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Optimizing management in Bihar: A multi-faceted approach

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Abstract
The case study of waste management issues in Bihar, carried out in this study, brings out that the complex waste management problem can be dealt with in a comprehensive manner by using several strategies. This paper presenting a Mathematical Optimization Model MOP that includes several objectives including energy production, greenhouse gas emissions, material recovery, cost, job creation, and wastewater generation as a framework for assessing the WM strategies. This study translated the MOP into an SOP and used Matlas to look for Pareto-optimal solutions; it proved that incineration and composting are two technologies with advantages. Incineration has relatively high performance in energy production compared to source reduction while composting gives better material return and cost optimization. The use of the ELECTRE method for decision-making help to narrow down the decision's evaluation allowing to give precise policy and practice indications. This approach recognises the fact that waste management, thus needs to be fluid and systematic in Bihar.

Keywords: Sustainable waste management, mathematical optimization model (MOM), incineration, composting, electre method

Introduction
Yearly, around 1. 3 billion tons of strong waste are created universally with projection to arrive at an expected 2. From the current 1. 2 billion tons it is projected that the global coal consumption will be 2 billion tons by end of 2025. SWM also consists of collecting, transporting, treating and disposal of wastes which remains a hard nut to crack for the municipal authorities. SWM is a complex procedure that employs quite a number of technologies as well as techniques for managing the environment, and the economy. Besides the cost benefits, balanced waste treatment is a process that helps to preserve the environment to the maximum, putting the recovered material to use and producing energy. The selection of treatment technologies impacts operation and maintenance costs, material recovery, energy generation, CO2 emissions, employment generation, and wastewater generation, and this implies that a set of objectives, each of which conflicts with other objectives, must be met. This work is carried out with the aim to improve SWM in Bihar using Multi-Objective Optimization in order to maximize energy generation and material recovery with minimum emission of greenhouse gases and operating cost. The next sections will show the theoretical framework and the analytical background of Multi-Objective Optimization, decision making techniques and relevant studies, which will lead to the detailed presentation and analysis of the results.

Multi-objective optimization problems
This part gives a work of Multi-Objective Improvement Issues (MOP), the issue detailing as well as the arrangement draws near. It gives the reader an understanding on how the Weighted Sum Method works. MOP enables the assessment of multiple objectives integrated with the aim of developing the solutions that would provide a balance between objectives and technical conditions. Arguably, since MOP delves into all adjacent solutions, it unearths the best results in the mathematical perspective. For this study, MOP is preferred over other methods, including LCA that is often employed in the solid waste management research because of its comprehensive assessment of multiple criteria.

Formulation and Concepts
The basic MOOP formulation is provide by the following equations:

$$\text{Min } f(x) \in R, \; x \in \Phi m \qquad (1)$$

Subject to

$$\Phi = \begin{cases} g_j(x) \le 0, & i = 1,\dots,p \quad (1) \\ h_j(x) = 0, & j = 1,\dots,q \quad (2) \\ x \in X & \quad (3) \end{cases}$$

The objective functions in the formulation of MOP can be of two types of form, but all must be minimized and can be competitive with each other. This leads to a possibility of genera facility for every possibility rather than looking for the best among them. To assess these solutions the notion of dominance is used. There being an affirmation that x1 is better compared to x2 in something like one goal capability and feebly better than x2 in all the others. Thus the strength relationship is caught numerically by the articulation:

$$(x1) \rightarrow (x2) \qquad (5)$$

Inside the arrangement of arrangements, an answer $x*$ is viewed as the worldwide ideal on the off chance that it fulfils the accompanying condition (Eq. 6):Within the arrangement of arrangements, an answer $x*$ is viewed as the worldwide ideal in the event that it fulfils the accompanying condition (Eq. 6):

$$\neg x \neq \exists x^* \wedge x \in \Phi \ | f(x) \Rightarrow f(x^*), \qquad f: X \subset \mathbb{R}^n \rightarrow Y \subset \mathbb{R}^m \qquad (6)$$

Every one of the non-sub-par or productive arrangements which are additionally named as the worldwide ideal arrangements are supposed to lie in the worldwide Pareto-ideal set. The picture of this set in the goal space is for the most part known as the Pareto front. As a matter of fact the Pareto front can contain countless focuses might be even an endless number of focuses. In actuality, issues, it is more helpful as a rule to get a guess of a limited number of close ideal arrangements among every one of the effective arrangements. To find a solitary point on the Pareto front, those philosophies are utilized that change the Multi-Objective Issue (MOP) into Single Objective Issue (SOP). Nonetheless, it is prudent to apply this strategy, the goal capabilities ought to be standardized since they might be in various units or significant degrees. One such way is by following the commitment of Eq. (7):

$$\hat{f}_k(x) = \frac{f_k(x)}{f_k^{max}}, f_k^{max} > 0 \qquad (7)$$

To standardize the goal capabilities, where f_k^{max}\ addresses the greatest worth of the goal capability fk, a few strategies can then be utilized to change a Multi-Objective Issue (MOP) into a Solitary Objective Issue (SOP):To standardize the goal capabilities, where f_k^{max}\ addresses the most extreme worth of the goal capability fk, a few techniques can then be utilized to change a Multi-Objective Issue (MOP) into a Solitary Objective Issue (SOP):

- **Distance to a Reference Objective Technique**: This converts the goal capabilities into one capability utilizing standards, reference focuses and loads.
- **Epsilon-constrained Method:** In this method all the constraints are forced into the objective functions while one of them is kept in its normal form.
- **Weighted Product Method:** In this strategy loads are utilized as type to the goal capabilities and these capabilities are then included by their item.
- **Weighted Aggregate Strategy (WSM):** The reliant goal capabilities are summarized into one capability using loads to achieve that.

For this study, the WSM will be used in arriving at the Overall Importance Score and it is explained below:

Weighted Sum Method (WSM)

The Weighted Total Strategy (WSM) changes a given Multi-Objective Issue (MOP) into a Solitary Objective Issue (SOP) by in gular condition of goal capability. The subsequent issue is planned as displayed in Conditions (8-12): The coming about issue is figured out as displayed in Conditions (8-12):

$$\min_x \ w^t f(x) = \sum_{k=1}^{m} w_k f_k(x), x \in \Phi \qquad (8)$$

Subject to

$$\Phi = \begin{cases} g_j(x) \le 0, & i = 1,\dots,p \quad (4) \\ h_j(x) = 0, & j = 1,\dots,q \quad (5) \\ x \in X & \quad (6) \end{cases}$$

with

$$\sum_{k=1}^{m} w_k = 1, w_k \ge 0 \qquad (12)$$

One more benefit of the WSM is that it is not difficult to utilize; furthermore, the quantity of boundaries, which is required, is equivalent to the quantity of targets. Notwithstanding, it produces just all Pareto-ideal arrangements assuming the first MOP is arched just, and an extra limitation should be fulfilled at that. As referenced before when used to get a solitary Pareto-ideal point, the chief's inclinations are consolidated in the weight boundaries. Otherwise, WSM can be used in an iterative approach where weight values are amended and successive optimization issues are solved to come close to the Pareto-optima set. This implies that it is likely to give different optimal solution though at times adjusting the weights might give the same solution.

Decision-Making

This segment presents the overall meaning of decision-production as well as the depiction of the most often applied dynamic strategies with accentuation on the ELECTRE strategy.

Decision-Making Methods

The next problem that arises as soon as one has an idea of what the Pareto-optimal set looks like, is how to decide which of the solutions should be implemented. Several

decision-making techniques help in this regard as they deal with the cases where more than one and often contradictory objectives are possible and the outcome optimally suits the preference of the decision-maker.
Dynamic strategies can be sorted into two primary schools: The American and the French the American and the French The American and the French A portion of the renowned techniques for the American school include:

- **Logical Ordered progression Cycle (AHP):** An estimating hypothesis that includes an arrangement of correlation with the utilization of other raters for determining needs specifically positions.
- **Multi-Characteristic Utility Hypothesis (MAUT):** A coordinated way to deal with the dynamic cycle by the thought of utility capabilities in the assessment of the compromises among the numerous objectives.
- **Straightforward Multi-Property Rating Method (Shrewd):** One is different quality utility capability, which utilizes a direct added substance model in a specific utility capability of a standard.

The French school, then again, utilizes outclassing techniques, such as: The French school, then again, utilizes outclassing strategies, for example,

Inclination Positioning Association Technique for Improvement Assessments (PROMETHEE): Summoned an inclination diagram model.

Removal Et Choix Traduisant la Realité (ELECTRE) Pummelling relations allude to a proper methodology in math and software engineering, particularly with regards to rationale and programming, where requirements or conditions are utilized to decide the legitimacy or consistency of specific articulations or states. To actually deal with these relations, techniques frequently include assessing concordance (arrangement or understanding among requirements) and non-mercilessness limits (staying away from over-the-top power or prohibitive measures). The best strategies centre around making adjusted frameworks that regard these standards, utilizing procedures like imperative proliferation and enhancement calculations to guarantee that arrangements line up with the ideal requirements while staying away from excessively forceful implementation that could prompt failures or clashes.
When it comes to SWM - it is important to store multiple options for the decision maker. Thus, this work uses the ELECTRE method which has been deemed as one of the most reliable methods of the MCDM and is free from any subjective examination.

ELECTRE Method
The ELECTRE method combines a number of techniques which are essentially different from each other but possess unique characteristics. Electre II is used for this purpose for the present study. The initial step is the weighting of every standard j where j ∈ J = 1, 2, n.., c. Then, correlations are made between the options computer-based intelligence and against the models in which are then characterized in the accompanying sets as follows:

$$J^{+}(a_i, a_k) = \{j \in J | g_j(a_i) > g_j(a_k)\} \quad (13)$$

$$J^{=}(a_i, a_k) = \{j \in J | g_j(a_i) = g_j(a_k)\} \quad (14)$$

$$J^{-}(a_i, a_k) = \{j \in J | g_j(a_i) < g_j(a_k)\} \quad (15)$$

Then, the connections between the options are evaluated by changing over them into mathematical qualities, using the loads p_j as characterized by Eqs. (16-18):

$$P^{+}(a_i, a_k) = \sum_j p_j,\ j \in J^{+}(a_i, a_k) \quad (16)$$

$$P^{=}(a_i, a_k) = \sum_j p_j,\ j \in J^{=}(a_i, a_k) \quad (17)$$

$$P^{-}(a_i, a_k) = \sum_j p_j,\ j \in J^{-}(a_i, a_k) \quad (18)$$

Utilizing these qualities, the concordance record is determined as displayed in Eq. (19):

$$C_{ik} = \frac{P^{+}(a_i,a_k) + P^{=}(a_i,a_k)}{\sum_{j \in J} p_j,} \quad (19)$$

also, the non-conflict file by the Eq. (20):

$$D_{ik} = \begin{cases} 0 \text{ if } J^{-}(a_i,a_k) = \phi \\ \delta \max(g_j(a_k) - g_j(a_i)), j \in J^{-}(a_i,a_k) \end{cases} \quad (20)$$

The outclassing connection between the other options, where artificial intelligence is liked or considered not interested in a_k (meant as), still up in the air by Eq. (21):

$$a_i S\ a_k = \begin{cases} C_{ik} \geq \tau_C \\ D_{ik} \leq \tau_D \end{cases} \quad (21)$$

The inevitable values of τC are about 0. 7 and τD about 0. 3. While this relation is forged between two possibilities, it is usual to run through several proposals at a time. Wherein, ai ≥ ak for those where ai ≠ ak, for each of the alternatives, a connected graph G=(V, A) can be established whereby: Building this graph becomes difficult as the number of alternatives increases.
In the refining system, this is finished by organizing choices in a rundown where the option seems the higher is the quantity of arrangements that are outclassed by it. The most noteworthy positioning is doled out to the people who rank above additional individuals than any other person does. After that, alternatives can be ranked based on how many solutions are ranking above them, where the highest rank to any particular solution is given to the solution that is least ranking to the others. The final ranking as therefore calculated by computing the mean of the two classification systems. However, where one or the other is considerably different between the two rankings (for instance, an alternative ranking first in one and last in the other), it may be considered as inapplicable.

Optimization Applied to Solid Waste Management (SWM): Solutions that correspond to the Pareto-optimal set but have higher utility levels from our point of view. Commonly, such methods relate to the identification of the landfill site and the determination of the choice of waste treatment technologies. There are also the uses of optimization tools especially the Multi-Objective Optimization Problem (MOP) in the waste management studies. For example, Multi-objective Mixed Integer Programming (MOMIP) is used for optimizing goal such as economical factor control, noise control, air pollution, and traffic congestion. There is then the use of such methods such as Distance-Based Compromise Programming among others to arrive at the best solution as seen from the case studies. The other methodology includes, Nonlinear Multi-objective Advancement Issue (NLMOP models) where the targets incorporate monetary expense, measure of waste that isn't reused, measure of waste that goes into the landfill and furthermore the impacts on climate. These models might incorporate such intuitive systems as reference point methodology and are utilized in specific circumstances. Likewise, a few targets of multi-objective-improvement in civil waste administration remember minimization of the natural and monetary expenses for different urban communities.

2. Materials and methods

To accomplish the goals of this evaluation, an exhaustive structure was created and carried out. This structure was fastidiously intended to address explicit objectives, as outlined in Figure 1. The system incorporates key stages and procedures pointed toward accomplishing the ideal results really. It consolidates nitty gritty cycles and precise ways to deal with guarantee that all objectives are met exhaustively. By following this organized system, the review plans to achieve its framed goals, guaranteeing a careful and powerful assessment of the topic. The system fills in as a guide to direct the review's advancement and work with the accomplishment of its key objectives.

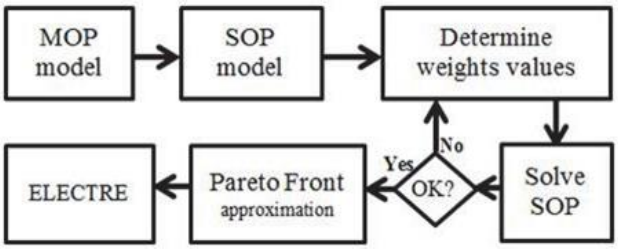

Fig 1: Study Process Flow

The essential endeavour of this assessment is to address the SWM circumstance as a MOP. Taking the quantitative data got from the SWM game plan of a medium-sized city, the model was stacked up with veritable data. The MOP was then changed to a SOP utilizing the Weighted Number of Standardized Goals which is the WSM. In this way, there is Pareto improvement, changing the loads of elements made an estimation of the Pareto Front. At long last, the ELECTRE strategy was utilized to help in dynamic on the last positioning of choices. Utilizing Matlab, the accompanying whole cycle was finished. The ensuing sub-segments have been intended to provide the peruser with a definite record of every one of these means.

Model Training

In the MOP model, the going with sets and factors are described:

- **I**: Strong waste sorts (i∈{1,2,3,4,5,6} for paper, glass, metal, plastic, natural material, and others).
- **J:** Processing technologies (j∈{1,2,3,4} for recycling, composting, incineration, and landfill).

The key variables and parameters include

- x_{ij}**:** Amount of material iii processed by technology j.
- C_{ij}**:** Processing cost.
- p_{ij}**:** Remaining material rate after processing.
- t_{ij}**:** Energy production rate.
- r_{ij}**:** Greenhouse gas emissions rate.
- W_i**:** Total waste of type i.
- e_j**:** Jobs created by technology j.
- l_j**:** Wastewater generated by technology j.

The model incorporates six goal capabilities zeroing in on energy age, outflows, material recuperation, costs, work creation, and wastewater age. The primary capability, f1, augments energy creation from handled and remaining materials.

$$\max_x f_1 = \sum_{j=1}^{4}\sum_{i=1}^{6} t_{ij}x_{ij} + \sum_{j=1}^{2}\sum_{i=1}^{6} t_{i4}p_{ij}x_{ij} \qquad (22)$$

The subsequent goal, f2, looks to limit the ozone depleting substance outflows created by handling materials across the different advances (Eq. 23):

$$\min_x f_2 = \sum_{j=1}^{4}\sum_{i=1}^{6} r_{ij}x_{ij} + \sum_{j=1}^{2}\sum_{i=1}^{6} r_{i4}p_{ij}x_{ij} \qquad (23)$$

The third goal, f3, centres around upgrading the proficiency of material recuperation processes for reusing and squander the executives. This incorporates supporting the recuperation paces of different materials like paper, glass, metal, and plastic for the reusing plant, as well as streamlining the assortment of ordinary waste materials planned for the treating the soil plant. By working on the isolation and recuperation of these materials, the objective is to boost their reuse and reusing potential. This won't just help the supportability of the reusing and treating the soil tasks yet additionally add to diminishing generally speaking waste and advancing natural preservation.

$$\max_x f_3 = \sum_{i=1}^{4} x_{i1} + x_{53} \qquad (24)$$

The fourth objective, f_4, seeks to minimize the system's cost (Eq. 25):

$$\min_x f_4 = \sum_{j=1}^{4}\sum_{i=1}^{6} C_j x_{ij} + \sum_{j=1}^{3}\sum_{i=1}^{6} C_4 p_{ij}x_{ij} \qquad (25)$$

The fifth goal, f5, plans to amplify work creation inside the framework (Eq. 26):

$$\max_x f_5 = \sum_{j=1}^{4}\sum_{i=1}^{6} e_j x_{ij} \qquad (26)$$

The sixth objective, f_6, focuses on minimizing wastewater generation within the system (Eq. 27):

$$\min_x f_6 = \sum_{j=1}^{4}\sum_{i=1}^{6} l_j x_{ij} \qquad (27)$$

The requirements guarantee adherence to mass equilibrium, limit cutoff points, and material handling abilities. The principal sort of requirement is the mass equilibrium for every material kind (Eq. 28):

$$\sum_{j=1}^{6} x_{ij} = W_i \text{ with } i = 1,2,3,4,5,6 \qquad (28)$$

The fertilizing the soil plant processes just natural material, as determined in Eq. (29):

$$\sum_{i=1}^{4} x_{i2} + x_{62} = 0 \qquad (29)$$

Condition (30) guarantees that the reusing plant doesn't handle natural material:

$$x_{51} = 0 \qquad (30)$$

Equation (31) stipulates that other types of material can only be processed by the incinerator or sent to the landfill:

$$\sum_{j=1}^{2} x_{6j} = 0 \qquad (31)$$

Equation (32) defines the domain of the variables:

$$x_{ij} \geq 0 \ \forall i \in I \ e \ \forall j \in J \qquad (32)$$

The MOP model is straight and obliged. Given its bended nature, the Weighted Total Procedure (WSM) can be used to unpleasant the Pareto front.

Input Data: This study surveys a speculative city of a million get-together. Considering data from the Brazilian Public Sanitization Information Structure (BNSIS, 2016), such metropolitan regions produce around 1.00 kg of waste per capita ordinary, amounting to 1,000 tons of common solid waste (MSW) every day. The waste parts analysed consolidate paper, glass, metal, plastic, normal, and others. The "others" class, including materials like cigarettes and wood, is separated in much the same way among organics and inactive materials. Squander plan information is gotten from the Establishment to Assist the Movement of the Public power With tutoring of Pernambuco, as displayed in Table.

Table 1: Composition of Municipal Solid Waste (MSW) Used in This Study

Waste Composition	***Brazil [%]***
Paper	13.01
Glass	2.04
Metal	2.09
Plastic	13.05
Natural	51.04
Others	16.07

Waste Treatment Streams

Figure 2 layouts the waste treatment processes assessed in this review for Bihar, India. These cycles incorporate fertilizing the soil, reusing, squander to-energy cremation, and landfilling with energy recuperation. Every strategy is nitty gritty in Table 2, which gives a breakdown of the functional expenses customized to the Indian setting. The table additionally remembers data for work creation and wastewater age related with every treatment choice. Wastewater age envelops all effluents created, including leachate from landfills, featuring the ecological and financial effects of each waste administration technique.

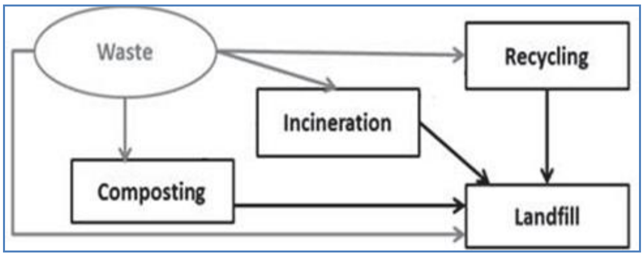

Fig 2: Solid Waste Management Plan

CO2 Emissions & Power Generation

Table 3 includes showing the estimations of Carbon dioxide releases from each waste treatment development. Reusing has a negative worth since it forestalls the making of new materials which thusly brings down discharges. The table likewise incorporates the electrical age of every one of these innovations.

Key suspicions are

- While some fertilizing the soil processes just natural waste, others join different squanders like plastic materials.
- Reusing worries about paper, glass, metal and plastic materials.
- Burning treats a wide range of waste, secures volume as well as makes power however has no material reusing.
- •There is additionally other strategy for garbage removal through landfilling.

As may be obvious, there is consistently waste to manage, and the last scene mirrors the portion of waste requiring landfilling after treatment. Cremation brings about buildups that can't be used for energy recuperation in landfills.

Goal: to draw near to the Pareto front, the SOP was tackled iteratively utilizing Matlab linprog capability. To accomplish complex inclusion of arrangements 98 weight mixes were utilized albeit some of them yielded comparable qualities.

Table 2: Operational Costs of Waste Facilities, Wastewater Output, and Employment Generation

Technology	*Operational Costs (USD/ton)*	*Jobs Created (per ton)*	*Wastewater Generated (m³/ton)*
Treating the soil	2.000	2.000	00.015
Cremation	27.050	00.005	00.020
Reusing	25.000	5.000	00.005
Landfilling	9.000	00.030	00.020

Table 3: Energy Output and CO2 Emissions by Waste Facility

Technology	*Waste fraction*	*CO2 Emissions [CO2TEQ/ton]*	*Electricity Generation [kWh/ton]*	*Residual Waste Quantities [%])*
Composting	Paper	00	-	100
	Glass	00	-	100
	Metal	00	-	100
	Plastic	00	-	100
	Natural	00.16	-	5
	Others	00	-	100
Recycling	Paper	199e-3	-	30
	Glass	-88e-3	-	30
	Metal	-4.5	-	30
	Plastic	-1.3	-	30
	Natural	00	-	100
	Others	00	-	100
Incineration	Paper	1,279	440	5
	Glass	00.059	00	100
	Metal	00	00	50
	Plastic	2.7	1200	3
	Natural	00.58	500	3
	Others	00.29	250	50
Landfilling	Paper	1.009	00	-
	Glass	00	00	-
	Metal	00	00	-
	Plastic	00	00	-
	Natural	00.41	200	-
	Others	00.2	100	-

There was a system utilized to sift through arrangements from the Pareto-ideal set that was then a piece of the dynamic interaction.

Dynamic Interaction

For evaluating the Pareto-ideal arrangements, for example, the outclassing techniques, for example, the ELECTRE II were utilized. This helps since it makes it conceivable to think about and rank al the non - ruled arrangements to help the leaders to contrast useful arrangement and the best arrangements.

Responsiveness Investigation

Responsiveness examination decided the impact of relative changes in squander piece and chief inclinations. The examination looked at three situations: one with squander organization information just from Bihar and two with information gathered from various pieces of India having expected a city of populace a million with day-to-day squander age of 1 kg for every head.

Table 4: Waste Composition for Sensitivity Analysis

Waste Composition	*Europe [%]*	*Japan [%]*	*USA [%]*
Paper	29	33	28.05
Glass	11	5	4.06
Metal	5	3	9
Plastic	8	13	12.04
Organic	31	34	27.01
Others	16	12	18.04

In the context of the sensitivity analysis of the decision-making preferences the following four weight scenarios were considered - each of the weights assigned double importance to one criterion only. The current analysis employed the waste composition data relevant to the Bihar, India.). The following criteria weights for each scenario used in this paper are presented in table 5.

3. Result & Discussion: In Bihar the Pareto Front approximation helped to find 21 solutions among 98 weights possibility. In the figure 3 the optimal outcomes are numerous and varied; while composting and incineration are presented as two rather antagonistic technologies. The two are mutually exclusive because, in order to improve energy recovery rates, incineration has to be done at the cost of composting and similarly if composting has to be done, it will reduce incineration rates. Re-use is a major factor in the reduction of landfill usage, with the best recycling solutions having not significantly over ˜%20 landfill contribution. This is in contrary to the present-day practices whereby landfills are the most common technique used in disposal of wastes. In waste allocation, our table 6 shows that paper and glasses should preferably be recycled and land-filled; metals go to the recycling; plastics to incineration; while organics go to composting or incineration.

Table 7 has demonstrated that those solutions based on incineration (19, 20, 21) are leaders in energy production, and solutions based on composting and recycling (solution 5) are leaders in the reduction of greenhouse gases and the maximum recovery of materials.

Table 5: Sensitivity Analysis Scenario Weights for Objective Function

Objective functions label	*Criteria weights*						
	Base Scenario	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***	***Scenario 5***	***Scenario 6***
f1	1	2	1	1	1	1	1
f2	1	1	2	1	1	1	1
f3	1	1	1	2	1	1	1
f4	1	1	1	1	2	1	1
f5	1	1	1	1	1	2	1
f6	1	1	1	1	1	1	2

Table 6: Optimal Waste Fraction Allocation

Waste fraction	***Treatment technology***	***Waste allocation by solution [tons]***																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Paper	Recycling	00	00	131	131	131	00	00	00	131	00	131	00	00	131	00	131	00	131	00	00	00
	Composting	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Incineration	00	00	00	00	00	00	00	00	00	131	00	00	00	00	131	00	00	00	131	131	131
	Landfilling	131	131	00	00	00	131	131	131	00	00	00	131	131	00	00	00	131	00	00	00	00
Glass	Recycling	00	00	24	24	24	00	00	00	24	24	24	00	00	24	00	24	00	24	00	8	24
	Composting	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Incineration	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	9	00
	Landfilling	24	24	00	00	00	24	24	24	00	00	00	24	24	00	24	00	24	00	24	7	00
Metal	Recycling	00	29	29	29	29	29	00	29	29	29	29	00	29	29	00	29	29	29	00	9	29
	Composting	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Incineration	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	11	00
	Landfilling	29	00	00	00	00	00	29	00	00	00	00	29	00	00	29	00	00	00	29	8	00
Plastic	Recycling	00	00	135	135	135	00	00	00	00	00	135	00	00	135	00	00	00	00	00	00	00
	Composting	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Incineration	00	00	00	00	00	00	135	135	135	135	00	135	135	00	135	135	135	135	135	135	135
	Landfilling	135	135	00	00	00	135	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
Organic	Recycling	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Composting	514	514	514	514	514	00	514	514	514	514	00	00	00	00	00	00	00	00	00	00	00
	Incineration	00	00	00	00	00	00	00	00	00	00	514	00	00	514	00	514	514	514	514	514	514
	Landfilling	00	00	00	00	00	514	00	00	00	00	00	514	514	00	514	00	00	00	00	00	00
Others	Recycling	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Composting	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	Incineration	00	00	00	76	167	167	00	00	00	00	00	00	00	77	00	00	167	167	167	167	167
	Landfilling	167	167	167	91	00	00	167	167	167	167	167	167	167	90	167	167	00	00	00	00	00

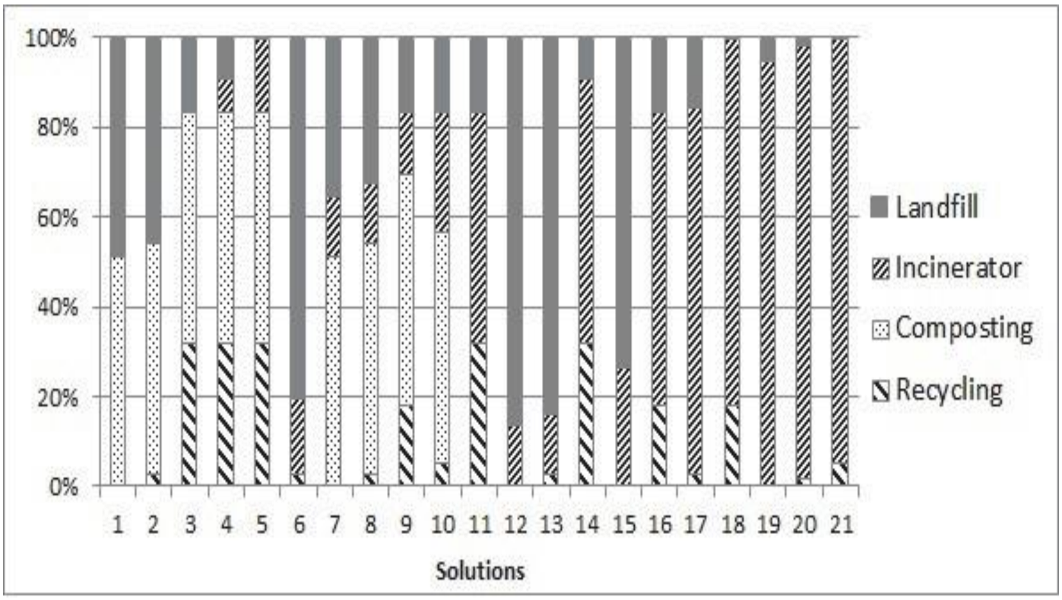

Fig 3: Optimal Waste Allocation Solutions

Concerning optimality of waste management in Bihar, it was observed that both Solution 3 and 4 best performed in the recovery of materials hence were optimal to this goal. Arrangement 1 was the most financially savvy considered arrangement which was because of the way that treating the soil and landfilling has lower functional consumption than different other options. As for the number of jobs created, Solution 3 was more effective because recycling and composting process are more labor consuming. As well, Solutions 3, 4, and 5 were mentioned to produce the least wastewater making the solutions environmentally sound. Figure 4 illustrates the trade-offs between different objectives: minimizing resource loss calls for higher material recovery and this affect the amount of material that can be incinerated thus energy generation and emissions. This often leads to considerable organisational costs. Lastly, table 8 shows the ranking of the 21 solutions in terms of 10 levels using ELECTRE method that gives a full over view of their performance.

Table 7: Results of Objective Functions for Each Solution

Solution	*f1 (kWh/ton)*	*f2 (ton CO2eq/ton)*	*f3 (ton/ton)*	*f4 (U$/ton)*	*f5 (job/ton)*	*f6 (m³/ton)*
1	21840.00	407.8	514.00	5633.3	1173.08	174.03
2	21840.00	277.03	543.00	6175.06	1310.01	170.00
3	21840.00	25.08	833.00	11598.06	2673.01	126.05
4	33274.09	18.02	833.00	13351.09	2654.00	126.05
5	46890.00	9.01	833.00	15439.06	2631.04	126.05
6	144550.00	378.06	29.00	13383.03	394.06	195.07
7	183840.00	772.03	514.00	8167.03	1140.01	174.03
8	183840.00	641.08	543.00	8709.06	1276.04	170.00
9	183840.00	565.08	698.00	11608.01	2004.09	146.07
10	241480.00	168045.09	567.00	11640.08	1356.04	166.04
11	273700.00	231.02	319.00	24613.01	1670.08	152.02
12	281500.00	890.03	0.00	11534.00	266.03	200.00
13	281500.00	759.08	29.00	12076.03	402.06	195.07
14	285192.01	223.05	319.00	26375.02	1651.07	152.02
15	339140.00	168296.05	0.00	14016.04	233.05	200.00
16	435700.00	771.02	184.00	24622.05	1002.06	172.04
17	460750.00	830.05	29.00	25565.00	232.03	195.07
18	460750.00	754.05	184.00	28463.05	960.08	172.04
19	518390.00	168367.02	0.00	27505.02	63.03	200.00
20	518390.00	168325.06	17.00	28336.03	137.08	197.05
21	518390.00	168234.06	53.00	28496.03	312.04	192.01

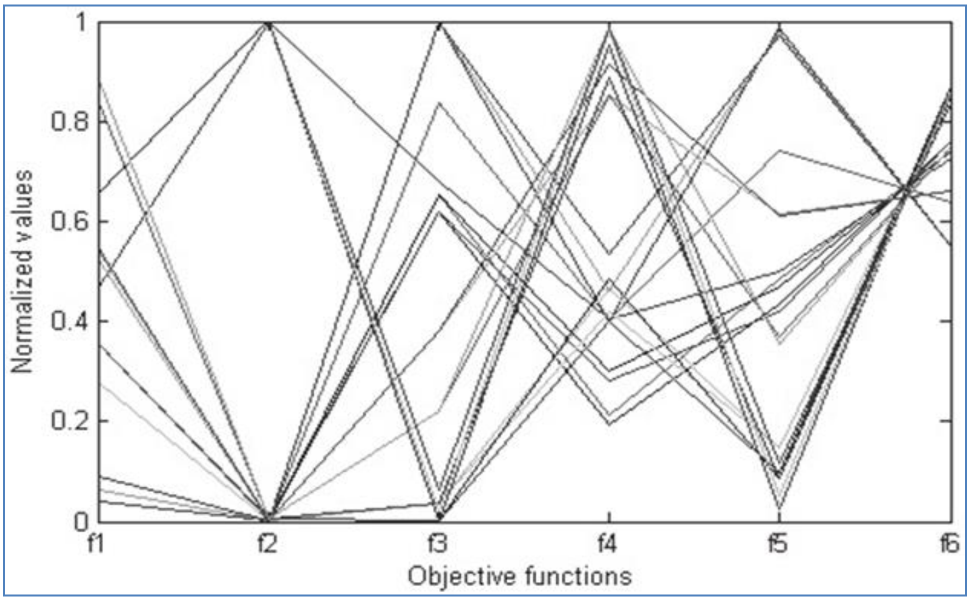

Fig 4: Objective Function Values of the Pareto Front

The best arrangement, Arrangement 9, gave all waste administration advances. As is illustrated in fig. 3, this solution provides 51 percent of the resources needed in this situation. 4% of the waste taken to composting while and the remaining 18% taken to recycling, landfilling and incineration. 4%, 16. 7%, and 13. The respective proportions are 5% of the waste age throughout the proposed procedure, and 5% of waste generation in the course of procedure. Table 6 shows that all sorts of organic matter are recycled by composting, plastic through incineration because of its calorific worth, metals, papers, and glass are taken to the recycling center. The category of products that fall under 'others' are dumped into the landfill. This is the explanation that Arrangement 9 is positioned at the top for instance, by appropriately conveying waste sorts into the best reasonable advances, Solution9 expands the advantages of each waste division and makes a best split the difference with regards to the set goal capabilities.

Table 8: Solutions Ranked by ELECTRE Method

Solution Label	*Rank*
9	1
16	2
3	3
8	3
18	4
2	5
4	5
13	5
5	6
7	6
10	6
11	6
14	6
17	6
21	6
1	7
12	7
20	7
15	8
19	9
6	10

Breaking down the responsiveness of rules loads, Ref. Fig. 5 uncovered that rankings were generally steady across situations depicting a low variety of expected botch. The classification outcomes of Scenarios as ranking the images are as follows: Scenarios 3 and 6 had the same ranking, with fifty percent of the classification being similar to the Base Scenario; so did Scenarios 4 and 5. However, comparing with the Base Scenario, the Rankings of Scenarios 1 and 2, which respectively preset double weights on energy generation and material recovery, only 30% of rankings were consistent. This means that setting higher value on the energy recovery caused shifts in ranks since solutions which possess very high energy production and material recovery nearly always performed poorly in other objectives.

In all the scenarios, everybody concurred that Solution 9 was the best-ranked solution. On the basis of differential waste compositions, it was found that waste management activities were much sensitive to such changes. Observing the changes of the composition of the wastes for the various cases explored, it was found that all cases emphasized more in recycling than in the base case. Table 6 summarises the assigned wastes for the best solutions for different waste composition scenarios described in Fig. 6. The ELECTRE II method provided more than one top configuration depending on the type of wastes being treated. For the general waste composition of Bihar, the results proposed focussing on recycling and composting for the waste composition specific to Bihar. This was the case since the proportion of organic waste was comparatively small, and waste had to be dealt with efficiently under conditions prevailing in the region. These suggestions hinted at the central theme that the strategies which should be adopted to deal with waste in Bihar must be different from the waste which is being produced since it is not suitable to implement a single strategy for all the waste.

4. Conclusion

In conclusion, the study on optimizing waste management in Bihar demonstrates the effectiveness of a multi-faceted approach to addressing the region's complex waste management challenges. By leveraging a Mathematical Optimization Model (MOP), which integrates various objectives including energy production, greenhouse gas emissions, material recovery, cost, job creation, and wastewater generation, the research provides a holistic framework for evaluating waste management strategies. The change of the MOP into a Solitary Objective Issue (SOP) and ensuing examination utilizing Matlab recognized Pareto-ideal arrangements, uncovering that both burning and fertilizing the soil are practical advances, each succeeding in various viewpoints. Incineration proved advantageous for energy generation, while composting excelled in material recovery and cost-efficiency. The study's use of the ELECTRE method for decision-making further refined the evaluation process, offering clear recommendations for policy and practice. This comprehensive approach underscores the importance of adopting flexible and integrated strategies to enhance waste management outcomes, ultimately contributing to more sustainable and effective waste management practices in Bihar.

Future Research

The research that can be conducted in the future regarding the strategies that will improve waste management in Bihar should cover several points to make the best results and achieve the best possible outcomes in waste management. Firstly, optimisation models can consider other factors outside of cost and technical considerations like socio-economic consequences, health effects, and acceptance by the public amongst other factors. Other research goals to include in the framework will also be to assess the sustainable long-term effects of the various waste management technologies on the environment and health of people. However, the enhancement of current real time information, artificial intelligence and machine learning into the models could bring the progressive and flexible concepts of waste management. Benchmarking of Pilot projects and case studies of other regions on successful waste management practices could be very helpful to Bihar.

Recommendations

1. **Policy Integration**: Policies that incorporate multiple waste management technologies which are appropriate to the local conditions should be adopted according to the results which come from the optimization models.
2. **Community Engagement:** There should be a stepped-up public participation and sensitisation so as to encourage people to sort their wastes correctly and take them to recycling centres appropriately.
3. **Infrastructure Investment:** Increase efficiency and sustainability by upgrading the present waste management facilities such as recycling plants as well as waste to energy plants.
4. **Data Collection:** Have proper records collection and checking mechanisms for frequent evaluating and reviewing of waste management practices in relation to their efficiency and novelties.

Thus, these areas indicate the possibilities for the development of various subsequent investigations that can help enhance the efficiency in the sphere of waste management, thus contributing to the support of environment in Bihar and the increase in the level of people's welfare.

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