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A SCORING SYSTEM TO EVALUATE THE PERFORMANCE OF ENTITIES AT VARIOUS LEVELS OF A MSW MANAGEMENT SYSTEM

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ABSTRACT
Waste generators, particularly at the household level, waste collectors, and local governments play pivotal roles in municipal solid waste management (MSWM) systems worldwide, especially in developing countries. In the Indian state of Kerala, waste collection has been formalized through a predominantly female workforce known as the Haritha Karma Sena (HKS), which undertakes door-to-door collection of non-biodegradable waste from households. This initiative has significantly enhanced the efficiency of MSWM in the state. To systematically evaluate the performance of HKS and other key stakeholders in the MSWM system, this study proposes a comprehensive scoring system developed using the Delphi method. The framework encompasses twenty parameters across three primary stakeholders: waste generators, Haritha Karma Sena waste collectors, and Local Self Government Institutions (LSGIs). The scoring system is designed to identify critical performance gaps and guide improvements, ultimately enhancing the overall efficiency of MSWM in Kerala. Moreover, this model holds potential for adaptation in other developing countries with similar waste management challenges.

1. INTRODUCTION

The continuous increase in urban population, along with an improvement in their standard of life have led to a substantial rise in the annual generation of municipal solid waste (MSW) (Singh, 2021; Singh, 2023a, b). This rise in generation has necessitated a paradigm shift in the approach to managing MSW the world over. In many countries, municipal solid waste management (MSWM) systems are currently undergoing a transitional phase aimed at safeguarding public health from waste-related hazards while promoting circularity. However, these efforts are often impeded by a lack of reliable, comprehensive, and high-quality data, which are essential for informed decision-making and effective system improvements (Singh, 2025). This situation underscores the need for continuous enhancements and revisions in MSWM systems (Singh, 2024). A performance evaluation system based on suitable indicators becomes important in this context. Such a system helps track progress during the transition, ensures accountability, supports evidence-based decision-making, facilitates benchmarking and standardization, enhances transparency and public trust, and drives continuous improvement.

A review of 63 works spread across four continents (Africa, Europe, America and Asia) and 32 countries identified various performance indicators (PI) for MSWMs that were classified under different heads: technical, environmental, economical, exogeneous, social and institutional (Colivicchi et al., 2025). A study conducted in Nagpur, India, on the evaluation of MSWM systems using Technical Indicators (TI) provided a valuable resource for establishing ground-level support mechanisms and incentive-based schemes, particularly to strengthen the role of the informal sector in MSW management (Singh, 2025). A well-structured scoring system improves the policy decision-making. A study on the effectiveness of construction and demolition waste management (CDWM) across 11 cities in China based on the performance indicators revealed a lack of coordinated development between CDWM outcomes and supporting guarantee systems (Wu, 2024). In a study conducted in Patras, a city in Western Greece, the performance indicators objectively assessed 'Circularity' in MSWM (Emmanouil et al., 2025).The eight indicators, namely, municipal waste generation, municipal waste recycling rate, food waste generation, bio-waste recycling, glass packaging recycling, paper and cardboard recycling, collected quan-

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tities of waste electronics and material reuse rate, were effectively used to measure the extent of circularity in the MSWM of the city. These PIs also showed the bottlenecks in the implementation of Circular Economy (CE)-based MSWM of a city like Patras. Performance indicators offer a good solution to the poor data management that hinders the identification of improvement opportunities and benchmarking of the performance. In a Sri Lankan study of 22 composting stations situated in urban and peri-urban areas, the four composite key performance indicators, General Facility Management Index (GFMI), Composting Process Management Index (CPMI), Compost Quality Index (CQI), and Cost Recovery Index (CRI), helped local authorities to improve the efficiency of MSWM (Manipura et al., 2025).

The Solid Waste Management Rules, 2016, notified by the Government of India, marked a significant policy shift by placing the responsibility for the segregated collection, transportation, treatment, and scientific disposal of solid waste on the Local Self Government Institutions (LSGIs), with a particular focus on urban bodies. In response, several states developed localized waste management frameworks to align with these rules. Among them, the state of Kerala has implemented a notable decentralized and community-centric model through the establishment of the Haritha Karma Sena (HKS).

This study proposes a structured performance assessment framework designed to evaluate the contributions of three principal stakeholder groups within the MSWM system of the state: waste generators (households), waste collectors (HKS personnel), and the regulatory authority (LSGI). The scoring system developed serves not only as a tool for performance benchmarking and accountability but also as an instrument for motivating continuous improvement by identifying best practices and highlighting areas requiring attention.

Unlike many existing scoring systems (Cai et al., 2025, Colivicchi et al., 2025, Manipura et al., 2025) this case-specific scoring system evaluates the performance of an MSWM framework by assessing the efficiency of individual primary stakeholders rather than the system as a whole, thereby enabling more targeted and effective interventions. The framework is designed to be scalable and adaptable across diverse local governance contexts, including panchayats, municipalities, and urban local bodies. Unlike indicators commonly used to assess MSWM systems in developing countries, the proposed method is based on real-time, field-level data. Owing to its reliance on real-time inputs, the scoring system is inherently dynamic and can be effectively applied at different LSGI levels, where responsibilities for waste management and safe disposal are clearly defined under existing legislation. The approach provides a clear, systematic, and replicable methodology that helps in customizing the scoring systems for use in societies with comparable municipal solid waste collection and management practices. By promoting transparency, encouraging behavioural change, and facilitating more effective policy implementation, the proposed model can contribute to the broader objective of achieving sustainable and inclusive solid waste management.

2. METHODOLOGY

2.1 Study area and context of the study

The state of Kerala (Figure 1), laying along the southwest coast of India (8°17'30" N to 12°47'40" N and 74°27'47" E to 77°37'12" E), is divided into 14 major revenue administrative units called Districts. As per census 2011(the last official census to be carried out in India) the total population of the state is 33.41 million with a density of 860/km^2 which is much higher than the national average of 382/km^2. Kerala experiences a tropical climate, characterized by mild winds and heavy monsoon showers. There are three distinct seasons - South-West monsoon (June-September), North-East monsoon (October – December) and summer (March- May). The winter season in Kerala during the months of December to February is not a marked one, compared to other parts of India.

Kerala is among the top states in India with high per-capita Gross State Domestic Product (GSDP) at constant price of ₹1,62,992 in 2021-22, the corresponding national average being ₹1,07,670. The state is known for its success in decentralized planning, devolving power to local democratic entities. The three-tier system of LSGI comprises Gram Panchayats, Block Panchayats, and District Panchayats. In addition, there is separate governing structure for urban centres- Corporations for the major cities and municipalities for the other cities. Presently, Kerala's local self-government framework encompasses 941 Grama Panchayats, 152 Block Panchayats, 14 District Panchayats, 87 Municipalities, and 6 Corporations with a Ward or Division (consisting of 400-450 households) representing the smallest sub-unit of the these LSGIs. The Department of Local Self-Government shoulders the responsibility of orchestrating the activities of these 1200 local bodies.

Central Pollution Control Board (CPCB), the statutory authority that monitors pollution and waste management in India, has reported the MSW generation in the urban and semi-urban areas in the state of Kerala as 3472 TPD in the year 2021-22. The national figure for the year was 1,70,462 TPD. The gap between generation and treatment in Kerala was 781 TPD for this year(MSW_AnnualReport_2021-22 CPCB, n.d.). The annual waste generated, as per the state nodal agency for waste management, the Suchitwa Mission, is 3.7million tonnes (~300 g/person/day). Biodegradable fraction of the waste is 69% and the remaining 31% is non-biodegradable fraction. 79% of the non-biodegradable fraction has got a good calorific value which encourages the state to segregate the waste properly (Suchitwa mission, 2021)

The Government of Kerala has adopted a policy for solid waste management with two strategies:

- Decentralised waste management;
- Centralised waste management wherever necessary.

Figure 2 shows the process flow diagram of the Waste management in Kerala.

The Decentralized Solid Waste Management (DSWM) as conceived in Kerala, is a system involving the segregation and processing of waste at source to the maximum extent possible and then at the community level. There are

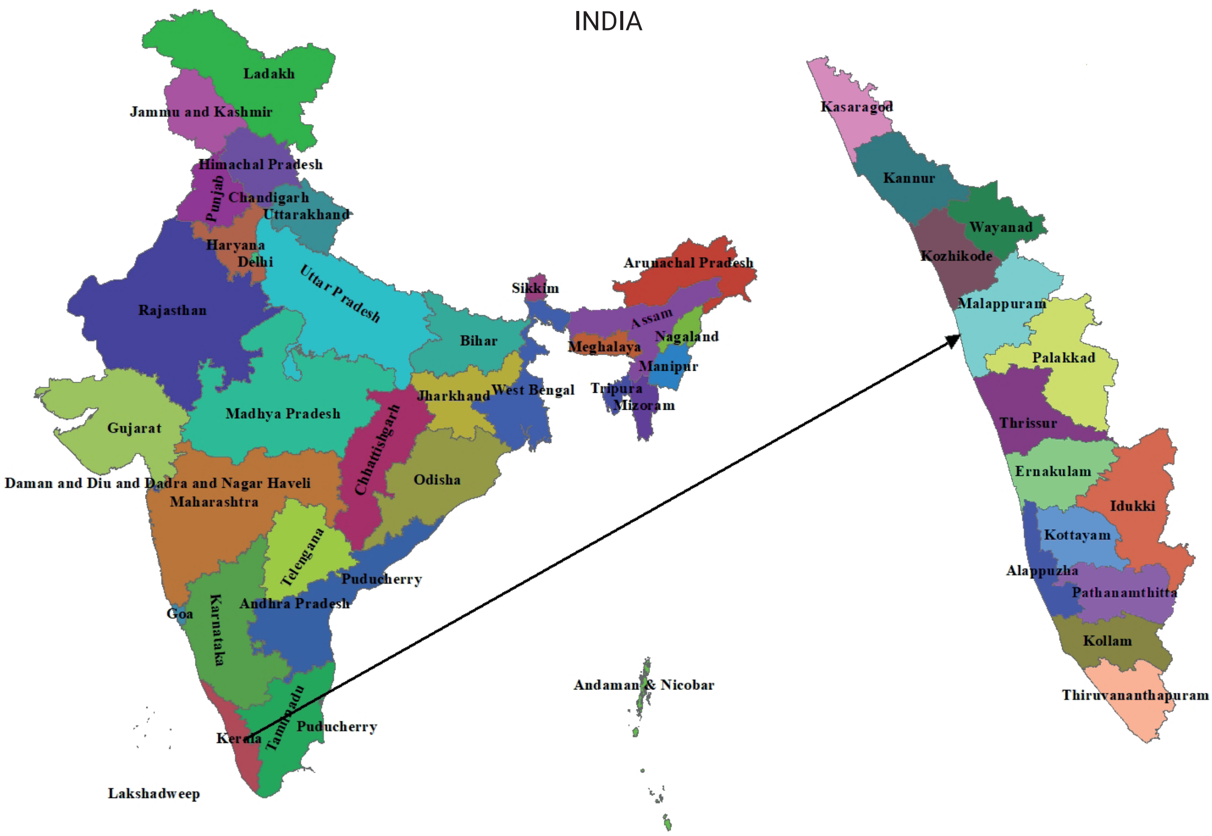

FIGURE 1: State of Kerala in India.

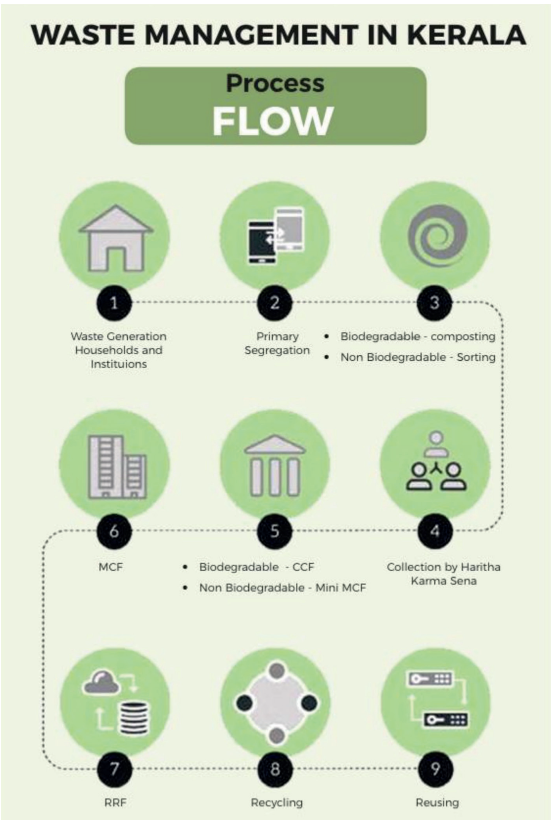

FIGURE 2: Flow diagram of Waste management in Kerala state (Source: Suchitwa Mission, Kerala).

different methods for the treatment of biodegradable and non-biodegradable waste in such a system. While composting and biomethanation are common methods used for treatment of biodegradable waste, non-biodegradable wastes are collected and made available for recycling processes. The aim is to substantially reduce the amount of waste reaching the landfill sites and minimise the associated issues.

2.2 Haritha Karma Sena

The Haritha Karma Sena (HKS, meaning the green work force) in Kerala, is a structured waste management work force operational since 2017 under the Haritha Kerala Mission. It serves as a decentralized, community-driven initiative aimed at enhancing municipal solid waste management (MSWM) at the local level. Comprising primarily women, the HKS operates under the supervision of Local Self Government Institutions (LSGIs). Each LSGI deploys at least a two-member HKS team per ward, managing waste collection from approximately 300 to 500 households monthly.

This model focuses on the door-to-door collection of segregated non-biodegradable waste, followed by the systematic sorting, resource recovery, and channelization of recyclables to authorized units. By promoting the principles of recycling and circular economy, the HKS significantly mitigates landfill dependency and environmental pollution. The HKS model offers valuable insights for replication in other urban and semi-urban contexts across India and other developing countries. Although the initiative has substantially improved waste management practices statewide, the absence of a performance appraisal mechanism impedes a systematic evaluation of the roles and effectiveness of its key stakeholders.

2.3 Procedure for Scoring System development

The stages involved the formulation of the scoring system are:

i. Based on literature survey and discussions with subject experts and officials in charge of the MSWM system, a preliminary scoring system was developed;
ii. The scoring system developed was shared with experts for their inputs through a Delphi process;
iii. Based on the expert inputs, the scoring system was further refined and finalised.

Numerous studies have highlighted that the use of performance indicators can significantly enhance the effectiveness of municipal solid waste management (MSWM) systems by enabling systematic evaluation and continuous improvement. In the present study, a preliminary scoring framework was developed through consultations with 25 experts, including academic researchers and field-level practitioners involved in MSWM in the state of Kerala. The expert panel comprised 13 academics actively engaged in teaching and research on MSWM and 12 field-level professionals involved in the implementation of MSWM systems at the local level. The experts possessed professional experience ranging from 8 to 15 years in the field. The framework aimed to assess the performance of three key stakeholder groups: household-level waste generators, Haritha Karma Sena (HKS)- the waste collectors, and the LSGIs responsible for coordination and oversight.

The initial framework was structured around nine main criteria and 24 sub-criteria, covering various dimensions of stakeholder performance. To validate and refine these indicators, a two-round Delphi method was employed. A panel of 15 waste management experts was invited to evaluate the relevance and applicability of each criterion and sub-criterion for inclusion in the final scoring system. A consensus threshold was applied, whereby any sub-criterion receiving over 50% of responses indicating irrelevance was excluded from the framework. This ensured that the final system retained only those indicators considered meaningful, widely accepted, and practically applicable.

Based on expert feedback, two sub-criteria—namely, “training attendance” under the HKS based waste picker stakeholder group and “infrastructure availability” under the LSGI stakeholder group—were excluded due to limited perceived relevance. The finalized scoring framework thus consisted of 22 sub-criteria distributed under nine main criteria. Each indicator was defined using quantifiable parameters, which were subsequently rated and assigned weights, resulting in a robust and adaptable performance assessment tool for evaluating decentralized MSWM systems.

3. RESULTS AND DISCUSSION

3.1 Scoring System

The scoring system for the key stakeholders- waste generators, waste pickers and LSGIs- was formulated based on clearly defined criteria and sub-criteria that reflect their specific responsibilities, such as waste segregation, service quality, operational efficiency, and resource management. By converting day-to-day practices into measurable indicators, the system provides a transparent and standardized method to monitor, compare, and improve waste management outcomes.

Table 1 gives the identified criteria for evaluating the HKS based MSWM in the state of Kerala after expert opinion survey findings and following a due process in the Delphi analysis. After these criteria identification, the next step was to develop a scoring system based on these criteria.

3.2 Waste Generators

Household-level waste generators are one of the primary stakeholder groups in MSWM. A dedicated scoring system was developed to assess their performance, structured around three main criteria and nine sub-criteria.

3.2.1 Waste Generation

The first main criterion identified for evaluating household-level waste generators was ‘waste generation’. This was assessed using two sub-criteria: Per Capita Generation Score (PGS) and Efforts to Reduce Waste (ERW). The PGS indicator measures the average quantity of non-biodegradable waste (NBW) generated per person per day within a household. It serves as a direct metric to quantify waste generation behaviour. Households were scored based on their PGS values, using the following scoring equation:

$$PGS = \text{Total NBW for N days}/N*\text{household size} \quad (1)$$

The second sub-criterion, Efforts to Reduce Waste (ERW), evaluates the initiatives undertaken by households to minimize waste generation at the source. This includes practices such as reducing packaging, reusing materials, and adopting low-waste lifestyle choices. The Waste Reduction Score (WRS) was developed to quantify these efforts, using the following equation:

$$WRS = \text{Practices adopted by household}/\text{Total applicable practices} \quad (2)$$

The list of practices and its evaluation method is described in the Table 2.

3.2.2 Segregation

Household-level segregation of non-biodegradable waste (NBW) was assessed using four sub-criteria: segregation accuracy, segregation consistency, availability of required bins, and a segregation quiz. The scoring system was developed for the first three sub-criteria, while the segregation quiz is designed to be conducted quarterly at the household level to evaluate improvements in residents’ knowledge of waste management practices. The Segregation Accuracy Score (SAS) measures how accurately

TABLE 1: List of stake holders and the criteria for the evaluation.

Stake holder	Main Criteria	Sub criteria	Score name
Waste Generators	Waste generation	Per Capita Generation	Per Capita Generation Score (PGS)
		Efforts to reduce waste	Waste reduction score (WRS)
	Segregation	Accuracy	Segregation accuracy Score (SAS)
		Consistency in segregation	Consistency score (SCS)
		Presence of required bins	Bin availability score (BAS)
		Segregation quiz	Quiz (SQS)
	Handling Habits	Pre-treatment of Waste	Pre-treatment Score (PTS)
		Avoidance of littering and open dumping	Littering Avoidance Score (LAS)
		Timeliness of Disposal	Timeliness of Disposal score (TDS)
Waste Collectors	Service Quality	Collection Coverage Rate	Collection Coverage Score (CCS)
		Mismatch Error	Quantity mismatch score (QMS)
		On Time Collection Rate	On Time Collection Score (TCS)
	Interactions with Generators	Household Satisfaction	Household Satisfaction score (HSS)
	Interaction with Authorities	Timely execution of duties	Timely execution score (TES)
LSGI authorities	Support for Collectors	Timely disbursement of wages	Wage timeliness score (WTS)
		Provision of equipment	Equipment availability score (EAS)
		Adequate working conditions	Adequate working conditions score (WCS)
	Handling of collected waste	Recycling rate	Recycling rate score (RRS)
		Facility downtimes	Facility Downtime score (FDS)
	Resource management	Budget utilization	Budget utilization Score (BUS)
		Staff strength	Staff strength Score (SSS)
		Issues resolved	Issues resolved score (IRS)

households separate waste into the appropriate categories (e.g., organic, recyclable, non-recyclable). The Segregation Consistency Score (SCS) assesses the regularity with which proper segregation practices are maintained. The Bin Availability Score (BAS) evaluates whether households possess the necessary color-coded bins corresponding to different waste categories. The Segregation Quiz Score (SQS) will be arrived based on the number of correct answers provided by the households.

The scoring equations for these sub-criteria are as follows:

Segregation Accuracy Score (SAS) = Number of categories household segregates into/ Number of waste types generated by the household (3)

TABLE 2: List of practices for waste reduction at source.

Practice	Example	Verification
1) Reduction of Single- use Plastics	Avoiding plastic bags, disposable cups, etc.	Spot check
2) Use of Reusable Bags, Containers & Bottles	Cloth totes, steel lunchboxes, glass containers	Spot check
3) Buying in Bulk to Reduce Packaging Waste	Buying whole grains in bulk instead of packaged items	Spot check
4) Repair and maintenance of Electronics	Reusing old phones, participating in take-back or swap programs	Verify records/physical verification
5) Donation & Reuse of Clothes and Other Items	Donating unused clothing and items to charity	Proof of donation (receipt/photo) / spot check
6) Use of natural cleaning	Using homemade detergents, Vinegar-based cleaners etc.	Spot check
7) Reducing paper usage	Using digital copies instead of printed	Spot check
8) Avoidance of Overpacked & Disposable items	Preferring loose vegetables, avoiding individually wrapped items	Spot check (packaging/unnecessary wrapping)
9) Repurposing & Upcycling Items Instead of Discarding	DIY projects using waste material, converting old clothes into bags	Spot check survey/verification
10) Composting of Organic Waste (Only if Applicable)	Backyard composting	Physical check
11) Participation in Community Waste Reduction Initiatives	Zero-waste workshops, swap shops, repair cafés	Survey

SCS = Days with correct segregation/Total collection days (4)

BAS = Bins available/Bins needed (5)

SQS = Questions answered correctly/Total number questions asked (6)

3.2.3 Handling Habits

The handling habits of households were evaluated using three sub-criteria: (i) pre-treatment of waste, (ii) timely disposal of generated waste, and (iii) avoidance of littering in the surroundings. The Pre-Treatment Score (PTS) assesses whether households perform any preparatory actions—such as washing, drying, or compressing waste—prior to disposal. The Timely Disposal Score (TDS) measures the promptness with which waste is disposed of according to the scheduled collection days. In calculating the TDS, the number of days during which waste was ready for collection is compared against the total number of scheduled collection opportunities within the review period. The third and final sub-criterion, Avoidance of Littering and Open Dumping, evaluates adherence to proper waste disposal practices. The Littering Avoidance Score (LAS) will be calculated based on the littering instances noticed in and around the housing premises during the household visits for the collection of waste.

The scoring equations are as follows:

PTS = Amount of waste Pre-treated/Total amount of pre-treatable waste generated (7)

TDS = Timely disposal/Total disposal opportunities (8)

LAS = No of littering instances/Total number of inspections (9)

The final score for the household level waste generators, Waste Generator Score (WGS) as described in equation 13, will be a proctored fraction score between 0 and 1 and will be arrived based on the three main-criteria score as described in equation 10, 11 and 12.

Waste generation Score = (PGS+WRS)/2 (10)

Segregation Score = (SAS + SCS + BAS + SQS)/4 (11)

Handling habit Score = (PTS +TDS + LAS)/3 (12)

Waste generators(Households) Score (WGS) = (Waste generation score +Segregation score + Handling habits score)/3 (13)

3.3 Waste Collectors

The performance of HKS-based waste collectors was evaluated using three key criteria: service quality, interaction with waste generators, and interaction with local authorities. A scoring system was developed to assess these dimensions comprehensively.

3.3.1 Service quality

Service quality of HKS-based waste collectors was assessed using three sub-criteria: collection coverage, on-time collection rate, and mismatch error. The Collection Coverage Score (CCS) represents the percentage of households receiving waste collection services. The on-time collection will be assessed based on the Timely Collection Score (TCS) which measures the punctuality and adherence of collection activities to the scheduled timings. The mismatch error will be evaluated as Quantity Mismatch Score (QMS) which monitors instances of incorrect waste collection or missed pickups. The scores for these sub-criteria were calculated using the following equations:

Collection coverage score (CCS) = Household served/Total household assigned (14)

Timely collection score (TCS) = Total collections on time/Total schedule collections (15)

Quantity Mismatch Score (QMS) = Total weight of waste from households/Total weight of waste at collection centre (16)

3.3.2 Interaction with Generators

Interaction with household-level waste generators was evaluated using a single sub-criterion, the Household Satisfaction Score (HSS), which gathers feedback from households to assess the quality of service and responsiveness of waste collectors. The HSS was calculated using the following formula:

HSS = (households satisfied/total household surveyed) (17)

3.3.3 Interaction with Authorities

This sub-criterion was evaluated through the Timely Execution of Duties Score (TES), which measures how promptly and effectively collectors perform their assigned responsibilities.

TES = (actual time taken for duty/Time allotted for duty) (18)

The final score for the HKS based waste pickers, Waste Picker Score (WPS) as described in equation 20, will be a proctored fraction score between 0 and 1 and will be arrived based on the three main-criteria score as described in equation 17, 18 and 19.

Service quality Score = (CCS+TCS+QMS)/3 (19)

Generators interaction Score = HSS
Authority interaction Score = TES

Waste Pickers, HKS, Score (WPS) = (Service quality score + Generators interaction score + Authority interaction score)/3 (20)

3.4 LSGI Authorities

The Local Self Government Institutions (LSGIs), which support the Haritha Karma Sena (HKS) and oversee the implementation of municipal solid waste management (MSWM), shall also be evaluated in this system. Their role in relation to both waste generators and waste collectors was assessed using a scoring system developed around three main criteria, further detailed by six sub-criteria.

3.4.1 Support for Collectors

LSGI support for waste collectors was evaluated based on three sub-criteria: timely disbursement of wages, equipment availability, and adequate working conditions. The Wage Timeliness Score (WTS) assesses whether payments to collectors are made punctually, as verified through payroll records and wage receipts. The Equipment Availability Score (EAS) measures the provision of necessary tools and protective gear to collectors. Lastly, the Adequate Working Conditions Score (WCS) evaluates the overall work environment with respect to safety, hygiene, and institutional support. The WCS was calculated using criteria outlined in Table 3.

The score equations are as follows:

WTS = Wages paid on time/Total wages due (21)

EAS = Total equipment provided/Total equipment required (22)

WCS = score for no. of conditions satisfied/maximum score (23)

3.4.2 *Handling of Collected Waste*

The efficiency of Local Self Government Institutions (LSGIs) in handling collected waste was assessed using two sub-criteria: the Recycling Rate Score (RRS) and the Facility Downtime Score (FDS). The RRS quantifies the percentage of non-biodegradable waste (NBW) that is effectively recycled, reflecting the success of resource recovery efforts. The FDS evaluates the operational efficiency of waste processing facilities by tracking their downtime during the assessment period. The equations used to calculate these scores are provided below:

RRS = Recycled waste/Total Recyclable waste (24)

FDS = No. of days facilities were down/Total no. of operations days (25)

3.4.3 *Resource Management*

Resource management at the LSGI level, with respect to both waste generators and collectors, was evaluated using four sub-criteria. The Budget Utilization Score (BUS) measures how effectively the allocated funds for waste management are utilized. The Staff Strength Score (SSS) assesses the adequacy of staffing levels and the efficiency of workforce management. Additionally, the effectiveness of addressing operational challenges within the MSWM system was assessed through the Issue Resolving Score (IRS), which compares the number of issues reported to those resolved. The final scoring equations for these sub-criteria are presented below:

BUS= (Fund spent/Total fund allotted in Budget) (26)

SSS= (Active work force/Total work force required) (27)

IRS = (Issues reported/issues resolved) (28)

The final score for the LSGI authority, LSGI Score as described in equation 32, will be a proctored fraction score between 0 and 1 and will be arrived based on the three main-criteria score as described in equation 29,30 and 31

Support Score = (WTS+EAS+WCS)/3 (29)

Handling Score = (RRS+FDS)/2 (30)

Resource management Score = (BUS+SSS+IRS)/3 (31)

Final score of the LSGI Authority, LSGI Score = (Support Score + Handling score + Resource management score)/3 (32)

3.5 Weightage to Scoring system

Each main-criterion for the three key stake holders was then distributed among Seven field level experts for arriving a weightage to each of the main criterion in the implementation at the field level. The weights so assigned is summarised below

3.5.1 *Waste Generators*

The experts have the opinion of giving equal weightage to the two main criteria namely waste generation and segregation and a lesser weightage to handling habits. Accordingly, the weights assigned by the experts was as follows

Waste generation = 0.4
Segregation = 0.4
Handling habits score = 0.2

Hence the equation given 13 was modified as:

WGS = (0.4*Waste generation Score + 0.4*Segregation Score + 0.2*Handling habits Score)

3.5.2 *Waste collectors*

The experts were of the opinion that Service quality must be given a higher weightage than the other two criteria and the weights assigned based on the feedback of experts are as follows:

Service quality = 0.50
Generators interaction = 0.25
Authority interaction = 0.25

The final equation given in 20 was modified as below:

WPS = (0.5*Service quality score + 0.25*Generator interaction score + 0.25*Authority interaction score)

3.5.3 *LSGI Authorities*

The opinion of the experts was that all the three criteria can be given an equal weightage so that the entire system functions effectively and efficiently and hence the equation given in 32 is valid after assigning a weightage.

During the initial phase of implementing the scoring system, equal weightage was assigned to each sub-criterion score. The average of these sub-criteria scores was

TABLE 3: Adequate working conditions.

Factors	Assessment Criteria	Score
Wage & Benefits	Above min wage with benefit	3
	Min wage with no benefit	2
	Below min wage	1
Access to Medical Checkups	Regular health checkups	3
	Irregular checkups	2
	No medical support	1
Workload Feasibility	Fair workload per worker	3
	Slightly overloaded	2
	Highly overloaded	1
Rest Breaks & Facilities	Adequate breaks & rest areas	3
	Few breaks	2
	No rest facilities	1
Ventilation & Air Quality at work	Proper ventilation & temperature	3
	Some ventilation	2
	No ventilation & uncomfortable working temperature	1

calculated to determine the score for each main criterion, which was then averaged to produce a final performance score for each stakeholder group. The scoring system is designed to be dynamic; sub-criteria scores will be monitored regularly, and as improvements are observed in specific sub-criteria, differential weightage will be assigned accordingly. This adaptive weighting approach aims to incentivize continuous improvement and enhance the overall efficiency of the MSWM system.

The performance of the three key stakeholders—namely household-level waste generators, HKS waste collectors, and the LSGI authority—will be qualitatively ranked using a five-level scale, as presented in Table 4, based on their respective final scores.

3.6 Discussion

The current study developed a scoring system for the main MSWM stakeholders, including waste producers, waste collectors, and local governments that carry out and are accountable for the safe disposal of waste in accordance with current national regulations. This decentralized scoring approach, which evaluates each stakeholder using a primary criterion and a sub-criterion, aids in identifying each stakeholder's weaknesses and evaluating the stakeholder's performance based on their functionality.

This strategy encourages long-term environmental, economic, and social sustainability within MSWM systems and enables more informed decisions, as demonstrated by a performance assessment model study carried out in Qassim Province, in the central region of the Kingdom of Saudi Arabia, Alhumid (2019). This scoring system functions as an effective tool for benchmarking municipal solid waste management practices in various local bodies. Additionally, the current study highlighted how these variables allow for comparisons across towns inside and within administrative regions.

These scores in the 22 parameters are useful not only for the local organizations that implement the MSWM but also for analyzing the state's administrative districts' performance. This method will be helpful for identifying the gaps in each district and for a statewide integrative approach to the MSWM system. Waste management operations in the state of Kerala are overseen and guided by the designated nodal agency, Suchitwa Mission (www.suchitwamission.org). The same agency could also oversee the implementation of the proposed scoring system. In this role, Suchitwa Mission may be responsible for conducting evaluations, providing feedback, recommending improvements, and instituting recognition mechanisms, such as awards, to acknowledge best-performing local bodies or stakeholders across various categories.

TABLE 4: Performance assessment of key stake holders.

Score of stake holder	Performance of key stake holders
Greater than 0.85	Excellent Performance
0.7 – 0.85	Good Performance
0.5 – 0.7	Average Performance
0.3 – 0.5	Below Average Performance
Less than 0.3	Poor Performance

The proposed scoring system shall also be useful in addressing the state's restricted landfill capacity as a result of its dense population and in advancing the development of an MSWM system that is more focused on the circular economy. A similar case is addressed in a study carried out in the city of Jakarta which confronts pressing municipal solid waste management (MSWM) issues, with limited landfill capacities and rampant illegal dumping in slum and non-slum areas, exacerbating land consumption challenges (Suryawan & Lee, 2024). The study used twelve indicators across five adaptive capacity dimensions, correlating them with the Importance-Performance (I-P) metrics and the participant demographics. This study helped both slum and non-slum communities to underscore the importance of bolstering the circular economy and waste segregation. While a pronounced awareness regarding waste treatment was observed among non-slum residents, the individuals from slum locales indicated a greater need for focused encouragement and resources to engage in waste segregation initiatives effectively. The insights from this study are pivotal for urban planners, policymakers, and scholars. Using the stakeholders' scores, our study evaluates the performance of important MSWM system participants in the state of Kerala. More involvement in source-level waste management is encouraged by this scoring system, which also makes it possible to identify operational inefficiencies and implement data-driven ward-level improvements. Incentive mechanisms like tax rebates can be devised. The LSGI Score shall serves as a benchmark for assessing LSGIs' performance throughout the state. This score makes it possible to identify systemic issues and provides guidance for focused activities meant to improve Kerala's MSWM framework as a whole.

The state of Kerala's implementation of the HKS system, which formalized waste collection, represents a new change in MSW management that can be embraced by developing nations worldwide. The scoring system established for the HKS can be utilized as measure of the formalisation in the MSWM which is absent in the system when the globe is moving towards a Circular Economy (CE) based MSWM

The present study also has certain limitations. Methodological constraints include the exclusion of stakeholders' perspectives during the development of the grading system and the relatively small number of experts (n = 25, for criteria identification, n=7 for assigning weights to criteria) involved in the Delphi process. In addition, the limited participation of specialists in the system development discussions may have restricted the identification of more comprehensive and contextually relevant parameters in the initial framework. Another limitation is the context-specific nature of the scoring system, which was developed for an MSWM system that rely on manual door-to-door collection of non-biodegradable solid waste in response to a legal requirement. An operational limitation of the study is the absence of rigorous field testing of the scoring system.

Future studies may focus on improving the proposed scoring system by addressing the identified limitations and by incorporating sustainability considerations into key parameters such as waste composition, waste streams, and technical capabilities. Evidence from a case study conducted in Istanbul, Turkey (Ak & Braida, 2015) suggests that such integration can significantly enhance municipal solid waste management. This approach may facilitate the identification of best practices while promoting accountability and continuous improvement among local authorities. Additionally, the applicability and effectiveness of the scoring system as a tool for assessing circular economy components within MSWM warrant further investigation. The evaluation of MSWM systems and their stakeholders could also be strengthened by applying the scoring system within an implementation–feedback framework, followed by iterative revisions based on field-level outcomes.

4. CONCLUSIONS

A scoring system focused on household waste management can provide significant value by identifying low-performing households within a community and establishing clear benchmarks for improvement. Beyond individual assessment, such a system has the potential to foster a competitive spirit among households and communities, motivating collective efforts to enhance waste management practices and achieve higher performance scores. This framework evaluates multiple dimensions of waste management, including waste segregation, collection efficiency, recycling efforts, and community participation. By quantifying key performance indicators, the scoring system offers a transparent and objective means to monitor progress, recognize achievements, and guide targeted interventions to strengthen overall municipal solid waste management.

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