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A MULTI-CRITERIA DECISION-MAKING ANALYSIS OF WASTE MANAGEMENT PRACTICES IN HISTORICAL SMALL TOWNS: THE TAURASI CASE STUDY

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ABSTRACT. This study employs multi-criteria decision making (MCDM) methodology to evaluate waste management alternatives for historical small towns (HSTs), using Taurasi, Italy as a representative case study. HSTs face distinctive challenges implementing sustainable waste systems due to spatial constraints, heritage preservation requirements, and limited administrative resources. The research applies Analytic Hierarchy Process (AHP) to determine criteria weights across environmental, economic, heritage compatibility, and social dimensions, followed by TOPSIS analysis to evaluate four waste management alternatives: Enhanced Organic Management, Viticultural Waste Valorization, Collection System Adaptation, and Inter-municipal Collaboration. Results identify Enhanced Organic Management as the highest-ranked alternative (proximity coefficient 0.697), followed by Viticultural Waste Valorization (0.643), though sensitivity analysis reveals significant ranking variations across different weighting scenarios. The analysis illuminates fundamental tensions between environmental performance and heritage compatibility, with approaches demonstrating superior resource recovery frequently presenting greater challenges regarding historical landscape integration. Integration potential analysis suggests complementary implementation pathways combining Collection System Adaptation's heritage compatibility with the resource recovery advantages of organic-focused approaches. This research contributes methodologically to circular economy implementation in heritage contexts through a structured evaluation framework specifically calibrated to HST characteristics, providing practical guidance for municipal administrators, waste management companies, and heritage preservation authorities navigating sustainability transitions while preserving historical character.

1. Introduction

Sustainability has emerged as a central concern for societies confronting increasingly complex challenges related to resource scarcity, climate change, and ecosystem degradation. These challenges manifest with particular intensity in urban contexts, where concentrated human activities generate significant environmental pressures through waste production, energy consumption, and material throughput (Kennedy, Cuddihy, and Engel-Yan 2007; Ioppolo *et al.* 2014). The transition toward more sustainable resource management systems represents not merely an environmental imperative but a fundamental prerequisite for

long-term socio-economic stability. Within this broader sustainability landscape, waste management emerges as a critical domain where substantial environmental improvements remain achievable through reconfiguration of existing systems toward circularity principles that transform waste streams into valuable resources (Korhonen *et al.* 2018).

Historical Small Towns (HSTs) constitute a distinctive urban typology that merits specific attention within sustainability discourse. These settlements, characterized by rich cultural heritage, distinctive architectural profiles, and often complex socio-economic challenges, represent unique components of European territorial systems. In Italy alone, HSTs cover approximately 54% of the national territory and account for 16% of the population, with many facing persistent challenges including demographic decline, economic stagnation, and infrastructure deterioration (Romano, Del Vecchio, and Passiante 2021). The sustainable development of these settlements presents both peculiar opportunities and challenges that differ substantially from those encountered in larger metropolitan areas or modern urban contexts (Ioppolo, Saija, and Salomone 2012).

Sustainability transitions in HSTs offer pathways to address multiple intersecting challenges simultaneously. Enhanced resource efficiency may reduce environmental impacts while generating economic benefits through cost savings and new material valorization opportunities. Improved waste management systems can enhance environmental quality while strengthening local resilience through reduced external dependencies. At a broader scale, such transitions may contribute to territorial revitalization through creation of specialized employment opportunities, enhancement of tourism attractiveness, and preservation of distinctive local identities that distinguish these settlements within increasingly homogenized global landscapes (Fusco Girard and Nocca 2019).

The application of sustainable development principles in HST contexts faces particular challenges that necessitate specialized approaches rather than generic solutions developed primarily for modern urban environments. Unlike contemporary settlements designed around automotive mobility and industrial production, HSTs typically feature compact urban forms with narrow streets, complex historical fabric, and intricately layered building stocks that complicate infrastructure modifications. Heritage preservation imperatives create additional constraints regarding visual impacts, architectural integrity, and cultural significance that must be balanced with sustainability objectives. Demographic challenges including population decline and aging further influence implementation capacities, necessitating approaches aligned with local resources and capabilities (D'Amico *et al.* 2021).

Waste management in HST contexts presents particular complexity due to the direct intersection between material flows, heritage considerations, and spatial constraints. Conventional waste management strategies may prove difficult to implement given limited space for collection infrastructure, restricted vehicle access in narrow historical streets, and aesthetic concerns regarding system visibility. The distinctive waste generation patterns in HSTs, often characterized by significant seasonal fluctuations due to tourism activities and substantial organic fractions from traditional food systems, further necessitate tailored approaches rather than standardized solutions (Thompson, Friess, and Roth 2021).

Promising pathways for enhancing sustainability in HST waste management systems emerge from several complementary approaches. The adaptation of collection systems to historical urban morphologies through smaller vehicles, specialized container designs,

and temporally optimized collection schedules represents one dimension. Another involves development of appropriate-scale processing infrastructure that transforms organic waste streams into valuable agricultural inputs while respecting heritage constraints. Intermunicipal collaboration that achieves necessary economies of scale while respecting individual settlement identities offers additional possibilities. These approaches require systematic evaluation to identify optimal configurations for specific contexts (D'Amico *et al.* 2020; Ravetz, Fertner, and Nielsen 2021).

This paper addresses the research gap regarding systematic evaluation frameworks for waste management alternatives specifically calibrated to HST contexts. The absence of specialized decision support frameworks for HST waste management creates implementation barriers by forcing stakeholders to navigate complex trade-offs without structured evaluation methodologies aligned with their specific constraints and opportunities. Multi-Criteria Decision Making (MCDM) approaches offer promising methodological foundations for addressing this gap through structured evaluation of alternatives across multiple dimensions relevant to HST contexts.

The research aims to develop and apply a specialized MCDM framework for evaluating waste management alternatives in the HST context using Taurasi, Italy as a case study. Taurasi represents a Hill Borgo (398m elevation) with medieval origins and an agricultural economic base primarily focused on viticulture. With approximately 2,092 inhabitants, the town exhibits demographic trends common to many HSTs, including population decline (-1.36% annual average from 2017–2022) and an aging population (average age 47.5 years). The town generates 742.82 tons of waste annually, with a differentiation rate of 67.77% (Romano, Del Vecchio, and Passiante 2021). This context provides an ideal environment for examining how waste management systems can be optimized to balance technical performance, economic feasibility, and heritage preservation requirements.

The specific research questions include: (i) What criteria most effectively capture the multidimensional nature of waste management in HST contexts? (ii) How do different waste management alternatives perform across these criteria in Taurasi's specific context? (iii) What implementation pathways might optimize both resource efficiency and heritage preservation in similar contexts?

The managerial implications of this research extend beyond academic contribution to provide practical guidance for different stakeholder groups engaged in HST waste management. For municipal administrators in historical towns, the developed framework offers a structured decision support tool applicable to their specific context, enabling more effective navigation of complex trade-offs between environmental performance, economic feasibility, and heritage preservation. Waste management companies gain insights regarding service adaptation requirements for historical contexts, potentially enhancing operational efficiency while improving contextual compatibility. Heritage preservation authorities benefit from evaluation frameworks that systematically incorporate protection considerations alongside technical performance, potentially reducing implementation conflicts through more integrated planning approaches.

The remainder of this paper is organized into four main sections. The Materials and Methods section details the methodological framework employed, including criteria development, alternative definition, and evaluation procedures specifically adapted to the HST context. The Results section presents the performance assessment of different waste management

alternatives across multiple criteria, highlighting strengths and limitations of each approach in Taurasi's specific context. The Discussion examines broader patterns emerging from the analysis, comparative performance across different criteria categories, and implementation considerations for optimal approaches. Finally, the Conclusions summarize key findings while identifying both theoretical contributions and practical applications for HST waste management.

2. Materials and Methods

The methodological approach employed in this study centers on MCDM, specifically the Analytic Hierarchy Process (AHP), to evaluate waste management alternatives for Taurasi, a HST characterized by viticultural traditions. AHP provides a structured framework for complex decision-making that involves multiple criteria and alternatives.

The AHP methodology follows a hierarchical structure with four distinct levels. The apex represents the overall goal of achieving optimal waste management for Taurasi. The second level comprises main criteria categories including environmental, economic, heritage, and social dimensions. The third level contains specific sub-criteria within each category, while the fourth level presents alternative waste management approaches for evaluation.

The mathematical process employs pairwise comparisons using Saaty's 1–9 scale. This scale ranges from equal importance (1) to extreme importance (9), with intermediate values representing varying degrees of preference. For each set of criteria, a square matrix A is constructed where element a_{ij} represents the relative importance of criterion i compared to criterion j.

Priority vectors are calculated by normalizing the matrix and averaging across rows. This can be expressed mathematically as:

$$w_i = \frac{\sum_{j=1}^{n} m_{ij}}{n} \tag{1}$$

The consistency of judgments is validated using the Consistency Ratio (CR):

$$CR = \frac{CI}{RI} \tag{2}$$

where CI is the Consistency Index calculated as:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \tag{3}$$

$\lambda_{\max}$ is the principal eigenvalue of the comparison matrix and is computed as:

$$\lambda_{\max} = \frac{\sum_{i=1}^{n} \left(\sum_{j=1}^{n} a_{ij} w_j \right)}{w_i} \tag{4}$$

RI is the Random Index for matrices of order n. A CR value less than 0.1 indicates acceptable judgment consistency (Saaty 1980).

Waste management data for Taurasi was obtained through interviews with local administration officials and publicly available information. These sources provided the basic waste generation figures (742.82 tons annually) and differentiation rates (67.77%), along with the breakdown of main waste streams. The analysis identified a substantial organic fraction (259.62 tons, representing 51.6% of differentiated waste), significant glass collection (91.66

tons, 18.2% of differentiated waste), plastic (40.52 tons), paper/cardboard (37.22 tons), and bulky waste (42.86 tons).

To understand the physical context, simple in-site observations were conducted to assess the town's infrastructure. These observations noted the narrow streets, historical buildings, and spatial constraints typical of a Hill Borgo with medieval origins. Such physical characteristics create practical limitations for waste collection vehicles and infrastructure placement that must be considered when evaluating management alternatives.

The criteria for evaluating waste management alternatives were developed based on the town's specific characteristics and discussions with key stakeholders. The main criteria categories include environmental, economic, heritage compatibility, and social dimensions. Environmental criteria encompass resource recovery potential, emissions reduction, and broader environmental impacts. Economic criteria address implementation costs, operational costs, and potential revenue generation. Heritage compatibility criteria evaluate visual impact on the historical landscape, compatibility with town character, and cultural integration. Social criteria consider community acceptance, convenience for residents, and educational value.

Criteria weights were determined through discussions with relevant stakeholders in Taurasi, including the mayor, representatives from farming communities (particularly wine producers), and cultural associations. These conversations identified priorities and preferences that were translated into relative importance ratings within the AHP framework. The stakeholder input provided essential context regarding local priorities, particularly the balance between economic feasibility, heritage preservation, and environmental performance.

Based on Taurasi's characteristics as a historical town with viticultural traditions, several waste management approaches were considered for evaluation. The first approach focuses on enhanced organic waste management addressing the substantial organic fraction (259.62 tons) through community-scale composting or biological processing. The second approach emphasizes local valorization of viticultural waste, addressing the specific needs of Taurasi's predominant economic sector. A third approach considers collection system adaptations optimized for the town's historical urban structure. The fourth approach explores intermunicipal collaboration for achieving appropriate economies of scale.

The alternatives were systematically evaluated using the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. This technique identifies solutions closest to an ideal positive solution and furthest from a negative ideal solution, providing a clear ranking of alternatives based on their performance across all weighted criteria. The process involved constructing a decision matrix containing the performance scores of each alternative across all criteria, weighted according to the priorities established through stakeholder consultation.

Sensitivity analysis was conducted by varying criteria weights to test the robustness of the results. This analysis examined how changes in relative priorities between environmental, economic, heritage, and social dimensions might affect the overall ranking of alternatives. The process ensured that recommendations remain valid across reasonable variations in stakeholder priorities and preferences.

The methodology prioritized practical, implementable solutions appropriate for Taurasi's scale, resources, and distinctive characteristics as a Historical Small Town with viticultural traditions and heritage value. This pragmatic orientation reflected the need for waste

management approaches that could realistically be implemented within the town's specific constraints while delivering meaningful improvements in resource efficiency and environmental performance.

3. Results

3.1. Criteria Weights from AHP Analysis. The application of the AHP methodology with stakeholder input yielded distinct weighting patterns across the four main criteria categories. Table 1 presents the final weights assigned to each criterion category and sub-criterion, reflecting the priorities expressed by Taurasi's stakeholders.

TABLE 1. AHP-Derived Criteria Weights for Waste Management Evaluation in Taurasi

Main Criteria	Sub-criteria	Local Weight	Global Weight
Environmental (0.32)	Resource recovery potential	0.45	0.144
	Emissions reduction	0.30	0.096
	Environmental impact	0.25	0.080
Economic (0.30)	Implementation costs	0.40	0.120
	Operational costs	0.38	0.114
	Revenue potential	0.22	0.066
Heritage Compatibility (0.23)	Visual impact on historical landscape	0.46	0.106
	Compatibility with town character	0.34	0.078
	Cultural integration	0.20	0.046
Social (0.15)	Community acceptance	0.42	0.063
	Convenience for residents	0.38	0.057
	Educational value	0.20	0.030

The weighting distribution reflects a prioritization of environmental considerations (0.32), particularly resource recovery potential (global weight 0.144), followed closely by economic factors (0.30), with emphasis on implementation costs (0.120) and operational costs (0.114). Heritage compatibility received substantial weight (0.23), acknowledging Taurasi's significant historical character, with particular concern for visual impact on the historical landscape (0.106). Social criteria, while still significant, received comparatively lower weighting (0.15).

This weighting pattern aligns with Taurasi's context as a historical town with viticultural traditions facing economic constraints. The prioritization of resource recovery potential

specifically addresses the substantial organic waste fraction (259.62 tons, 51.6% of differentiated waste) identified in the waste characterization data, indicating stakeholder recognition of this significant opportunity for circular economy implementation.

3.2. Performance Evaluation of Waste Management Alternatives. Table 2 presents the performance matrix showing normalized scores of each waste management alternative across the established criteria. These scores derive from systematic evaluation against each criterion using available data and stakeholder input regarding local conditions.

TABLE 2. Normalized Performance Matrix of Waste Management Alternatives

Criteria	Enhanced Organic Management	Viticultural Waste Valorization	Collection System Adaptation	Inter-municipal Collaboration
Resource recovery potential	0.842	0.758	0.412	0.683
Emissions reduction	0.736	0.627	0.493	0.574
Environmental impact	0.779	0.694	0.625	0.592
Implementation costs	0.487	0.452	0.823	0.438
Operational costs	0.603	0.554	0.831	0.471
Revenue potential	0.721	0.847	0.318	0.682
Visual impact	0.461	0.524	0.856	0.598
Compatibility with town	0.512	0.659	0.786	0.598
Cultural integration	0.642	0.827	0.529	0.602
Community acceptance	0.695	0.752	0.641	0.524
Convenience for residents	0.581	0.549	0.807	0.529
Educational value	0.771	0.854	0.492	0.613

The performance evaluation reveals distinctive patterns for each alternative. Enhanced organic waste management demonstrates superior performance in resource recovery potential (0.842) and environmental impact reduction (0.779), reflecting its focus on the substantial organic fraction that constitutes 51.6% of Taurasi's differentiated waste. However, this approach faces challenges regarding implementation costs (0.487) and visual impact on the historical landscape (0.461).

Viticultural waste valorization shows particular strength in revenue potential (0.847), educational value (0.854), and cultural integration (0.827), reflecting strong alignment with Taurasi's wine production identity. This approach effectively addresses the waste streams generated by the town's predominant economic sector, creating potential economic value while reinforcing cultural identity.

Collection system adaptation demonstrates superior performance regarding implementation costs (0.823), operational costs (0.831), visual impact (0.856), and compatibility with town character (0.786). These strengths reflect the approach's focus on operational adjustments within existing systems rather than development of new infrastructure, minimizing both costs and heritage impacts. However, this approach shows comparatively limited performance in resource recovery potential (0.412) and revenue generation (0.318).

Inter-municipal collaboration presents moderate performance across most criteria without exceptional strengths or weaknesses. This balanced profile reflects the approach's capacity to distribute both benefits and implementation challenges across multiple municipalities, achieving economies of scale while potentially diluting local control and specific alignment with Taurasi's distinctive characteristics.

3.3. TOPSIS Analysis Results. The application of the TOPSIS methodology, incorporating criteria weights from the AHP analysis and normalized performance scores, yielded final rankings of the waste management alternatives. Table 3 presents the distance measures, proximity coefficients, and resulting rankings for each alternative.

TABLE 3. TOPSIS Analysis Results and Final Rankings

Alternative	Distance to Positive Ideal	Distance to Negative Ideal	Proximity Coefficient	Rank
Enhanced Organic Management	0.142	0.327	0.697	1
Viticultural Waste Valorization	0.168	0.303	0.643	2
Collection System Adaptation	0.281	0.205	0.422	4
Inter-municipal Collaboration	0.233	0.236	0.503	3

The TOPSIS analysis identifies Enhanced Organic Management as the highest-ranked alternative with a proximity coefficient of 0.697, followed by Viticultural Waste Valorization (0.643), Inter-municipal Collaboration (0.503), and Collection System Adaptation (0.422). This ranking is mathematically consistent with the performance scores and criteria weights, reflecting the strong performance of the organic management approach across heavily weighted criteria, particularly resource recovery potential (global weight 0.144) where it achieved the highest score (0.842).

The relative proximity coefficients demonstrate a significant gap between the top two alternatives (0.697 and 0.643) and the lower-ranked options (0.503 and 0.422). This mathematical separation underscores the superior performance of Enhanced Organic Management and Viticultural Waste Valorization under the established criteria weights. Their complementary strengths, with Enhanced Organic Management focused on municipal organic waste (259.62 tons annually) and Viticultural Waste Valorization addressing agricultural residues, suggest potential value in integrated implementation.

3.4. Sensitivity Analysis. Sensitivity analysis tested the robustness of the rankings by varying the weights assigned to each main criteria category while maintaining the relative weights of sub-criteria within each category. Table 4 presents the results of this analysis, showing how alternative rankings change under different weighting scenarios.

TABLE 4. Sensitivity Analysis Results for Different Weighting Scenarios

Scenario	Environ.	Econ.	Heritage	Social	Ranking
Base Case	0.32	0.30	0.23	0.15	EOM > VWV > IMC > CSA
Environmental Focus	0.50	0.20	0.15	0.15	EOM > VWV > IMC > CSA
Economic Focus	0.20	0.50	0.15	0.15	CSA > EOM > VWV > IMC
Heritage Focus	0.20	0.15	0.50	0.15	CSA > VWV > IMC > EOM
Social Focus	0.20	0.20	0.15	0.45	VWV > EOM > CSA > IMC

Note: EOM = Enhanced Organic Management; VWV = Viticultural Waste Valorization; CSA = Collection System Adaptation; IMC = Inter-municipal Collaboration

The sensitivity analysis highlights that ranking results vary significantly under different weighting scenarios, consistent with the alternatives' distinctive performance profiles across criteria categories. Enhanced Organic Management maintains its top position under both the base case and environmental focus scenarios, reflecting its strong performance in resource recovery (0.842) and emissions reduction (0.736).

Under an economic focus scenario, Collection System Adaptation emerges as the preferred alternative due to its superior performance in implementation costs (0.823) and operational costs (0.831).

When heritage considerations receive primary emphasis, Collection System Adaptation emerges as the optimal approach, with its minimal visual impact (0.856) and high compatibility with town character (0.786) directly addressing the most heavily weighted criteria in this scenario. Under a social focus scenario, Viticultural Waste Valorization takes precedence, reflecting its strong performance in community acceptance (0.752) and educational value (0.854).

This analysis implies that while Enhanced Organic Management represents the optimal approach under current stakeholder priorities, its superiority is not absolute across all possible preference structures. Collection System Adaptation offers compelling advantages when economic efficiency or heritage preservation receive greater emphasis, consistent with its high scores in these domains (0.823 for implementation costs and 0.856 for visual impact). Viticultural Waste Valorization demonstrates robust performance across multiple scenarios, indicating its value as a complementary approach within an integrated waste management strategy.

3.5. Integration Potential Analysis. Table 5 presents an analysis of integration potential between different approaches, focusing on waste stream coverage, implementation considerations, and potential synergies.

TABLE 5. Integration Potential Analysis of Waste Management Approaches

Integration Combination	Primary Waste Streams Addressed	Potential Synergies	Implementation Barriers
EOM + VWV	Household organic waste (259.62 tons); Viticultural residues	Shared processing infrastructure; Complementary feedstock characteristics	Implementation cost accumulation (€125,000–€175,000); Governance complexity
EOM + CSA	Household organic waste; General municipal waste	Enhanced collection efficiency for organic fraction; Reduced visual impact	Limited revenue generation potential; Incomplete viticultural waste coverage
VWV + CSA	Viticultural residues; General municipal waste	Cultural heritage reinforcement; Lower combined implementation costs	Fragmented implementation responsibility; Limited household organic fraction management
EOM + IMC	Household organic waste; Regional organic streams	Enhanced economies of scale; Implementation cost distribution	Reduced local control; Increased stakeholder coordination requirements
Comprehensive Integration	All municipal and agricultural waste streams	Complete waste stream coverage; Maximized resource recovery	High initial complexity; Substantial governance coordination requirements

The integration potential analysis shows strong complementarity between Enhanced Organic Management and Viticultural Waste Valorization, which together would address both municipal organic waste (259.62 tons annually) and agricultural residues from wine production. This combination offers potential synergies through shared processing infrastructure and complementary feedstock characteristics that could enhance biological processing efficiency. The primary implementation challenges include accumulated costs estimated between €125,000–€175,000 (based on similar-scale facilities in comparable contexts) and governance complexity requiring coordination between municipal and agricultural stakeholders.

Collection System Adaptation presents compelling integration potential with both organic-focused approaches, offering enhanced efficiency for collection while reducing visual impact on Taurasi's historical landscape. This addresses a key weakness of Enhanced Organic Management, which scored relatively poorly on visual impact (0.461). The combination of Viticultural Waste Valorization with Collection System Adaptation

shows particularly strong cultural and heritage alignment, while offering lower combined implementation costs compared to other integration options.

A comprehensive integration approach potentially offers the most complete waste management solution but faces substantial implementation complexity. The mathematical analysis suggests a phased implementation strategy would optimize resource allocation while managing complexity, beginning with approaches demonstrating highest immediate feasibility (Collection System Adaptation) followed by progressive integration of organic management approaches.

4. Discussion

The prioritization of resource recovery (weight 0.144) over emissions reduction (0.096) displays a pragmatic orientation among Taurasi's stakeholders that challenges conventional environmental hierarchies. While climate discourse typically emphasizes emissions (Firtescu *et al.* 2023), these stakeholders recognize that transforming organic waste into agricultural inputs offers immediate, tangible benefits for a wine-producing community. This finding suggests that HSTs may be more receptive to circular economy initiatives when framed around resource creation rather than waste reduction (Das *et al.* 2025). The distinction proves subtle but consequential for policy design, as it shifts focus from what communities must sacrifice to what they can gain.

The inverse relationship between environmental performance and heritage compatibility exposes a fundamental design challenge for sustainable transitions in historical contexts. Enhanced Organic Management's scores (0.842 for resource recovery, 0.461 for visual impact) quantify what preservation advocates have long intuited: sustainability infrastructure often conflicts with historical aesthetics (Rosa 2020).

Viticultural Waste Valorization's consistent performance across sensitivity scenarios (ranking first or second in four of five weightings) demonstrates a critical principle: waste interventions aligned with territorial identity exhibit unusual resilience to stakeholder preference shifts. This approach scored highest in both revenue potential (0.847) and educational value (0.854). The correlation suggests economic and pedagogical benefits may be mutually reinforcing when rooted in local practice (Suriyankietkaew, Krittayaruangroj, and Iamsawan 2022). For the 16% of Italy's population living in similar agricultural HSTs (Romano, Del Vecchio, and Passiante 2021), this finding implies that sector-specific waste strategies may outperform generic municipal approaches, even at smaller scales. The success stems not from technical superiority but from alignment with existing knowledge networks, market relationships, and cultural meanings that already organize community life (Broekel *et al.* 2021).

The integration analysis reveals an overlooked opportunity in phased implementation strategies (Niwalkar, Indorkar, Gupta, *et al.* 2023). Starting with Collection System Adaptation (implementation cost score 0.823) creates immediate visual improvements while establishing operational foundations for subsequent interventions. This approach addresses the primary weakness of environmentally optimal solutions, their heritage impacts, through temporal sequencing rather than technical compromise. Inter-municipal Collaboration's moderate performance (0.503) suggests potential for improvement through enhanced coordination mechanisms (Niwalkar, Indorkar, Gupta, *et al.* 2023). Integration thus emerges not as

a compromise between inadequate alternatives but as a strategy for capturing complementary strengths across temporal and spatial scales.

The Inter-municipal Collaboration alternative merits deeper consideration for its regional economic implications. Evidence from inter-municipal cooperation demonstrates operational cost savings of 10–20% through economies of scale, particularly benefiting small municipalities like Taurasi (Bel and Warner 2015). Establishing a regional waste processing hub serving multiple wine-producing HSTs could generate significant positive externalities through shared infrastructure investments that reduce per-unit costs across municipalities. This approach aligns with successful CE initiatives in Italian agri-food clusters, where coordinated waste valorization creates regional value chains (Simboli, Taddeo, and Morgante 2015). Such inter-municipal coordination could strengthen applications for EU Cohesion Fund resources designated for CE transitions, as regional approaches demonstrate greater impact than isolated municipal initiatives.

Furthermore, to address the identified governance complexity barrier, implementation requires specific operational structures. Following principal-agent risk allocation frameworks (Shrestha *et al.* 2019), a multi-stakeholder steering committee should include municipal officials, wine consortium representatives, and waste management operators, with roles formalized through memoranda of understanding. For conflict resolution between heritage preservation and environmental objectives, structured negotiation protocols based on integrated assessment indicators provide objective criteria for decision-making (Rigamonti, Sterpi, and Grosso 2016). Communication protocols should include quarterly stakeholder meetings with standardized performance reporting on material recovery, costs, and heritage impact metrics, ensuring transparent progress monitoring and maintaining engagement throughout implementation phases.

Methodological limitations merit explicit acknowledgment. Performance scores for criteria such as "cultural integration" and "community acceptance" necessarily relied on stakeholder assessments rather than empirical measurement, introducing evaluative subjectivity despite the structured AHP framework (Saaty 1980). Additionally, the focus on Taurasi's specific context, while providing analytical depth, limits direct transferability to HSTs with different economic bases or demographic profiles. Future research incorporating longitudinal data from implemented projects could address these limitations.

Practical implications emerge at multiple scales. Municipal administrators should consider beginning with Collection System Adaptation not merely for its low cost but for its capacity to build stakeholder confidence while preserving future options. The 0.856 visual impact score demonstrates this approach's minimal heritage disruption while initiating circular transitions. Waste management companies might invest in processing equipment that can begin at community scale (serving Enhanced Organic Management) but expand to accommodate agricultural residues as Viticultural Waste Valorization develops. For heritage authorities, the findings suggest developing assessment protocols that distinguish between reversible operational changes and permanent infrastructure installations. Regional development agencies could prioritize funding mechanisms that support phased implementation strategies.

The Taurasi analysis ultimately shows that successful circular transitions in HSTs require more than technical optimization. They demand recognition that implementation sequences matter as much as end states, and that heritage concerns can be mitigated through cultural

alignment rather than technical compromise. These insights suggest reconceptualizing waste management in historical contexts not as a technical service to be optimized but as a practice embedded in territorial identity and local economic systems.

5. Conclusions

This study adopted a multi-criteria evaluation framework calibrated for waste management decisions in HSTs. The application to Taurasi yielded that optimal solutions emerge not from maximizing environmental performance alone, but from recognizing how waste interventions intersect with territorial identity, economic networks, and heritage preservation imperatives. The finding that stakeholders prioritize resource recovery over emissions reduction suggests a need to reframe circular economy initiatives in HSTs around value creation rather than environmental sacrifice. Furthermore, the integration analysis suggests that complementary approaches implemented through phased strategies can achieve outcomes superior to any single intervention, suggesting that temporal sequencing deserves equal consideration with technical design.

However, limitations must be acknowledged. The performance scoring relied on stakeholder assessments rather than empirical measurements, particularly for intangible criteria like cultural integration. The static nature of AHP weights cannot capture how community preferences might evolve as implementations unfold. The single case study design, while providing depth, limits understanding of how findings might transfer to HSTs with different economic bases, demographic profiles, or governance structures. Additionally, the analysis assumed technical feasibility without detailed engineering assessments, and cost estimates remained approximate given the conceptual stage of alternatives.

Practical implementation pathways emerge from recognizing that low-impact, high-visibility interventions can build stakeholder confidence for subsequent innovations. Beginning with collection system adaptations preserves optionality while demonstrating municipal commitment to both sustainability and heritage. The strong performance of sector-specific approaches like viticultural waste valorization suggests that successful circular transitions in HSTs build upon existing economic activities rather than imposing external models. Heritage authorities require new evaluation protocols distinguishing reversible operational changes from permanent infrastructure modifications.

Future research could test this framework across diverse HST typologies to identify which findings reflect Taurasi's specific characteristics versus generalizable patterns. Longitudinal studies tracking actual implementations would illuminate how stakeholder preferences and system performance evolve through transition processes. Detailed feasibility studies incorporating engineering assessments and lifecycle costing would strengthen the technical foundation for implementation. Investigation of innovative financing mechanisms adapted to HST fiscal constraints could address the gap between environmental optimality and economic feasibility.

Indeed, success depends on aligning technical interventions with cultural meanings, economic relationships, and spatial constraints that define these communities. This perspective reframes waste management from a service to be optimized toward a practice to be evolved within specific territorial contexts. Such an approach offers HSTs pathways toward

circularity that strengthen rather than compromise their distinctive character, contributing to both environmental sustainability and cultural resilience.

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