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Decision making model to reduce the burden on municipalities

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ABSTRACT

The growing population puts municipalities under pressure in managing waste The challenging task is to protect the environment and natural resources through waste management programs. If the sources are dumped in the landfill without sending it for treatment, the life span of dumping yard will not sustain. Hence a careful planning is required in carrying out these activities to accomplish this in a optimal way.

Introduction

India had all potential to produce any sort of products and services to meet out the requirement of an individual citizen. But due to the larger consumption of fossil fuels, India is in a crunch and scarcity in generating all sort of energy to fulfill the demand of the individuals. Government is taking innumerable campaign to yield energy through various renewable sources. Still the high consumption of the individual, the growing population and the shortage of fossil fuels urged India in frantic pressure to accomplish the task.

About 55 million tonnes of Municipal Solid Waste (MSW) and 38 billion liters of sewage are generated in the urban areas of India. It is estimated that the amount of waste generated in India will increase at a per capita rate of approximately 1-1.33% annually.

The Ministry of New and Renewable Energy has predicted that there exists a power generation potential of about 1500 MW from the MSW generated in India and the Indian Government is actively promoting the waste to energy technologies, by providing various incentives and subsidies for waste to energy projects. But according to the Indian Renewable Energy Development Agency (IREDA), only 2% of the potential has been tapped in India so far.

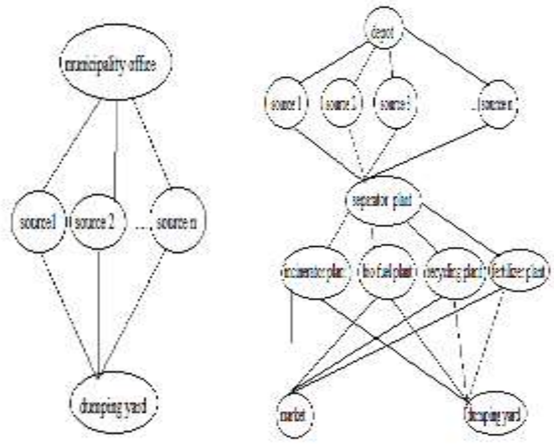
Nagapattinam district is an eastern coastal region of Tamilnadu, India. Major population depends on fishing and its by-products. Everyday tones and tones of sea food are collected from the sea, not only for local consumption but also for export. In every value addition stage of improving the quality of sea foods, leads to lots of wastage. In the boat house and fish markets tones of fish waste due to improper size or poor quality are collected. 44% of the waste is collected from residential areas. 19% from hospitals,17% from fish market, 11% from commercial areas and 9% waste from institutional areas. At present, waste is disposed off through dumping in a disposal yard outside the town.

The disposal yard is situated at a distance of 5 km from the town and it is spread over 19 acres. The disposal yard is sufficient for another 15 years. The disposal is done only through dumping. Nagapatinam municipality is in the process of implementing measures to develop the dumping yard and implement composting.

Necessity for Solid Waste Management:

Waste management is necessary for every country because it directly affects the health of the people and environment. In Nagapattinam town, dengue breaks out in rainy season due to the mosquitoes for which the garbage is the dwelling place. It spreads many diseases like malaria, cholera, typhoid, chikunkunia etc.,

The municipal solid waste mixes up with the river water which affects the quality of water. It also affects the living organisms like fish. The nutrients from the waste make the river and lakes a better place to grow for water hyacinth and other unwanted weeds, which leads to loss of water sources. From the rotten garbage, toxic gases emerge out which is deadly to human beings, animals and plants. As population grows year by year, there will be a scarcity in land which is used for disposal.



Therefore there is a urgent need for solving all those problems. Solid waste management by mathematical models will be definitely useful for decision makers for reducing waste, for minimizing travelling cost and also to maximize the usage of dumping yard.

Tele:

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Model 1 is what the present situation. In this model all the wastes are directly taken to the dumping yard and only a minimum quantity is taken for compost.

Model 2 is the proposed model in which the wastages are taken to treatment before dumping it. This will increase the life span of the dumping yard. The effective use of fish wastage and recoverable waste will definitely improve the revenue of the town.

Waste is a threat to land, water and air which in turn danger to the planet. Mathematical modeling is used to decision makers in day to day planning and execution of managing solid waste.

Let a represent the location point of waste source a=1,2,3….A

Let s represent the location point separator plant s= 1, 2, 3, … S

Let i represent the location point of incinerator plant i= 1, 2, 3, … I

Let j represent the location point of bio fuel plant j= 1, 2, 3,…J

Let k represent the location point of compost plant k= 1, 2, 3,…K

Let r represent the location point of recycling plant r= 1, 2, 3,…R

Let m represent the location point of market m= 1, 2, 3,…M

Let z represent the location point of dumping yard z= 1, 2, 3,…Z

Let the recoverable waste type be $\dot{w}$=1,2, … $\dot{W}$

Let the absolute waste type be $\underset{.}{w}$=1,2,… $\underset{.}{W}$

These waste types are carried by vehicles like lorries, minivan, tricycles, truck etc.,

Let us denote the vehicle type by v= 1, 2,… V and the volume of vehicle type v be denoted as V_v

Let the number of vehicle of type v involved every day by N

At present there is no separator, incinerator plant, recycling plant, biomass plant, and fertilizer plant in the town. Therefore the initial capital amount to construct these plants should be considered.

Let δ_s, δ_i, δ_j, δ_k, δ_r, δ_z, δ_m be the fixed cost in starting up a separator plant, incinerator plant, bio-fuel plant, compost plant, recycling plant, dumping yard, government aided market.

Let p_s, p_i, p_j, p_k, p_r, p_z, p_m indicate the presence of a separator plant, incinerator plant, bio-fuel plant, compost plant, recycling plant, dumping yard, government aided market.

Let γ_s, γ_i, γ_j, γ_k, γ_r, indicate the variable cost required in handling a unit mass of waste at a separator plant, incinerator plant, bio-fuel plant, compost plant and recycling plant. Let γ_m represent the variable cost in handling a unit mass of recovered waste in the market. Let γ_z represent the variable cost in handling a unit mass of recovered waste in the dumping yard.

Let wt_s, wt_i, wt_j, wt_k, wt_r indicate the amount of waste transported everyday to a separator plant, incinerator plant, bio-fuel plant, compost plant and recycling plant. Let wt_m represent the amount of recovered waste transported to the market. Let wt_z represent the amount of absolute waste transported to the dumping yard.

The objective function is to minimize the overall daily waste management costs.

The first objective function is to minimize the overall investment, waste handling expenses.

$$\min C^1 = \sum_{s=1}^{S}(\delta_s p_s + \gamma_s wt_s) + \sum_{i=1}^{I}(\delta_i p_i + \gamma_i wt_i) + \sum_{j=1}^{J}(\boldsymbol{\delta_j p_j + \gamma_j wt_j}) + \sum_{k=1}^{K}(\boldsymbol{\delta_k p_k + \gamma_k wt_k}) + \sum_{r=1}^{R}(\boldsymbol{\delta_r p_r + \gamma_r wt_r}) + \sum_{z=1}^{Z}(\boldsymbol{\delta_z p_z + \gamma_z wt_z}) + \sum_{m=1}^{m}(\boldsymbol{\delta_m p_m + \gamma_m wt_m}) \; ------(\mathbf{1})$$

The separator plant, processing plants, govt. co-operative market and dumping yard should actually exist.

$$p_s \in (0,1),\ p_i(\mathbf{0,1}),\ p_j(\mathbf{0,1}),\ p_k(\mathbf{0,1}),\ p_r \in (\mathbf{0,1}),\ p_z \in (\mathbf{0,1}), p_m \in (\mathbf{0,1}) \; ---------------------(\mathbf{2})$$

The second objective function is to minimize the transportation cost from the sources to the separator plant.

Let C_{vas} be the transportation cost per unit mass of waste carried by a vehicle of type 'v' from source 'a' to separator plant 's'.

Let us denote the vehicle type by v= 1, 2,… V and the volume of vehicle type v be denoted as V_v

Let a represent the location point of waste source a=1,2,3….A

Let s represent the location point of separator plant s= 1, 2, 3, … S

Let w = 1,2,3,….W represent the waste type.

Let X_{vaws} denote the total number of trips made by vehicle 'v' from source 'a' , carrying waste type 'w' to the separator plant 's'.

To minimize the transportation cost from the sources to the separator plant, objective function is,

$$\min C^2 = \sum_{vaws}(C_{vas} V_v X_{vaws}) --------(3)$$

Subject to the constraints,

$$\sum_{vaws}(V_v X_{vaws}) \geq q_a\,, \quad a = 1,2 \ldots A --------(4)$$

where q_a is the total quantity of waste source at 'a', that is, the total waste collected from waste source 'a' should be at least be equal to the total quantity of waste found at that point.

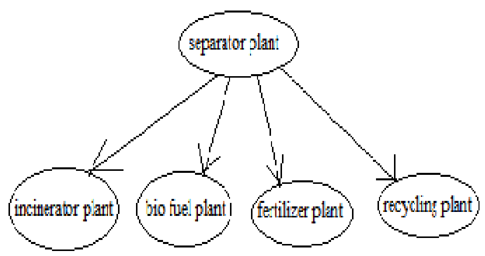
$$wt_s \leq cap_s\ p_s -------------- (5)$$

$$V_v X_{vaws} \leq cap_s\ p_s ----------- (6)$$

$$X_{vaws} \geq 0 ---------------- (7)$$

(5) shows that the amount of waste transported to the separator plant should not exceed the separator plant's capacity.(6) shows that the flow to separator plant must be positive, the plant should actually exist. (7) shows that the total number of trips made by vehicles of type v must be positive.

The third objective function is to minimize the transportation cost from the separator plant to the processing plants.



Let s represent the location point of separator plant s= 1, 2, 3, … S

Let i represent the location point of incinerator plant i= 1, 2, 3, … I

Let j represent the location point of bio fuel plant
j= 1, 2, 3,…J
Let k represent the location point of compost plant
k= 1, 2, 3,…K
Let r represent the location point of recycling plant
r= 1, 2, 3,…R
Let us denote the vehicle type by v= 1, 2,… V and the volume of vehicle type v be denoted as V_v
Let C_{vsi} , C_{vsj} , C_{vsk} , C_{vsr} be the transportation cost per unit mass of waste carried by a vehicle of type 'v' from the separator plant 's' to the processing plants (ie)incinerator plant , bio fuel plant, fertilizer plant and recycling plant.
Let X_{vswi} , X_{vswj} , X_{vswk} , X_{vswr} denote the total number of trips made by vehicle 'v' from separator plant 's' carrying waste type 'w' to the processing plants (ie) incinerator plant , bio fuel plant, fertilizer plant and recycling plant.
To minimize the transportation cost from the separator plant to the processing plants,

$$\min C^3 = \sum_{vswi}(C_{vsi}V_vX_{vswi}) + \sum_{vswj}\left(C_{vsj}V_vX_{vswj}\right) + \sum_{vswk}(C_{vsk}V_vX_{vswk}) + \sum_{vswr}(C_{vsr}V_vX_{vswr}) ------- (8)$$

Subject to the constraints,

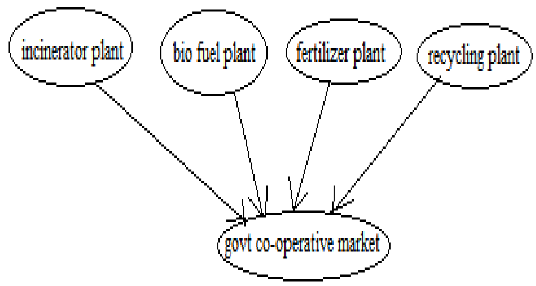
$$\sum_{vswi}(V_vX_{vswi}) + \sum_{vswj}\left(V_vX_{vswj}\right) + \sum_{vswk}(V_vX_{vswk}) + \sum_{vswr}(V_vX_{vswr}) \geq q_s , s = 1,2, \dots S --------- (9)$$

where q_s is the total quantity of waste at the separator plant, that is, the total waste collected from separator plant 's' should be at least be equal to the total quantity of waste found at that point.

$$wt_i \leq cap_i \; p_i -------------- (10)$$
$$wt_j \leq cap_j \; p_j -------------- (11)$$
$$wt_k \leq cap_k \; p_k -------------- (12)$$
$$wt_r \leq cap_r \; p_r -------------- (13)$$
$$V_vX_{vswi} \leq cap_i \; p_i ------------ (14)$$
$$V_vX_{vswj} \leq cap_j \; p_j ------------ (15)$$
$$V_vX_{vswk} \leq cap_k \; p_k ------------ (16)$$
$$V_vX_{vswr} \leq cap_r \; p_r ------------ (17)$$
$$X_{vswi} \geq 0 ----------------- (18)$$
$$X_{vswj} \geq 0 ----------------- (19)$$
$$X_{vswk} \geq 0 ----------------- (20)$$
$$X_{vswr} \geq 0 ----------------- (21)$$

(10-13) shows that the amount of waste transported to the incinerator plant, bio fuel plant, fertilizer plant and recycling plant should not exceed the incinerator plant , bio fuel plant, fertilizer plant and recycling plant's capacity.(14-17) shows that the flow to incinerator plant , bio fuel plant, fertilizer plant and recycling plant must be positive, the plant should actually exist. (18-21) shows that the total number of trips made by vehicles of type v must be positive.

The fourth objective function is to minimize the transportation cost from the processing plant to the government co-operative market carrying the recoverable products.



Let i represent the location point of incinerator plant
i= 1, 2, 3, … I
Let j represent the location point of bio fuel plant
j= 1, 2, 3,…J
Let k represent the location point of compost plant
k= 1, 2, 3,…K
Let r represent the location point of recycling plant
r= 1, 2, 3,…R
Let m represent the location point of market
m= 1, 2, 3,…M
Let us denote the vehicle type by v= 1, 2, … V and the volume of vehicle type v be denoted as V_v
Let the recoverable waste type be ẇ=1, 2, … Ẇ
Let C_{vim} , C_{vjm} , C_{vkm} , C_{vrm} be the transportation cost per unit mass of recoverable material carried by a vehicle of type 'v' from the processing plants (ie)incinerator plant , bio fuel plant, fertilizer plant and recycling plant to the govt. co-operative market.
Let $Y_{vi\dot{w}m}$, $Y_{vj\dot{w}m}$, $Y_{vk\dot{w}m}$, $Y_{vr\dot{w}m}$ denote the total number of trips made by vehicle 'v' from the processing plants (ie) incinerator plant , bio fuel plant, fertilizer plant and recycling plant carrying recovered material ẇ to the govt. co-operative market.
To minimize the transportation cost from the processing plants to the govt. co-operative market.

$$\min C^4 = \sum_{vi\dot{\mathbf{w}}m}(C_{vim}V_vY_{vi\dot{\mathbf{w}}m}) + \sum_{vj\dot{\mathbf{w}}m}\left(C_{vjm}V_vY_{vj\dot{\mathbf{w}}m}\right) + \sum_{vk\dot{\mathbf{w}}m}(C_{vkm}V_vY_{vk\dot{\mathbf{w}}m}) + \sum_{vr\dot{\mathbf{w}}m}(C_{vrm}V_vY_{vr\dot{\mathbf{w}}m}) ----22)$$

Subject to the constraints,

$$\sum_{vi\dot{\mathbf{w}}m}(V_vY_{vi\dot{\mathbf{w}}m}) \geq q_i , i = 1,2, \dots I ----------(23)$$
$$\sum_{vj\dot{\mathbf{w}}m}\left(V_vY_{vj\dot{\mathbf{w}}m}\right) \geq q_j , j = 1,2, \dots J --------- (24)$$
$$\sum_{vk\dot{\mathbf{w}}m}(V_vY_{vk\dot{\mathbf{w}}m}) \geq q_k , k = 1,2, \dots K --------(25)$$
$$\sum_{vr\dot{\mathbf{w}}m}(V_vY_{vr\dot{\mathbf{w}}m}) \geq q_r , r = 1,2, \dots R --------(26)$$

where q_i , q_j , q_k , q_r is the total quantity of recovered products at the processing plant, that is, the total recovered material collected from processing plants 'i','j','k' and 'r' should be at least be equal to the total quantity of recovered material found at that point. Let wt_m represent the amount of recovered waste transported to the market.

$$wt_m \leq cap_m\ p_m \ ------------- (27)$$

$$V_v Y_{vi\dot{\mathbf{w}}m} \leq cap_m\ p_m ------------- (28)$$

$$V_v Y_{vj\dot{\mathbf{w}}m} \leq cap_m\ p_m ------------- (29)$$

$$V_v Y_{vk\dot{\mathbf{w}}m} \leq cap_m\ p_m ------------- (30)$$

$$V_v Y_{vr\dot{\mathbf{w}}m} \leq cap_m\ p_m ------------- (31)$$

$$Y_{vi\dot{\mathbf{w}}m} \geq 0 ------------------ (32)$$

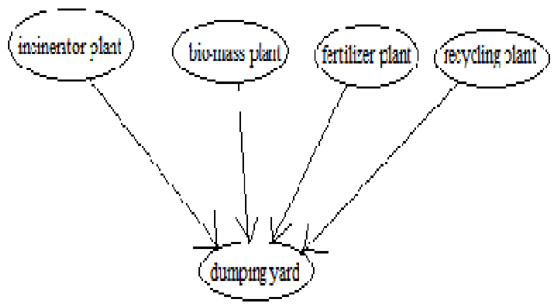
$$Y_{vj\dot{\mathbf{w}}m} \geq 0 ------------------ (33)$$

$$Y_{vk\dot{\mathbf{w}}m} \geq 0 ------------------ (34)$$

$$Y_{vr\dot{\mathbf{w}}m} \geq 0 ------------------ (35)$$

(27) shows that the amount of recovered material transported from the incinerator plant, bio fuel plant, fertilizer plant and recycling plant to the market should not exceed the market's capacity.(28-31) shows that the flow from incinerator plant , bio fuel plant, fertilizer plant and recycling plant to the market must be positive, the plant should actually exist. (32-35) shows that the total number of trips made by vehicles of type v must be positive.

The fifth objective function is to minimize the transportation cost from the processing plant to the dumping yard carrying the absolute waste which cannot be recovered.



Let i represent the location point of incinerator plant
i= 1, 2, 3, … I
Let j represent the location point of bio fuel plant
j= 1, 2, 3,…J
Let k represent the location point of compost plant
k= 1, 2, 3,…K
Let r represent the location point of recycling plant
r= 1, 2, 3,…R
Let z represent the location point of dumping yard
z= 1, 2, 3,…Z
Let us denote the vehicle type by v= 1, 2, … V and the volume of vehicle type v be denoted as V_v
Let the absolute waste type be ẉ=1,2,… Ẉ
Let C_{viz} , C_{vjz} , C_{vkz} , C_{vrz} be the transportation cost per unit mass of recoverable material carried by a vehicle of type 'v' from the processing plants (ie)incinerator plant , bio fuel plant, fertilizer plant and recycling plant to the dumping yard.
Let $Y_{vi\underset{\cdot}{w}z}$, $Y_{vj\underset{\cdot}{w}z}$, $Y_{vk\underset{\cdot}{w}z}$, $Y_{vr\underset{\cdot}{w}z}$ denote the total number of trips made by vehicle 'v' from the processing plants (ie) incinerator plant , bio fuel plant, fertilizer plant and recycling plant carrying absolute waste material ẉ to the dumping yard.
To minimize the transportation cost from the processing plants to the dumping yard carrying waste.

$$\text{Min } C^5 = \sum_{vi\underset{\cdot}{\mathbf{w}}z} \left(C_{viz} V_v Y_{vi\underset{\cdot}{\mathbf{w}}z}\right) + \sum_{vj\underset{\cdot}{\mathbf{w}}z} \left(C_{vjz} V_v Y_{vj\underset{\cdot}{\mathbf{w}}z}\right) + \sum_{vk\dot{\mathbf{w}}m} \left(C_{vkz} V_v Y_{vk\underset{\cdot}{\mathbf{w}}z}\right) + \sum_{vr\dot{\mathbf{w}}m} \left(C_{vrz} V_v Y_{vr\underset{\cdot}{\mathbf{w}}z}\right) - - - (36)$$

Subject to the constraints,

$$\sum_{vi\underset{\cdot}{\mathbf{w}}z} \left(V_v Y_{vi\underset{\cdot}{\mathbf{w}}z}\right) \geq q_i , i = 1,2, \ldots I ----(37)$$

$$\sum_{vj\underset{\cdot}{\mathbf{w}}z} \left(V_v Y_{vj\underset{\cdot}{\mathbf{w}}z}\right) \geq q_j , j = 1,2, \ldots J ----(38)$$

$$\sum_{vk\underset{\cdot}{\mathbf{w}}z} \left(V_v Y_{vk\underset{\cdot}{\mathbf{w}}z}\right) \geq q_k , k = 1,2, \ldots K ----(39)$$

$$\sum_{vr\underset{\cdot}{\mathbf{w}}z} \left(V_v Y_{vr\underset{\cdot}{\mathbf{w}}z}\right) \geq q_r , r = 1,2, \ldots R ----(40)$$

where q_i , q_j , q_k , q_r is the total quantity of unrecovered waste at the processing plant, that is, the total unrecovered material collected from processing plants 'i','j','k' and 'r' should be at least be equal to the total quantity of absolute waste material found at that point. Let wt_z represent the amount of absolute waste transported to the dumping yard.

$$wt_z \leq cap_z\ p_z \ ------------- (41)$$

$$V_v Y_{vi\underset{\cdot}{\mathbf{w}}z} \leq cap_z\ p_z ------------- (42)$$

$$V_v Y_{vj\underset{\cdot}{\mathbf{w}}z} \leq cap_z\ p_z ------------- (43)$$

$$V_v Y_{vk\underset{\cdot}{\mathbf{w}}z} \leq cap_z\ p_z ------------- (44)$$

$$V_v Y_{vr\underset{\cdot}{\mathbf{w}}z} \leq cap_z\ p_z ------------- (45)$$

$$Y_{vi\underset{\cdot}{\mathbf{w}}z} \geq 0 ----------------(46)$$

$$Y_{vj\underset{\cdot}{\mathbf{w}}z} \geq 0 ----------------(47)$$

$$Y_{vk\underset{\cdot}{\mathbf{w}}z} \geq 0 ----------------(48)$$

$$Y_{vr\underset{\cdot}{\mathbf{w}}z} \geq 0 ----------------(49)$$

(41) shows that the amount of absolute waste transported from the incinerator plant, bio fuel plant, fertilizer plant and recycling plant to the dumping yard should not exceed the dumping yard's capacity.(42-45) shows that the flow from incinerator plant , bio fuel plant, fertilizer plant and recycling plant to the dumping yard must be positive, the plant should actually exist. (46-49) shows that the total number of trips made by vehicles of type v must be positive.
Therefore, the objective function is to minimize the overall transportation cost C.

$$Min\ C = C^1 + C^2 + C^3 + C^4 + C^5 ----------(50)$$

Conclusion

Waste management includes collection, transport, processing, recycling, disposal and monitoring of waste materials. In India, more than 60% of waste is recoverable or reused. But in many places, all the waste collected are completely taken to the dumping yard which would certainly reduce the life span of dumping yard. Therefore a careful planning is needed. Several important decisions have to be made. Solid waste management by mathematical models will be definitely useful for decision makers for reducing waste, for minimizing travelling cost and also to maximize the usage of dumping yard.

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