byrd, 1990, Skumatz and Breckinridge, 1990). Virgin material taxation or disposal tax combined with reuse subsidy is also suggested in some studies (Dinan, 1993; Meidema, 1983). But charging households while trying to solve the problem provides incentives for illegal disposal, which may further aggravate it. Our model deals with policies not connected with households who are the generator of wastes, but for the authorities who have the responsibility to dispose of such wastes.

Let us assume that the stock of garbage X cumulates to a volume A over T years. It is required to dispose of the total stock over the same period by adopting a suitable rate of disposal indicated by q (=dx/dt). Various economic uses of wastes are possible. We here consider only the production of manure, although there are uses for the gas that is a by-product in the process of manure production. The amount of manure produced is directly proportional to amount of wastes used in the production.

We can now state our problem in the following way. With given rate of cost, return, and amount of garbage disposal at the initial period, it is possible to determine the break-even point when cumulative cost and cumulative return will reach the same level.

That means the total loss of the firm will be compensated at that point. The break-even concept is widely used in different ways to solve the production and pricing problem for economic viability. The break-even point is an equilibrium point at which total cost and total revenue exactly match each other. This is also helpful in making various managerial decisions. A simple model to illustrate this objective is the following:

$$r_t = r_0 e^{\gamma t} \tag{1}$$

where r stands for revenue earned per unit of input use and γ is the rate of growth of revenue.

The revenue from the sale of compost produced from garbage is assumed to be increasing over time. The reason behind it is that as a result of increasing population, the demand for agricultural product is rising over time, which leads to the increase in the demand for compost . This increasing demand leads to the increase in revenue level.

The productive use of wastes involves some cost in which input cost is nothing as waste is freely available. Cost incurred here is mainly shared by capital investment, and the remaining part is due to labor use. Any change in the cost is for the change in the input use. Therefore, with the increase in demand for waste as input, cost is assumed to be increasing over time. Now we can write the cost function as

$$c_t = c_0 e^{\alpha t} \tag{2}$$

where c is cost per unit of input use and α is the rate of growth of cost over time.

We further assume that initial cost is higher than the initial revenue, but rate of increase of revenue is faster than that of cost, i.e., $c_0 > r_0$ but $\gamma > \alpha$. It implies that the firm may run a loss in the beginning, but it will earn profit from this operation in the near future.

The amount of garbage to be used as input in the production is also assumed as an increasing function of time:

$$q_t = q_0 e^{\lambda l} \tag{3}$$

where q stands for amount of waste used as input and λ stands for rate of growth of input.

Now following these assumptions if the required break-even point of time is t_1, then at t_1

$$\text{aggregate cost} = \text{aggregate return}$$

or,

$$C_{t_1} = R_{t_1} \tag{4}$$

or,

$$\int_0^{t_1} c_t q_t dt = \int_0^{t_1} r_t q_t dt \tag{5}$$

Now substituting the respective values from equations 1, 2, and 3, in equation 5 we get:

$$\int_0^{t_1} c_0 q_0 e^{(\alpha+\lambda)} dt = \int_0^{t_1} r_0 q_0 e^{(\gamma+\lambda)} dt \tag{6}$$

Now solving equation 6 we get,

$$[c_0 q_0/(\alpha + \lambda)] \,.\, \{e^{(\alpha + \lambda)t_1} - 1\} = [r_0 q_0/(\gamma + \lambda)] \,.\, \{e^{(\gamma + \lambda)t_1} - 1\}$$

or,

$$[e^{(\alpha + \lambda)t_1} - 1]/[e^{(\gamma + \lambda)t_1} - 1] = (r_0/c_0)[(\alpha + \lambda)/(\gamma + \lambda)] \tag{7}$$

For given values of α, γ and λ with given c_0 and r_0 t_1 can be estimated. It indicates that the initial losses will be compensated by t_1 and positive net gains from the production will be earned since then.

Again the values of α, λ and t_1 can help us to determine the desired price policies. It shows that the initial price should be lower and should rise gradually till t_1 when loss due to operation will be compensated and after that the price may be reduced for the bulk of production. An empirical exercise has been worked out using this model in section 3.

An alternative model can also be suggested for solving the same problem of disposal. The objective is to determine the rate of removal of garbage with a view to maximize the net return from the disposal within a given period of time T. Assuming cost per unit as a function of input use, i.e.,

$$c = \alpha.q + \beta \tag{8}$$

and revenue function as before, i.e.,

$$r = r_0 e^{\gamma t} \tag{9}$$

this objective can be formulated in the following way.

$$\text{Max. } \Pi = \int_0^T [r - c(q)]q dt \tag{10}$$

Subject to

$$\int_{o}^{T} q dt = A \tag{11}$$

Where Π = net return. Here also initial cost is higher than the initial revenue but rate of increase of revenue is faster than that of cost.

For solving the problem we then use Euler equation. The Euler equation for 10 and 11 is given by

$$d/dt(df/dq) = \delta/\delta t.F_q = 0 \tag{12}$$

Where $F = (r - c(q))q - \lambda q$.

Now substituting equation 8 and 9 in 12 and differentiating it with respect to t we get

$$2\alpha(dq/dt) = \gamma r_0 e^{\gamma t} \tag{13}$$

Then integrating this we get

$$\begin{aligned} q &= (r_0/2\alpha)e^{\gamma t} + k && \text{when } t < \underline{T} \\ &= 0 && \text{when } t = \overline{T} \end{aligned} \tag{14}$$

It follows that with the given α, γ, and r_o optimal rate of disposal of garbage will increase over time. This change is related with the rate of growth of revenue.

Further,

$$A = X(T) = \int_{0}^{T} q dt \tag{15}$$

Substituting the value of q from equation 14, in equation 15 we get

$$\begin{aligned} A &= (r_0/2\alpha)\int_{0}^{T} e^{\gamma t} dt + \int_{0}^{T} k dt \\ &= (r_0/2\alpha\gamma)(e^{\gamma T} - 1) + kT \end{aligned} \tag{16}$$

Therefore,

$$k = (1/T)[A - (r_0/2\alpha\gamma)(e^{\gamma T} - 1)] \tag{17}$$

The value of k indicates here the minimum amount of garbage needs to be removed in the initial year of operation, otherwise economy in the operation can not be achieved and it depends on the total stock, length of the period and the rate of disposal.

Now according to our assumption, firms may initially lose with the operation, but after some time say at t_2 ($< T$) they will start earning a profit. That means at t_2

$$c_{t_2} = r_{t_2}$$

which implies that

$$t_2 = (1/\gamma)\log[2(\alpha k+\beta)/r_0] \tag{18}$$

The above model can solve the problem of clearance of the stock of garbage already dumped. This does not deal with the problem of clearance of current flow of refuse, absence of which will create further stock. This will also increase over time with the increasing size of the population. It is possible to avoid this dumping problem if current flow of waste is totally disposed of in the same period along with the amount from stock. Then the increase in the amount to be disposed of may be possible if the rate of revenue increases. And the higher value of λ along with higher value of γ ensures the earlier achievement of break-even point.

Similarly, for this operation a certain amount of land is released due to disposal of garbage and may be used for other productive purposes. If we add the sale value of that land to the revenue from the compost, it will raise the rate of revenue without any addition to cost. Therefore, with the increase in revenue, a new break-even point can be observed, which is also earlier than the previous one.

It should be mentioned here that after T when the total stock will be exhausted, the supply of waste as input of the production of compost would be dropped down to the amount through present flow of waste . There may be a possibility of underutilization of capital goods, hence this may affect the revenue of the firm. Then choice of T is crucial. T must be chosen in such a way that at T total capital investment will be depreciated and new investment at a lower scale is required for further production.

3. RESULTS

The purpose of empirical analysis is to gain an understanding of how the policy regarding price, cost, and amount to be disposed of influence the achievement of break-even point on which the firm's decision of investment depends. Therefore, for empirical estimation related information on growth rates and other variables are necessary. However, experiments have been done to produce compost from waste by installing firms with low capacity. The information available from such experiments is not sufficient to estimate the growth rates of the functions used in model. Therefore, initially to approximate these values, we have to depend on

Table 1: Estimated Values of Break-Even Points

Growth Rates			Base Year[a]		Break-Even Point
Popul. (λ)	Cost (α)	Revenue (γ)	Cost (c_0) (rs)	Revenue (r_0) (rs)	(t_1) (year)
0.020	0.04	0.070	680.0	450.0	22
0.020	0.04	0.075	680.0	495.0	15
0.025	0.04	0.070	680.0	450.0	22
0.025	0.04	0.075	680.0	495.0	15
0.029	0.04	0.070	680.0	450.0	22
0.029	0.04	0.075	680.0	495.0	15
0.029	0.05	0.070	680.0	450.0	30
0.029	0.05	0.075	680.0	495.0	20
0.029	0.04	0.075	680.0	450.0	19

[a] Per ton of garbage disposal.

some assumptions relating to those rates. Here the values of α and γ have been chosen on the basis of the nature of the changes of different price levels. The rate of growth of population during the last decade in Calcutta is taken as that of waste generation which is directly proportional to the population size. Initial values of per unit cost and revenue are taken from the information collected from such firms. Then an exercise has been done by varying the values of these rates to get the effects of them on the determination of the break-even point. Table 1 depicts the values of break-even point t_1 for different values of γ, α, λ, c_0, and r_0.

It is observed from Table 1 that for any given set of values of α, γ, c_0 and r_0, the change in the value of t_1 does not depend on the change in the rate of growth of input use. But the value of t_1 declines gradually with the increase in the value of γ as well as r_0 for given values of α, λ, and c_0. It increases with the increase in the value of α for a given set of values of λ, γ, r_0, and c_0. That means the break-even point can be obtained earlier either by increasing the rate of revenue or by lowering the cost of production. Then if more economic uses of the garbage are possible, a firm can increase its revenue without affecting its cost significantly and is able to compensate its total cost by its total return from this operation much earlier. This also provides us knowledge regarding the decision about the determination of prices.

4. CONCLUSIONS

A suitable policy can be adopted to solve the problem of garbage disposal from large cities like Calcutta. It is desirable because it not only saves valuable urban land but also minimizes pollution of the city. This study suggests the formulation of a model to solve the problem of waste disposal through the productive use. One of the productive uses of urban waste is the production of compost, because urban refuse in tropical countries like India consists of wastes from agricultural and animal products. The formulation of the model considers the composting of waste as only one productive use. In formulating such a model for solving the problem of disposal, the basic objective is to earn net profit from this operation. For satisfying the objective of earning net revenue from this operation, it is suggested to find a break-even point when total revenue and cost are the same for a given set of values of growth rates of revenue, cost. and amount of disposal. After that point, a firm can earn a positive net profit. This is one way of dealing with such a problem. Alternatively, this objective can be achieved by finding an optimum amount of disposal of waste within a given period of time.

As the reliable data for empirical exercises are not available, the values of the growth rates have been chosen on the basis of some assumptions. The result shows that the value of t_1 is directly related to the rate of growth of cost and inversely to that of revenue. Therefore, earlier achievement of the break-even point depends on the higher rate of revenue growth. Instead of increasing the price of its product, a firm can raise its revenue by considering various uses of wastes without increasing the cost significantly. This model also helps to determine a suitable price policy. Considering lower prices at the initial stage and increasing them over time, a firm will be able to earn net profit from the operation and price may then be reduced for attainment of economy of scale due to the amount of product.

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