Chapter 8

A Tripple Bottom Line Assessment of Solid Waste Mangaement System: An Application of AHP

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Abstract: Effective solid waste management is essential for sustainable development, addressing environmental concerns, and achieving socio-economic well-being. This study presents a comprehensive analysis of the solid waste management system using the Triple Bottom Line (TBL) framework and employs the Analytic Hierarchy Process (AHP) as a decision-making tool. The research aims to evaluate the environmental, social, and economic dimensions of the waste management system, considering various criteria and sub-criteria.

The environmental dimension assesses the impact of waste management practices on ecosystems, natural resources, and climate change. Factors such as waste reduction, recycling, composting, and energy recovery are evaluated to determine their environmental effectiveness. The social dimension focuses on the implications of waste management on human health, community well-being, and equity. Parameters like public participation, awareness programs, employment generation, and social justice are considered. The economic dimension investigates the financial viability and cost-effectiveness of waste management strategies. Criteria such as cost of collection, treatment, disposal, revenue generation, and economic benefits are examined.

The Analytic Hierarchy Process (AHP) is applied to analyse the relative importance of criteria and sub-criteria in the TBL assessment. AHP allows decision-makers to structure the decision problem, prioritize criteria, and derive weights based on pairwise comparisons. Expert

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opinions, stakeholder inputs, and available data are utilized to establish the decision hierarchy and pairwise comparisons. The AHP process facilitates a systematic evaluation, enabling decision-makers to identify the most suitable waste management strategies based on TBL principles.

The findings of this study provide valuable insights into the performance of the solid waste management system from a TBL perspective. By considering the environmental, social, and economic dimensions simultaneously, decision-makers can identify strategies that achieve optimal outcomes across multiple dimensions. The AHP-based assessment enables a transparent and rational decision-making process, promoting informed choices and resource allocation in waste management. This research contributes to the existing body of knowledge by integrating the TBL framework and AHP methodology for solid waste management assessment. It emphasizes the importance of a holistic approach to waste management that goes beyond traditional cost considerations.

Keywords: Triple Bottom line Assessment, Application of AHP,Solid Waste Management system

8.1 Introduction

The term "solid waste management" describes the systematic and environmentally friendly gathering, moving, handling, and discarding of solid waste. It includes the methods and techniques used to manage different kinds of solid waste, such as hazardous waste, commercial, industrial, and residential waste as well as debris from building and demolition projects (Tiwari S et al., 2022). Solid waste management aims to maximize resource recovery, encourage sustainable practices, and reduce the harmful effects of waste on the environment and public health.

The Triple Bottom Line (TBL) is a sustainability framework that takes into account three interconnected dimensions: environmental, social, and economic. It expands the traditional focus on financial performance to include the broader impacts and outcomes associated with an organization's activities (Fatima S, 2023).

Strong waste administration is an essential part of ecological manageability and general wellbeing. It includes the assortment, transportation, removal, and reusing of strong waste created by human exercises. Strong waste can incorporate different materials, for example, family squander, modern waste, development and destruction trash, and the sky is the limit from there. The administration of strong waste is an intricate and diverse test that requires cautious preparation and execution of compelling methodologies to limit its ecological effect and advance asset productivity.

All in all, coordinating strong waste administration rehearses into the Triple Main concern system guarantees a thorough assessment of its effect on friendly, natural, and financial perspectives. An all-encompassing way to deal with squander the executives adds to feasible turn of events, addressing the necessities of the present without compromising the capacity of people in the future to address their own issues.

8.2 Literature Review

Finding the essential components for solid waste management success is the primary goal of the literature review in this study. An AHP-based model for the assessment of impact on life of solid waste has been developed using the results of the literature review and the input of an expert panel. The MCDM numerical device known as AHP was first introduced by Saaty in 1980. It separates muddled issues into sensible lumps and orchestrates them in a various levelled structure. Not at all like item life cycle evaluation (LCA), squander life cycle evaluation (LCA) assesses the natural exhibition of a few interrelated squander the board innovations in light of a specific waste creation from the place of waste age to its definitive removal (Gentil et al., 2010).The dynamic cycle is made more troublesome when monetary and social elements are incorporated due to their various units and often clashing objectives. Pointers from these three aspects have been acclimatized by specialists utilizing multi-standards examination (MCA) apparatuses to dependably create a general inclination positioning framework for the proposed other options.

As per De Benedetto and Klemeš (2009), cost and speculation information for various MSW

plan choices should be accumulated simultaneously with a LCA examination to guarantee powerful essential navigation. The financial examination is a troublesome errand due to the wide assortment of treatment plant choices, scale, monetary requirements, and persistently further developing treatment innovation. The intricacy of the LCA monetary plan is acquired by the perplexing and different outflows that should be coordinated with a financial worth. Commonplace financial pointers in the MSW setting incorporate things like the expenses related with building and laying out nonrecurring securing offices, repeating and working expenses, life ranges, innovation, working circumstances, natural effects and discharges, social acknowledgment, usage rates and efficiencies, squander the executives strategies, and so on. The kind of vehicle, the quantity of age hubs, treatment and removal offices, time spans, and distances all influence the expense of transportation. The expenses additionally incorporate energy deals from squander to-energy plants and incomes from recuperated and reused materials. Financial execution pointers incorporate productivity record (PI), inward pace of return (IRR), and old style net present worth (NPV). These are registered utilizing fitting restitution periods, breakeven amounts, deterioration life ranges, and rebate rates.

Applying the cultural BL to the macroeconomic framework, it takes a gander at what a specific civil waste administration system means for individuals living there (Foolmaun and Ramjeeawon, 2012; Reich 2005). To all the more likely comprehend how strategy and strategy producers can be associated with practical improvement that will either work on the social states of partners or at any rate act in a socially capable way, cultural life cycle evaluation plans to recognize tradeoffs (Dreyer et al., 2010; Mittal et al., 2021). There are huge contrasts in the effect of the social aspect on MSW between societies, philosophies, and formative stages. When considered, social pointers can contrast extraordinarily.

More elevated level thoughts of strengthening, association, value, social cohesiveness, institutional turn of events, destitution lightening, and populace security may likewise be incorporated.

8.3 Research Methodology

This study considers both waste created industrially, such as from stores, offices, and businesses, and waste produced locally, i.e., all solid waste originating from residential properties, including garden waste. The methodology aims to evaluate the expected Municipal Solid Waste (MSW) Sustainability Rankings (SRs) corresponding to the ecological, economic, and social pillars of sustainability. The methodology creates a Composite Sustainability Index (CSI) for each MSW SR after calculating the indicators within each Bottom Line (BL).

The eigenvalues can be computed with the formula:

$$\lambda_{\max} = \sum_{j=1}^{n} \frac{a_{ij} w_j}{w_i}$$

where W is the eigenvector and $\lambda_{\max}$ is the largest eigenvalue of the matrix.

Level of Preference	Explanations
1	Preferred equally
3	Preferred moderately
5	Preferred strongly
7	Preferred very strongly
9	Preferred extremely strongly
{2, 4, 6, 8}	Intermediate values

Table 8.1: Saaty's nine-point scale

AHP Methodology

1. Step 1: Clearly define and state the goals of the difficult and unclear problem.

2. Step 2: A survey method or group decision is used to break down the complex problem into a hierarchical structure. There are various levels within the hierarchical structure. The problem's objective is represented by the top level hierarchy. In the next level, this goal is further broken down into a number of criteria. The criteria are further broken

down into levels of sub-criteria that emphasize the specifics of the criteria. The hierarchy is broken down this way until there is no more room for breaking down the sub-criteria.

3. Step 3: A decision matrix can be used to perform a pairwise comparison in order to highlight the relative importance of each criterion. The decision making matrix is built using experts and decision makers, utilizing Saaty's (1994) nine-point rating system, which is displayed in Table III. The components that support a common node in the hierarchical structure are compared to the other components of that node. If a node has "n" elements, for instance, then n (n - 1)/2 comparisons occur under that node.

Environmental Fruitful reusing relies upon the nature of the reused materials and the amount they look like virgin material (Shonfield 2008). To prepare it for the reusing businesses, the MRF gets the 32% of the waste that is recyclable. Paper and cardboard make up 10.5% of the items, trailed by plastic PET jugs (4.8%), glass (4.3%), and metals (2.8%). The MRF residuals (9.5%) and the leftover waste (68%) will be shipped off an incinerator. The incinerator's extras will be unloaded in a landfill. Like SR5, SR6 (Fig. 3d) reuses metal, glass, plastic PET jugs, paper, and cardboard.34.7% of natural waste, including food and wood squander, is treated by fertilizing the soil rather than consuming. Along with treatment extras from fertilizing the soil and reusing, the excess squanders (18.4%) are scorched. The incinerator's extras will be landfilled.

The second the waste enters a MRF, landfill, or incinerator is remembered for the framework limits. As indicated by Goedkoop et al. (2010), the model considers a second-request framework limit, which incorporates all life cycle processes except for discarding capital products and foundation property. Since the transportation costs are no different for each SR, they are excluded. The methodology involves treating the soil or MRF to expect source division for the SRs. The sweltering climate and these boundaries make outflows decline or spread to the dirt. As indicated by the CML 2001 (Leiden 2001), the effect appraisal stage LCIA relegates the subsequent emanations to the fitting natural effect classes.

Table 8.2: Decision Matrix for Environmental Criteria

	PC	GS	RC	CE
PC	1	4	3	0.5
GS	0.25	1	3	0.25
RC	0.33	0.33	1	0.20
CE	2	4	5	1

Economical Civil strong waste technique estimating is an intelligent interaction. This is a result of the significant time-frame skylines of the elaborate expectations, which are connected to the country's coordinated long haul vision for MSW the executives notwithstanding the various variables that impact the amount of waste produced. Among them are the developing populace, moving socioeconomics, and various different things referenced in ECC (2014). Because of this, common next period time series forecasting techniques like seasonal forecasting, moving average, and exponential smoothing produce unreliable results (Armstrong 1985). Since linear regression yielded the most accurate estimates, we used it to extrapolate the MSW generation tonnage for this study. The pairwise comparison between the criteria is as follows:

Table 8.3: Criteria Impacts, Ranks, and Eigenvalues

Cat	Impacts	Rank	(+)	(-)	Eigenvalue
Cost Effectiveness	25.1%	3	5.4%	5.4%	0.25076
Job Creation	29.5%	2	4.3%	4.3%	0.294631
Resource Recovery	35.6%	1	9.6%	9.6%	0.35639
Economic Impact on Local Business	9.8%	4	9.8%	9.8%	0.98213

The equivalent yearly income throughout the span of the venture, addressed by the underlying expense and the possible rescue esteem, is the capital recuperation for some random speculation. Here, P, F, and n represent the office's originally cost, assessed rescue esteem, and assessed administration life, separately. The undertaking's rescue esteem following 50 years is assessed to be 10% in light of the fact that the underlying expense (an administration project)

did exclude land costs. Considering this, the expense per ton for each not entirely settled. The decision matrix comparing the criteria against each other is presented below:

Table 8.4: Decision Matrix

	CE	**JC**	**RR**	**EIB**
CE	1	1	0.5	3
JC	1	1	1	3
RR	2	1	1	3
EIB	0.33	0.33	0.33	1

Social Employment The quantity of workers and the quality of the working environment are the two factors that determine employment. The quantity of employment opportunities that the MSW SR will take advantage of defines the first parameter. The term "working conditions" refers to a range of factors that affect an employee's or individual's working environment, such as amenities, physical surroundings, degree of safety or danger, stress and noise levels, and labor rights (OHS 2015). standard of living The indicators of noise, odor, traffic, and living conditions are used to measure this. It is determined by the quantity of complaints that citizens of the nation or region have filed. The infrastructure pertaining to housing serves as a barometer for living conditions .The main markers of a good living environment are better water quality, availability of hygienic facilities, adequate size, and sturdy structural integrity.

The comparison between the criteria based on their impacts, ranks, and Eigenvalues is presented in the table below:

Table 8.5: Comparison of Criteria Impacts and Eigenvalues

Cat	**Impacts**	**Rank**	**(+)**	**(-)**	**Eigenvalue**
1. Public Health Impact	39.3%	1	9.4%	9.4%	0.392895
2. Community Acceptance	8.0%	4	1.6%	1.6%	0.079956
3. Environmental Justice	34.9%	2	3.0%	3.0%	0.349052
4. Quality of Life	17.8%	3	4.4%	4.4%	0.178097

Table 8.5 shows the detailed comparison among Public Health Impact (PH), Community Ac-

ceptance (CC), Environmental Justice (EJ), and Quality of Life (QOL) based on their impacts, ranks, and both positive (+) and negative (-) contributions, alongside their Eigenvalues.

The decision matrix comparing the criteria against each other is presented below:

Table 8.6: Decision Matrix

	PH	**CC**	**EJ**	**QOL**
PH	1	4	1	3
CC	0.25	1	0.25	0.33
EJ	1	4	1	2
QOL	0.33	3	0.5	1

The decision matrix provides a comparative analysis among the four criteria, indicating how each criterion compares against the others in terms of their relative importance.

8.4 Results and Discussions

To gauge the potential ecological expenses associated with MSW SRs, LCA was completed. Key components of energy, neighbourhood surface geography of land arrangements, and meteorological circumstances were remembered for our review's LCI frontal area and foundation. We found that discharges from the groundwater sub-classification and a piece of the sea subclass are redirected into the dirt by the country's very dry environment, which has low precipitation and a high pace of vanishing, as well as the close by topographical developments of the springs. The investigation uncovered that the genuine effect of abiotic asset consumption could be undervalued by almost 25 per cent while photochemical oxidation and human poisonousness could be undervalued by almost 9 per cent on the off chance that geographical and meteorological variables were not considered. Fertilizing the soil, reusing, and burning are all important for this SR. While considering the neighbourhood topographical arrangement of the surface geology and meteorological states of the country, the examination likewise shows that abiotic exhaustion was most impacted, trailed by photochemical oxidation and afterward human harmfulness.

Scores for the Economical We project the generation of MSW waste for over 30 years into the future, with a focus on the year 2050. For our long-term forecast, linear regressions were the most reliable approach because they generated the least amount of error. The first nonrecurring costs were determined empirically using data from AECOM (2012) and Tsilemou and Panagiotakopoulos (2006). Recurring operational costs comprise energy, laboratory, and raw material expenses,wastewater disposal, labour, supervision, facility maintenance,Insurance, overhead, and training programs (Mittal P et al., 2023).

Scores for the social Section 4 delves into the definition and assessment of social indicators and their sub-themes, drawing on Delhi's (2008) AHP method. Information from focus group discussions was combined with expert opinion and judgment to create the data for the social assessment of the suggested MSW SRs. Researchers, private companies involved in MSW collection and treatment, and executives and experts from Kuwait Municipality Department of Environment comprised the focus groups. The focus group talked about the administrative, social, legal, technical, economic, and physical aspects of various MSW alternatives in relation to the environmental aspects of local businesses. Additionally, previously gathered information from a survey of more than 800 homeowners was provided to the experts. This survey was designed to determine the social and demographic makeup of the waste-generating communities as well as their opinions of the advantages and disadvantages of the current waste management system.

TBL evaluation The computation and standardization of CSI values that were obtained by cross-augmentation are the means by which the TBL assessment is communicated. In this manner, the discoveries exhibit that the territory of Uttar Pradesh is currently ready to recommend an ISWM framework because of the extension of LCA to incorporate both the financial and social perspectives. Nonetheless, on the grounds that the strategy is delicate to squander organization, allocated needs to each BL, the feasibility of natural waste for fertilizing the soil, proficiency of arranging at the source and MRF productivity, nearby circumstances, and waste creation, these outcomes probably won't be ideal for different nations with various financial setting and needs.

Criteria	Eigenvalues
Environmental	4.206
Social	4.062
Economic	4.061

Table 8.7: Eigenvalues of Criteria

8.5 Conclusion

The solutions must be economically and socially acceptable, as well as environmentally viable, in order to develop an integrated and sustainable MSW system. The TBL framework was utilized in this research to facilitate the integrated MSW solutions' sustainability objectives. LCA was done inside the ecological BL as per the ISO 14044 norm to evaluate the conceivable natural weights associated with different MSW the board SRs. The accompanying classifications of natural effect — abiotic exhaustion, fermentation, eutrophication, an Earth-wide temperature boost, human harmfulness, and photochemical oxidation — had their still up in the air. The standardized qualities showed that landfilling is at present the most oppressive of the MSW the board SRs that were thought about. But the most effective SRs were those that combined composting with any other form of treatment, ideally incineration.

Given its heartiness for the long-range arranging skyline for the year 2050, direct relapse was utilized inside the monetary BL to work out figures for MSW age for a long-range arranging skyline. There was a lack of costing data accessible for the material recuperation offices, reusing incomes, and waste treatment offices, requiring broad information mining in both worldwide government reports and distributed writing. These nonrecurring first costs included site portrayal, natural appraisal, hydrogeological study, and land securing designing plan; development costs included clearing the site, exhuming it, building structures, and giving specialized hardware; furthermore, different expenses were incorporated. The yearly repeating functional expenses were additionally considered. These included expenses for work, natural substances, office upkeep, protection, above, and energy.

The societal BL looks at how the residents are affected by a certain MSW management

strategy. The research demonstrated how the social dimension's impact on MSW differs greatly amongst cultural contexts. The subcategories of waste composition and the most recent treatment technologies within each category will be the focus of future research. Further investigation will also focus on conducting more viability studies on financial incentives for the use of recycled and biodegradable materials in industry. Solid waste management is a critical global issue that requires comprehensive strategies to address its environmental, social, and economic dimensions. The integration of the Triple Bottom Line (TBL) framework, along with the application of Analytic Hierarchy Process (AHP), offers a valuable approach for evaluating and improving waste management systems. This study aimed to conduct a TBL assessment of solid waste management, employing AHP as a decision-making tool.

Table 8.8: Criteria Weights and Sub-Criteria Analysis

Criteria	**Sub-Criteria**	**Local Weight**	**Global Weight**
Social (4.062)	Public health impact	0.392895	1.5959
	Community acceptance	0.079956	0.3248
	Quality of life	0.349052	1.4178
	Environmental justice	0.178097	0.7234
Economic (4.061)	Cost effectiveness	0.25076	1.0181
	Job creation	0.294638	1.1965
	Resource recovery	0.35639	1.4472
	Economic impact on local business	0.098213	0.3988
Environmental (4.206)	Political compliance	0.3118421	1.3116
	Governmental support	0.132909	0.5590
	Regulatory compliance	0.076127	0.3201
	Community engagement	0.479122	2.0151

The findings of this research underscore the importance of considering the environmental, social, and economic dimensions in solid waste management. By incorporating the TBL frame-

work, decision-makers can assess the impact of waste management practices on ecosystems, natural resources, human health, and community well-being. The evaluation of environmental effectiveness enables the identification of strategies that minimize environmental impacts, such as waste reduction, recycling, and energy recovery.

The social dimension of waste management is crucial for ensuring equitable access to waste management services and promoting community engagement. Public participation, awareness programs, and social justice considerations contribute to building sustainable waste management systems that address the diverse needs and concerns of communities. By evaluating the social implications within the TBL framework, decision-makers can foster inclusiveness, social equity, and empowerment in waste management practices.

The economic dimension plays a vital role in shaping waste management strategies. Cost-effectiveness, revenue generation, and economic benefits are important considerations in evaluating waste management options. By assessing the economic viability of different strategies within the TBL framework, decision-makers can identify approaches that achieve financial sustainability while also considering environmental and social outcomes. This promotes the adoption of waste management practices that optimize resource recovery, generate employment opportunities, and contribute to overall economic well-being.

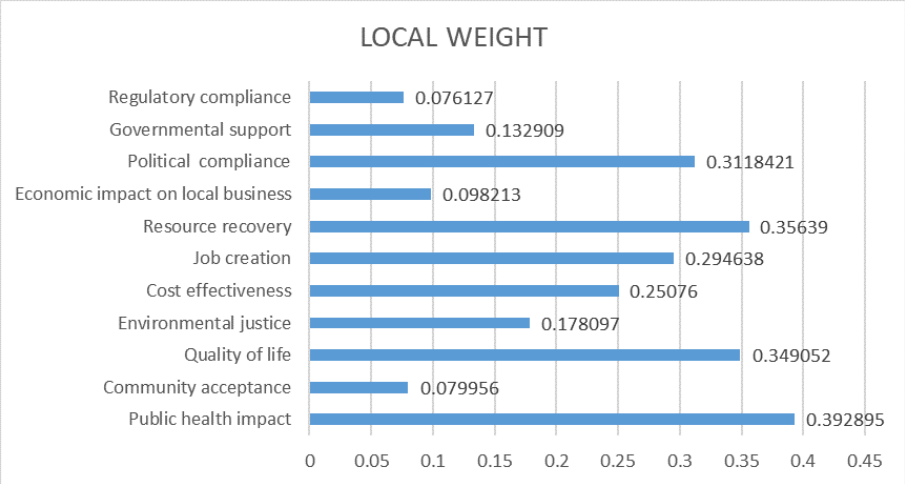

Figure 8.1: Local Weight

The application of Analytic Hierarchy Process (AHP) in the TBL assessment of waste management systems enhances decision-making processes. AHP provides a systematic and transparent methodology for structuring complex problems, prioritizing criteria, and deriving weights based on pairwise comparisons. By incorporating expert opinions, stakeholder inputs, and available data, AHP enables decision-makers to make informed choices and allocate resources effectively. This facilitates a comprehensive evaluation of waste management strategies, leading to more sustainable and balanced decisions.

References

Fatima, S., & Ahmad, N. (2023). Global Supply Chain in Covid-19 Crisis. VEETHIKA-An International Interdisciplinary Research Journal, 9(1), 1–6.

Gentil EC et al (2010) Models for waste life cycle assessment: review of specific doubts. Waste Manag 30:2636-2648

Tiwari, S., Dharwal, M., & Fulzele, R. (2022). An impact of environment on consumer loyalty towards sustainable businesses in India. Materials Today: Proceedings, 60, 911-916.

Dreyer L, Hauschild M, Schierbeck J (2010a) Depiction of social impacts in LCA. Int J Life Cycle Assess 15:247-259

Foolmaun RK, Ramjeeawon T (2012) Relative life cycle assessment and life cycle costing of four expulsion circumstances for used polyethylene terephthalate bottles in Mauritius. Environ Technol 33:2007-2018

Reich MC (2005) Monetary assessment of metropolitan waste organization systems — relevant examinations using a blend of life cycle assessment (LCA) and life cycle costing (LCC). J Clean Urge 13:253-263

De Benedetto L, Klemeš J (2009) The typical show methodology map: an incorporated LCA technique for overseeing help the major strong cycle. J Clean Nudge 17:900-9068.

Mittal, P., Chakraborty, P., Srivastava, M., & Garg, S. (2021, December). The Role of Learning Analytics in Higher Education: A Strategy towards Sustainability. In 2021 International Conference on Computational Performance Evaluation (ComPE) (pp. 614-618). IEEE

Goedkoop M, Schryver Advancement, Oele M, Durksz S, Roest Dd (2010) SimaPro 7 — introduction to LCA with SimaPro. 4.5 edn. PRé Consultants, San Francisco

Shonfield P (2008) LCA of the chiefs decisions for mixed waste plastics. Waste and Resources Action Program and Scott Wilson Ltd, Bandbury