

Towards zero marine plastic pollution: a multidimensional measurement model for evaluating waste management solutions informed by SDGs 12 and 14

Maria Serena Chiucchi, Alessandra Cioli and Michele Guidi

Abstract

Purpose – This paper explores how marine plastic waste management solutions can be holistically evaluated in alignment with Sustainable Development Goals (SDGs) 12 and 14. It aims to address the fragmentation in the existing literature by developing an integrated model for sustainability assessment that combines cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA).

Design/methodology/approach – Presenting an interventionist case study, the research examines a project aimed at collecting plastic waste from the sea and constructing a pyrolysis plant to convert non-recyclable plastics into energy in a major Italian port. A multidimensional evaluation model was developed through iterative stakeholder engagement, integrating financial and non-financial criteria across economic, environmental, and social dimensions to assess the investment. Data were gathered through semi-structured interviews, document analysis and field observations.

Findings – The study introduces an integrated CBA–MCDA framework tailored to the complexities of sustainability-oriented investments. The model enables a comprehensive assessment of infrastructure projects by combining economic valuation with participatory evaluation of qualitative impacts. It also strengthens alignment with the targets of SDGs 12 and SDG 14 by incorporating criteria related to waste recovery, emissions reduction and social outcomes.

Originality/value – This research contributes to the literature by operationalising the interdependence between SDGs 12 and 14 within a unified decision-making framework. It advances existing approaches by demonstrating how integrated methodologies can support investment decisions in contexts where environmental, economic, and social objectives converge, offering a replicable model for sustainability evaluation in waste management.

Keywords Marine plastic pollution, Waste management, Multidimensional assessment, Cost-benefit analysis (CBA), Multi-criteria decision analysis (MCDA), Sustainable Development Goals (SDG)

Paper type Research paper

Maria Serena Chiucchi is based at the Department of Management, Università Politecnica delle Marche, Ancona, Italy, and IRCCS INRCA, Ancona, Italy. Alessandra Cioli and Michele Guidi are both based at the Department of Management, Università Politecnica delle Marche, Ancona, Italy.

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1. Introduction

The Sustainable Development Goals (SDGs) established by the United Nations offer a universal framework for addressing critical global challenges, including environmental degradation and resource management. SDG 12 “Responsible Consumption and Production” promotes sustainable consumption and production to reduce the environmental impact of waste, while SDG 14 “Life Below Water” focuses on the conservation and sustainable use of marine resources, acknowledging the vital role of healthy oceans in ensuring environmental stability.

One of the most pressing challenges is marine plastic pollution, primarily resulting from inefficient terrestrial waste management. Common plastic debris enter oceans via wind,

rivers and currents (Yu and Singh, 2023; Zahari *et al.*, 2022), threatening marine biodiversity and harming economic sectors such as tourism and fishing through revenue losses, increased clean-up costs and diminished aesthetic value (Arabi and Nahman, 2020; Karlsson *et al.*, 2018; Apete *et al.*, 2024). Socially, it compromises seafood quality and endangers public health due to microplastic contamination (Sharma *et al.*, 2021; Apete *et al.*, 2024). Despite the evident interdependence between terrestrial and marine systems, existing literature often addresses SDG 12 and SDG 14 in isolation (Elliff *et al.*, 2022; Junkrachang *et al.*, 2024; Grewal *et al.*, 2024; Mahapatra *et al.*, 2024).

After a decade since the introduction of the SDGs by the United Nations' 2030 Agenda, there has been growing scholarly interest in how companies incorporate these goals into their corporate disclosures (Rosati and Faria, 2019; Pizzi *et al.*, 2021; Zampone and Guidi, 2024).

Early studies focused on integrating SDGs into corporate disclosures for external use, while recent research explores their links to sustainability (Raimo *et al.*, 2024), financial performance (Beretta *et al.*, 2024) and managerial decision-making (Kokubu *et al.*, 2023; Pigatto *et al.*, 2024). With increasing interest in SDG-related sustainability metrics (Nicolò *et al.*, 2024), recent work highlights the need for holistic approaches (Chen *et al.*, 2020).

This study aims to contribute to this emerging body of literature by exploring the integration of SDGs into methodologies that support managerial decision-making, with a specific focus on SDG 12 and SDG 14. To achieve this aim, this article introduces a multidimensional evaluation model that combines cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA) to assess the sustainability of plastic waste management solutions in line with these goals.

CBA is a well-established evaluation methodology used to conduct economic assessments, with numerous applications in quantifying the costs and benefits of waste management systems (Jamasb and Nepal, 2010; Khan *et al.*, 2022). Complementing this approach, this study integrates MCDA, a widely applied technique in sustainability contexts, to identify optimal alternatives in complex scenarios (Beria *et al.*, 2012).

Despite its extensive application in sustainability contexts, few studies apply MCDA to the management of plastic waste (Deshpande *et al.*, 2020), focusing predominantly on general waste streams (Yeh and Xu, 2013; Chadderton *et al.*, 2017; Kharat *et al.*, 2019; Yan *et al.*, 2019; Afrane *et al.*, 2021; Omran *et al.*, 2021; Santos *et al.*, 2022).

This paper seeks to address these gaps by examining how marine plastic waste management solutions can be holistically evaluated in alignment with the objectives of SDG 12 and SDG 14. To this end, an inductive approach is adopted through the development of a single case study based on an interventionist approach.

The case study concerns a project aimed at identifying innovative solutions for collecting plastic waste from the sea and constructing a pyrolysis plant for converting non-recyclable plastics into energy. The project is currently under evaluation in a city that hosts one of the major Italian maritime ports, facing growing challenges related to marine plastic pollution. As the project remains in an experimental phase, the focus of the analysis is not on quantitative outcomes *per se*, but rather on the evaluation process adopted by the stakeholders involved. The objective is to examine the decision-making dynamics that guide the assessment of the proposed infrastructure investment, highlighting the criteria and interactions that influence its feasibility.

The proposed evaluation model integrates CBA and MCDA to assess plastic waste management solutions across the three sustainability dimensions: economic, environmental and social. This study contributes to the literature by presenting a model that aligns waste management practices with SDG 12 and SDG 14.

The paper is structured as follows. The next section reviews the relevant literature, providing the foundation for the study. Section 3 outlines the research design adopted, while

Section 4 presents the evaluation model applied to the case study. Section 5 discusses the findings in relation to the research objectives, and Section 6 offers concluding remarks.

2. Literature review

2.1 Sustainable Development Goals 12 and 14 in plastic waste management

The ineffective management of terrestrial waste facilitates its transport to the oceans via wind, rivers and marine currents, significantly contributing to marine pollution and damaging aquatic ecosystems (Yu and Singh, 2023). These challenges were exacerbated during the COVID-19 lockdown, which led to inadequate wastewater treatment and the accumulation of waste on beaches, further harming marine biodiversity (Jiang *et al.*, 2022; Nirmal and Jacob, 2022).

This phenomenon underscores the intrinsic connection between SDG 12 and SDG 14, as sustainable terrestrial waste management not only mitigates local environmental impacts but also safeguards marine ecosystems, preserving biodiversity and promoting ocean health (Lee, 2021; Ferronato *et al.*, 2024). Despite this direct interrelation, the literature often addresses the management of plastic waste in a fragmented manner.

Research on SDG 12 frequently focuses on alternatives to landfilling and strategies to enhance material circularity. For example, Zhao and You (2024) explored chemical recycling methods, such as pyrolysis and upcycling, highlighting their potential to reduce greenhouse gas emissions while promoting resource efficiency. Similarly, Cho *et al.* (2024) demonstrated that recycling plastic packaging reduces emissions by 88.2% compared to incineration. Energy recovery has also emerged as a critical focus, with González-Sánchez *et al.* (2023) proposing advanced treatments and smart technologies like waste-to-energy processes in landfills to improve efficiency and minimise environmental impacts. Additionally, innovative mechanisms, such as plastic credit systems modelled on carbon credits, have been suggested to incentivise recycling and collection, particularly in regions where mismanaged plastic waste is prevalent (Lee, 2021).

In contrast, the literature on SDG 14 primarily centres on the environmental sciences, with limited exploration of management and business issues. Studies have investigated the impacts of microplastics on marine ecosystems (Elliff *et al.*, 2022; Mahapatra *et al.*, 2024) and the collection and analysis of data on the distribution and abundance of plastic waste (Pauna and Askham, 2022; Catarino *et al.*, 2023).

Only a few studies highlight the importance of this integration. For instance, Issifu and Sumaila (2020) examined this phenomenon by identifying the main contributors to pollution, including mismanaged urban waste and abandoned fishing gear, as well as the impacts on marine organisms and local economies, particularly in tourism and fisheries. Furthermore, the authors highlight the necessity of interventions, such as the enhancement of waste management practices. Strippoli *et al.* (2024) emphasised the synergy between terrestrial and marine waste, demonstrating how integrated strategies in the tourism sector can promote responsible resource use and reduce waste accumulation in marine ecosystems.

2.2 Models for assessing sustainability of waste management solutions

In recent decades, a vast array of methods and tools aimed at assessing sustainability impacts has been developed, with the primary objective of supporting decision-makers in making informed choices (Gasparatos and Scolobig, 2012).

Various scholars have explored the concept of “sustainability assessment” defining it as an appraisal methodology that integrates analytical methods and models to support decision-makers in making informed decisions in complex contexts characterised by multidisciplinary aspects (economic, environmental and social) (Hacking and Guthrie, 2008; Sala *et al.*, 2015).

In waste management, tools such as life cycle assessment, CBA and MCDA have been widely used to identify sustainable, cost-efficient solutions while addressing stakeholder demands for improved technologies and environmental outcomes (Karmperis *et al.*, 2013; Allesch and Brunner, 2014; Milutinović *et al.*, 2014).

CBA is valued for its ability to express outcomes in monetary terms, aiding investment evaluation, though it struggles with intangible and environmental costs (Babashamsi *et al.*, 2016). MCDA complements this by incorporating multiple variables, including social and environmental impacts, and engaging diverse stakeholders. However, its limitations include subjectivity in assessments and challenges in combining criteria weights (Beria *et al.*, 2012). Integrating these methods enables a comprehensive approach balancing economic, environmental and social considerations to support informed decision-making (Finnveden and Moberg, 2005; Saad *et al.*, 2019). Within the framework of MCDA, the analytic hierarchy process (AHP), developed by Saaty (1978), stands as one of the most widely utilised methodologies in waste management systems (Stefanović *et al.*, 2016).

When applied to plastic waste management, MCDA primarily focuses on environmental, and economic criteria, with less attention to social aspects (Santos *et al.*, 2022). Economic criteria include, for example, financial performance, costs and net present value (Bhagat *et al.*, 2016; Vo Dong *et al.*, 2019). Environmental criteria address greenhouse gas emissions, global warming impacts, energy recovery and waste reduction (Bachér *et al.*, 2018; Delvere *et al.*, 2019; Marazzi *et al.*, 2020). Finally, social criteria consider job creation (Deshpande *et al.*, 2020), worker health and safety (Mavi *et al.*, 2017), social impacts of alternatives (Balwada *et al.*, 2021) and corporate social responsibility (Senthil *et al.*, 2018).

3. Research design

This paper presents a case study of a project aimed at collecting plastic waste from the sea and constructing a pyrolysis plant to convert non-recyclable plastics into energy. As part of a multi-stakeholder research initiative, the authors actively contributed to the development of the multidimensional measurement model used to evaluate the investment. Accordingly, the study adopts an interventionist approach (Jönsson and Lukka, 2006).

Case study research is particularly well-suited to understanding organisational dynamics within a specific setting (Eisenhardt, 1989), typically relying on interviews, document analysis and observations as means of data collection (Yin, 2003). This methodological approach has been widely adopted in sustainability accounting research to investigate the evolution of reporting and management accounting practices (Gibassier and Schaltegger, 2015; Guidi *et al.*, 2024; Pizzi *et al.*, 2021). When case study research is conducted in an interventionist mode, researchers are actively involved in the process under investigation thus, the outputs are co-developed through collaboration between investigators and the case study participants (Jönsson and Lukka, 2006; Dumay, 2011; Korhonen *et al.*, 2021; Pigatto *et al.*, 2024).

In our study, the case was conducted in two phases. In the first phase, the authors designed an evaluation model to be used for a holistic assessment of the investments characterising the project; more specifically, key criteria of an economic, environmental and social nature were identified. In the second phase, the model was refined through an iterative process of stakeholder engagement, aimed at adapting and validating the criteria according to the stakeholders' point of view and in relation to the specific characteristics of the reference context.

The investment of the case study is currently under evaluation and involves various stakeholders in a coastal city that hosts one of Italy's major maritime ports, which is facing increasing challenges related to marine plastic pollution with significant environmental and public health implications. As the project remains in an experimental phase, the focus of the analysis is not on numerical results but on the evaluation process adopted by the

stakeholders involved. The objective is to examine the definition of criteria and indicators that guide the assessment of the proposed infrastructure investment.

The selection of this case is motivated by its exemplary value, as it encompasses all the key elements necessary to explore the definition of criteria and indicators in complex contexts, where evaluations must take into account multidimensional variables. The analysis focuses on the evaluation process adopted by stakeholders to assess the investment opportunity in the proposed infrastructure. Specifically, the case is distinguished by the need to integrate economic considerations with environmental and social impacts, given that the investment pertains to a sustainability-oriented infrastructure.

The project has engaged a wide range of stakeholders, including the port authority, a waste collection and disposal company, an association representing waste management firms, a pyrolysis plant manufacturer and an academic institution, all of whom are involved in assessing the project's feasibility and impact. The analysis conducted provides insights into the critical issues that emerged during the evaluation process, influencing the decisions of the stakeholders involved.

Data were collected from both primary and secondary sources (Table 1). Primary data came from semi-structured interviews, selected for their flexibility in eliciting in-depth insights into participant perspectives (Kvale and Brinkmann, 2009). Secondary data included corporate profiles, websites, technical reports, business plans, tariff schedules and regulatory documents.

Following the principle of data triangulation, multiple sources enhanced the study's credibility and completeness (Patton, 1999; Ryan, 2002). Interviewees included decision-makers from the Port System Authority and stakeholders directly involved in marine plastic waste management. Participants were selected based on strategic roles or direct operational involvement. Interviews were conducted via Microsoft Teams between February 2023 and February 2025, recorded with consent and transcribed for analysis.

An interview protocol was developed with the aim of collecting relevant data, standardising the interview approach and ensuring an appropriate level of flexibility (Hunter, 2012). The protocol was based on evidence from the literature and the research questions of the study (Galvani and Bocconcelli, 2022; Umeokafor et al., 2023) and structured into three main thematic areas. Section 1 explored current practices in plastic waste management, aiming to understand how organisations manage disposal processes, what types of plastic waste

Table 1 Data sources			
Interviews	Role	Organisation	Length (min)
	Researcher	Research entity in marine and environmental sciences	90
	Co-founder and CEO	Company specialising in pyrolysis technology	90
	Engineer, technical directorate	Port authority	60
	Office coordinator, development, promotion, statistics unit	Port authority	60
	Secretary general	National association for port and Maritime services	60
	Secretary general	National association for port and Maritime services	120
	Secretary general	National association for port and Maritime services	60
	CEO	Company specialising in marine waste management	60
	Waste manager	Company specialising in marine waste management	60
Documents analysed	Company profiles		
	Company websites		
	Technical performance reports of pyrolysis technology		
	Business plan of pyrolysis technology		
	Port service tariff schedules		
	Operational and financial reports on waste collection in the port		
Internal guidelines and regulations on waste disposal			
Source(s): Authors' own work			

pose the greatest challenges and how existing regulations influence their strategies in terms of sustainability and compliance.

Section 2 focused on the assessment of pyroliser adoption and its operational implications. This part of the interview examined stakeholders' perceptions of the effectiveness of pyrolysis technology, the potential advantages and challenges of its implementation, and its likely impact on daily operations and business processes.

The final section addressed the broader sustainability dimensions of the proposed investment, prompting participants to reflect on the potential economic, environmental and social impacts of adopting the technology. Questions invited respondents to identify expected costs and benefits, thereby contributing directly to the definition and validation of the evaluation criteria used in the MCDA model.

The semi-structured interviews allowed for consistency across different types of interviewees while also providing the flexibility to adapt the discussion to the specific roles, expertise and contextual knowledge of each participant. This approach ensured rich and nuanced insights while maintaining coherence across thematic areas. Furthermore, the protocol was revised and pilot-tested to improve its clarity, coherence, and functionality (Patton, 2014), particularly for the analysis of plastic waste management in relation to SDGs 12 and 14.

Qualitative data analysis was conducted to examine respondents' views and actions (Denzin and Lincoln, 2008; Patton, 2002). Following O'Dwyer (2004), the analysis was structured into three stages: data reduction, data display and interpretation. Initially, key themes were identified based on the interview guide, focusing on plastic waste management, the evaluation of pyrolysis technology and the integration of CBA and MCDA. These themes were further broken down into sub-themes, each associated with specific codes (e.g. waste types, regulatory barriers and economic, environmental and social impacts). In the second stage, to visualise the relationships among codes, sub-themes were organised into tables according to their respective themes. The final stage involved revisiting the interview transcripts to interpret the data and select illustrative quotes. A selection of these is presented in the following section.

4. The multidimensional measurement model: integrating cost-benefit analysis and multi-criteria decision analysis

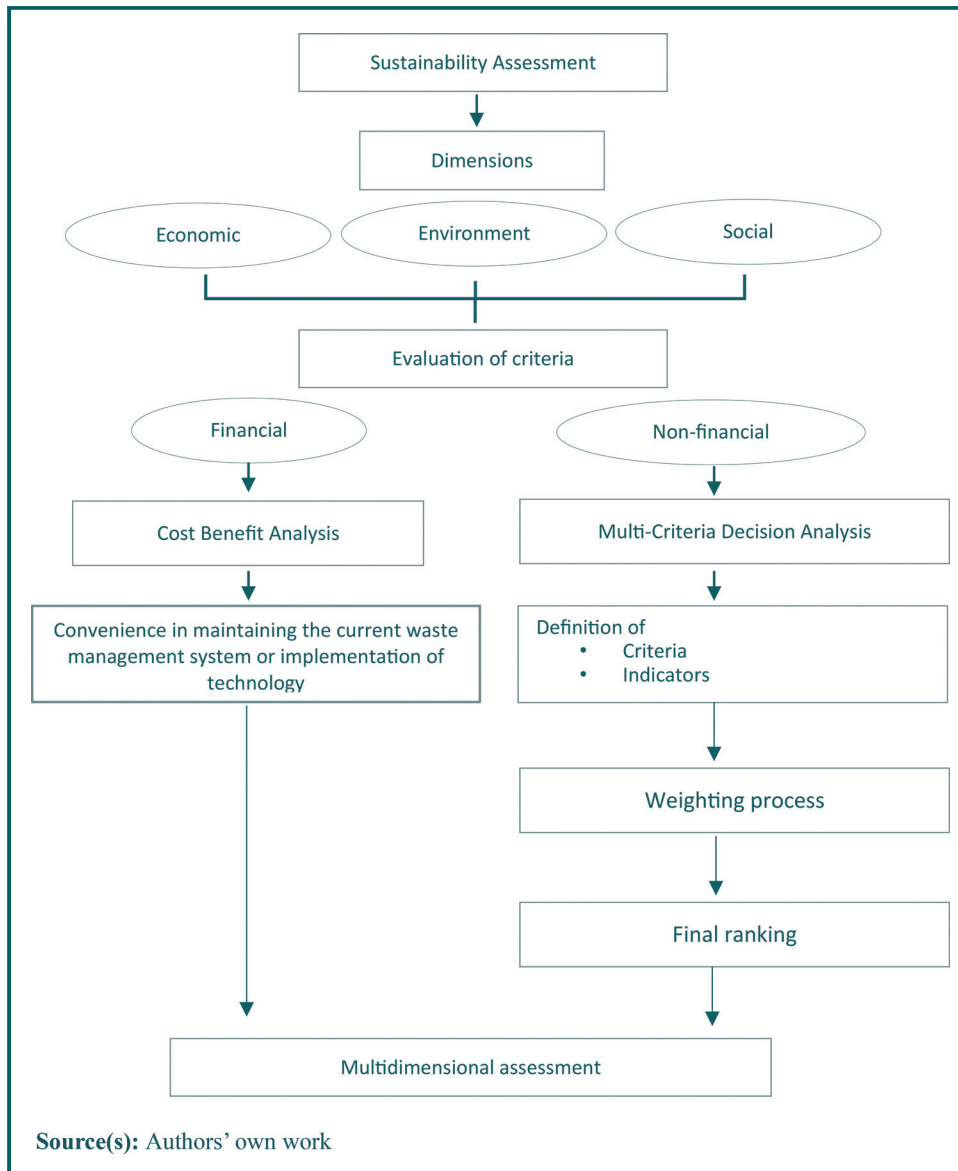
As previously stated, the interventionist case study was conducted in two phases. In the first phase the authors designed an evaluation model to be used for a holistic assessment of the investments characterising the project while in the second phase, the model was refined through the interaction with stakeholders.

Thus, in the first phase an integrated CBA-MCDA model was developed, combining financial and non-financial evaluation methods with the aim of providing a holistic analysis of the costs and benefits associated with the three dimensions of sustainability: economic (both in the short and long term), environmental and social, in the context of introducing new technologies for waste management (Finnveden and Moberg, 2005). This multidisciplinary approach represents an essential tool for decision-makers, as it enables the assessment of an investment's feasibility from a sustainability perspective, taking into account not only the immediately quantifiable and monetizable economic aspects, typically in the short term, but also the long-term implications as well as the environmental and social impacts, which are often more complex to measure (Babashamsi *et al.*, 2016).

In this context, the integrated model presented in Figure 1 is structured into three fundamental phases:

- Financial criteria-based evaluation through CBA, focusing on comparing the costs and benefits of the available alternatives to determine the most economically advantageous option for the organisation.

Figure 1 Decision support framework in a sustainable waste management system



- Non-financial criteria-based evaluation through MCDA, employed to identify the optimal choice by considering a range of qualitative factors that are often difficult to quantify using conventional methods. This process involves various groups of decision-makers, who may have different objectives and perspectives (Karmperis *et al.*, 2013; Milutinović *et al.*, 2014).
- Multidimensional evaluation, where the outcome of the CBA analysis is combined with the score derived from the MCDA application. This approach does not aim to aggregate the two results into a single metric but rather allows business decision-makers to balance the results of both methods according to their strategic objectives and the specific decision-making priorities of the context in question (Tsamboulas and Mikroudis, 2000).

The first phase of the combined method involves the application of the CBA methodology, structured into four main stages (Karmperis *et al.*, 2013). In the first stage, strategic

alternatives are identified: on the one hand, maintaining the current waste management system, and on the other, adopting an innovative technology for plastic waste management. The second stage entails an in-depth collection of economic data necessary to evaluate the costs and benefits associated with each option, including implementation costs, operational expenses and potential revenues derived from adopting the new technology (Table 2). In the third stage, the collected data are quantified and monetised, enabling economic comparability of the different cost and benefit components. Finally, in the fourth stage, the differential costs and revenues of the two alternatives are compared to assess the economic feasibility of adopting the new technology compared to maintaining the status quo. This approach allows for a detailed analysis to identify the most economically advantageous option for the organisation (Table 3).

The next phase of the combined method concerns the application of MCDA. The AHP method is considered particularly suitable in this context due to its accessibility, ease of use and well-established application within the MCDA framework (Balwada *et al.*, 2021; Taherdoost and Madanchian, 2023). The process involves a series of essential steps to ensure a structured and effective analysis (Saaty, 1978; Milutinović *et al.*, 2014; Delvere *et al.*, 2019).

The analysis begins with identifying the problem to be addressed and defining the knowledge required for an accurate evaluation. Subsequently, a decision-making hierarchy

Table 2 Data collection

<i>Variables</i>	<i>Starting situation</i>	<i>Implementation of waste management technology</i>
Variable cost per kg of non-recycled plastic waste sent to landfill (fee we pay to the waste company)	€	
Quantities of waste sent to landfill	kg/year	
Operating labour (plant maintenance)		€
Cost of separating recycled and non-recycled plastic		€
Machinery depreciation over 5 years		€
Consumable materials		€
Energy cost per kg/h of waste processed		€
Production capacity		kg/year
Net energy yield at full production capacity (70%)		kWh/year
Energy connection costs		€
Energy selling price (PUN)		€/kWh
Source(s): Authors' own work		

Table 3 Comparison of differential elements of the cost-benefit analysis (CBA)

<i>CBA elements</i>	<i>Starting situation</i>	<i>Implementation of waste management technology</i>
+ Variable costs for waste sent to landfill	€	
+ Feeding cost		€
+ Cost of separating recycled and non-recycled plastic		€
+ Machinery depreciation		€
+ Labour for maintenance		€
+ Consumables		€
+ Variable energy cost per kg/h of waste treated		€
+ Energy connection costs		€
– Energy sales revenue/lower energy cost		(€)
Source(s): Authors' own work		

is constructed, starting from the main objective, passing through intermediate levels with specific criteria and indicators, down to the alternatives to be analysed (Figure 2). At this point, pairwise comparison matrices are developed to assess the relative importance of the elements, using a numerical scale to quantify these relationships, following the scale proposed by Saaty (1978). This scale ranges from 1 to 9, where 1 indicates equal importance between two elements, and 9 represents the highest dominance of one element over the other, with intermediate values used to express compromise judgements. The resulting priorities are applied to weigh and aggregate values at the different levels of the hierarchy. Finally, the priorities of the alternatives are determined by calculating the composite weights at the lowest level of the hierarchical structure. Figure 2 illustrates the AHP method.

An essential phase in the implementation of MCDA is the definition of economic, environmental and social criteria useful for assessing the benefits and costs associated with adopting the innovative technology. In this case, the selection of criteria and indicators was conducted through a documentary analysis (desk analysis), based on a review of academic literature, an analysis of international standards (such as those adopted by the European Commission, 2014), and documents produced by the Italian Ministry of Ecological Transition (Yeh and Xu, 2013; Saad et al., 2019; Santos et al., 2022).

The criteria identified in the first phase of the case study were then refined in a second phase through an iterative process involving stakeholders (Table 4). The latter provided observations and specific suggestions for each dimension, contributing to the integration and improvement of the existing criteria emerging from the desk analysis. Moreover, the criteria were refined to reflect the specific context of the companies and stakeholders involved, as well as the different operational models that can be adopted, ranging from traditional tenders to outsourcing models with longer-term contracts, characterised by cooperation between the public and private sectors.

Table 4 shows the refined criteria, the stakeholders that may benefit from them and the interviewees that contributed to the refinement of the criteria. Some criteria (marked with an asterisk) may vary depending on the stakeholders involved and the operational model adopted. In particular, the criteria may influence beneficiaries differently depending on the stakeholder considered, and in some cases, certain criteria are relevant only for specific operational configurations. For instance, port waste management companies may operate through traditional tenders or outsourcing models characterised by long-term cooperation agreements, and some criteria apply exclusively to one of the two models.

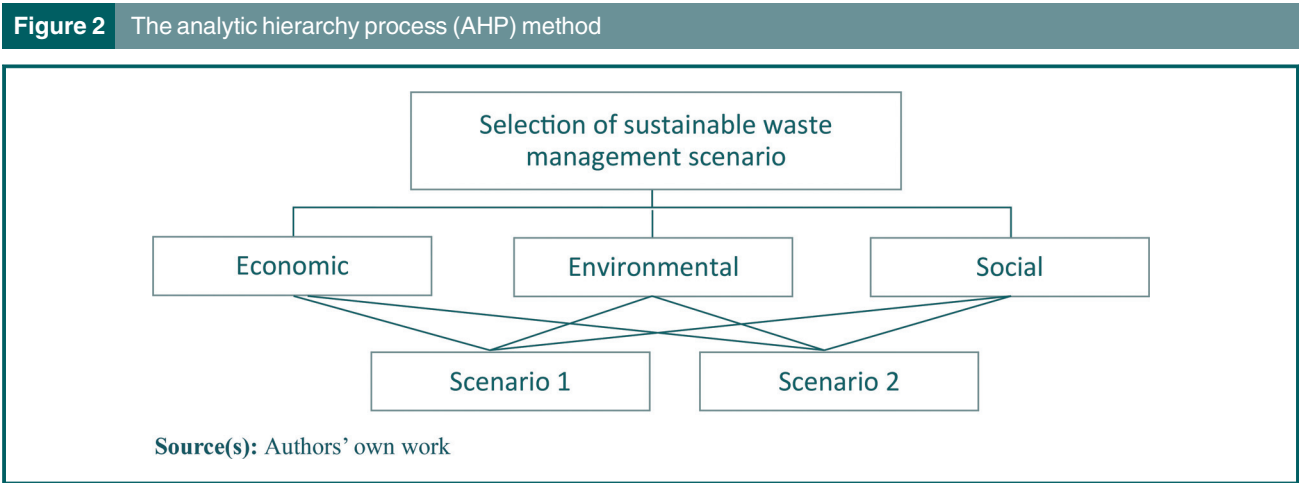


Table 4 Definition of economic, social and environmental criteria

<i>Economic criteria</i>	<i>Stakeholder</i>	<i>Sources</i>
Access to financing	Concessionaire	Santos et al., 2022
Depreciation period (*)	Concessionaire	Secretary general – National association for port and Maritime services CEO – Company specialising in marine waste management Waste manager – Company specialising in marine waste management
Scale and scope economies (*)	Concessionaire	Secretary general – National association for port and Maritime services CEO – Company specialising in marine waste management Waste manager – Company specialising in marine waste management
Tax incentives for the workforce	Concessionaire	Secretary general – National association for port and Maritime services CEO – Company specialising in marine waste management Waste manager – Company specialising in marine waste management
<i>Social criteria</i>		
Enhancement of employee satisfaction (related to possible long-term employment) (*)	Concessionaire	Secretary general – National association for port and Maritime services
Enhancement of employee skills (*)	Concessionaire	Secretary general – National association for port and Maritime services
Significance from a trade union perspective (*)	Concessionaire	Secretary general – National association for port and Maritime services
Reputation	Port authority	Engineer, technical directorate – Port authority Office coordinator, development, promotion, statistics unit – Port authority Secretary general – National association for port and Maritime services CEO – Company specialising in marine waste management
<i>Environmental criteria</i>		
Reduction of waste to landfill	Port authority	European Commission (2014)
Production of new energy	Port authority	European Commission (2014)
Reduction of visual disturbances, noise and odours	Port authority	European Commission (2014)
Reduction of greenhouse gas emissions	Port authority	European Commission (2014)
Reduction of health and environmental hazards	Port authority	European Commission (2014)
Note(s): (*) Vary depending on the stakeholders involved and the operational model adopted		
Source(s): Authors' own work		

To illustrate this differentiation, some examples of significant criteria and indicators are presented, highlighting those specific to certain configurations and those that are generally applicable.

Regarding the economic dimension, a relevant criterion is the “depreciation period”, which varies depending on the operational model adopted. Specifically, in contracts with long-term concessions, the depreciation period extends compared to a traditional tender, as investment costs are spread over a longer time horizon. In this case, the reference indicator

is “extension of the depreciation period up to a specified number of years”. When discussing the possibility of aggregated operational arrangements, one interviewee noted:

[...] the concessionaire making the investment would benefit from long-term depreciation, as the concession granted by the port authority would extend from five to fifteen or even twenty years.

(Secretary general – National association for port and maritime services)

Similarly, within the social dimension, certain criteria change according to the chosen operational configuration. A significant example is “enhancement of employee satisfaction (related to possible long-term employment)”, whose impact varies based on the contractual conditions stipulated in different outsourcing models. In this context, a useful indicator to measure the project’s effect on employees’ job continuity is “average employment duration”.

Conversely, within the environmental dimension, the identified criteria remain valid regardless of the adopted operational model. For example, “greenhouse gas emissions reduction” is a consistently relevant criterion, measurable through the indicator “calculation of avoided CO₂ emissions”.

The inclusion of such indicators was also framed as a compliance issue:

Emission reduction is also part of our DEASP – the port system’s environmental and energy document. [...] Any practice or technology that help us cut emissions, help us meet targets assigned to us as a Port Authority.

(Office coordinator, development, promotion and statistics unit – Port Authority)

These criteria served as the foundation for a multidimensional assessment, supporting a more comprehensive evaluation of investment alternatives. Each criterion may be further operationalised through context-specific indicators, allowing for the measurement and comparison of impacts across different scenarios and stakeholder configurations.

5. Discussion

The case study illustrated in the previous section was aimed at exploring *how marine plastic waste management solutions can be holistically evaluated in alignment with the objectives of SDGs 12 and SDG 14*. The findings show how, overall, the integrated CBA–MCDA model provides a structured approach to evaluating sustainability-oriented investments by capturing both quantitative and qualitative dimensions of value creation. By combining economic, environmental and social criteria – refined and validated through stakeholder engagement – the model supports more informed and transparent decision-making in complex contexts such as, for instance, port-based waste management. The flexibility of the proposed framework allows for adaptation to different operational configurations, ensuring relevance across a variety of public and/or private governance models.

Beyond its methodological contribution, the model directly supports the implementation of the SDGs, particularly SDG 12 and SDG 14. Several of the integrated criteria reflect core targets within these goals. For example, indicators related to waste recovery rates and the reduction of landfill use align with SDG targets 12.4 and 12.5, which promote the environmentally sound management of waste and a substantial reduction in waste generation through prevention, reduction and recycling. Likewise, the emphasis on life-cycle environmental impacts and emission reduction corresponds to SDG 12.6, which encourages organisations to adopt sustainable practices and integrate sustainability considerations into their reporting processes.

With respect to SDG 14, environmental criteria focused on reducing marine litter and mitigating pollution align with targets 14.1 and 14.2. These call for the prevention and significant reduction of marine pollution, particularly from land-based activities, as well as

the sustainable management and protection of marine and coastal ecosystems. By embedding these priorities within a decision-making framework, the model ensures that infrastructure investments not only address financial and operational considerations but also contribute meaningfully to broader environmental and societal objectives. In doing so, it enhances the alignment between project-level evaluation and the global sustainability agenda. The relationship between the model's economic, social and environmental criteria and the relevant SDG targets is summarised in [Table 5](#).

The proposed model deepens the integration of SDG 12 and SDG 14 by emphasising the managerial relevance of the interconnection between terrestrial plastic waste management and the preservation of marine ecosystems. While existing literature often addresses these goals separately, focusing either on reducing plastic waste through sustainable production and consumption ([Lee, 2021](#); [Cho et al., 2024](#); [Ram and Bracci, 2024](#)) or on marine biodiversity protection ([Eliff et al., 2022](#); [Mahapatra et al., 2024](#)), few studies consider the critical link between these two systems ([Chen et al., 2020](#); [Issifu and Sumaila, 2020](#); [Strippoli et al., 2024](#)).

This interconnection is operationalised within the multidimensional framework, which assesses the adoption of innovative solutions such as pyrolysis technology. These technologies offer a viable pathway for managing plastic waste at the terrestrial level by preventing improper disposal, thereby reducing leakage into aquatic environments. In doing so, they play a key role in protecting marine biodiversity and aquatic species by limiting the entry of plastic debris into marine ecosystems ([Ferronato et al., 2024](#)).

Additionally, the proposed model promotes a holistic management approach that considers the interplay between economic, environmental and social factors. This approach demonstrates how responsible terrestrial waste management is a prerequisite for marine biodiversity conservation and for mitigating negative impacts on economic sectors such as fisheries and tourism, which are closely tied to the health and attractiveness of marine environments ([Arabi and Nahman, 2020](#); [Karlsson et al., 2018](#); [Apete et al., 2024](#)). Additionally, human health benefits are highlighted, as plastic pollution poses risks to public health through the introduction of microplastics into the food chain ([Sharma et al., 2021](#); [Apete et al., 2024](#)).

Table 5 Contribution of economic, social and environmental criteria to SDG 12 and SDG 14

<i>Dimension</i>	<i>Criteria</i>	<i>SDG target</i>	<i>Alignment</i>
Economic	Depreciation period	Cross-cutting (supports enabling conditions for SDGs)	Ensures economic sustainability of environmentally and socially beneficial projects
Social	Enhancement of employee satisfaction (related to possible long-term employment)	SDG 12.6 – Adoption of sustainable practices	Promotes socially responsible operational models, including decent work conditions
Environmental	Reduction of waste to landfill	SDG 12.4 – Responsible waste management SDG 12.5 – Waste prevention, reduction and recycling	Supports improved treatment of waste and reduced environmental impact Contributes to substantially reducing waste generation through enhanced recovery processes
		SDG 14.1 – Marine pollution reduction SDG 14.2 – Marina and coastal ecosystems protection	Aims to prevent and significantly reduce marine pollution, especially from land-based sources Supports the sustainable management and restoration of marine and coastal environments
	Reduction of greenhouse gas emissions	SDG 12.6 – Adoption of sustainable practices	Encourages sustainability integration into business strategies and reporting

Source(s): Authors' own work

Furthermore, this study also advances the literature on the application of MCDA in plastic waste management systems (Omran *et al.*, 2021; Deshpande *et al.*, 2020), integrating MCDA with CBA to overcome the inherent limitations of each approach (Beria *et al.*, 2012; Babashamsi *et al.*, 2016). The integration enhances the ability to evaluate complex solutions in multidimensional contexts. In this regard, the model represents an innovative decision-making tool that combines financial and non-financial methods, supporting organisations in assessing investment decisions aligned with SDGs (Pigatto *et al.*, 2024).

Finally, the findings underscore the importance of a holistic approach to addressing sustainability complexities, overcoming the limitations of traditional analyses, which often focus on isolated dimensions (Finnveden and Moberg, 2005; Saad *et al.*, 2019). The model differentiates itself from other studies that predominantly concentrate on economic and environmental criteria (Santos *et al.*, 2022) by also incorporating the social dimension.

6. Conclusions

While SDG 12 and SDG 14 are inherently interconnected, existing literature tends to treat them in isolation, lacking integrated frameworks that holistically assess marine plastic waste management in alignment with both goals. This study aims to address this gap, presenting an interventionist case study on a pilot project in a major Italian port, where a multidimensional CBA–MCDA evaluation model assesses the sustainability of a proposed pyrolysis plant for marine plastic waste, integrating economic, environmental and social criteria in alignment with both SDGs.

The research offers practical implications for public policy and societal outcomes. The integrated CBA–MCDA framework constitutes a robust analytical tool for the appraisal of sustainability-driven investments, effectively bridging quantitative and qualitative dimensions of value creation. By integrating economic, environmental and social criteria – validated through stakeholder engagement – it enhances the transparency and quality of decision-making in complex contexts such as port-based waste management. Its adaptability ensures suitability across a variety of operational settings and public–private governance models.

By enabling a comprehensive assessment that incorporates ecosystem protection, resource efficiency and long-term socio-economic impacts, the model contributes to advancing the implementation of SDGs. In particular, it aligns with the objectives of SDG 12 by promoting the adoption of responsible production and waste treatment practices and supports SDG 14 by fostering initiatives aimed at reducing marine pollution and protecting coastal ecosystems. As such, the model offers a decision-support tool that goes beyond project-specific feasibility, promoting the broader integration of sustainability principles into infrastructure planning and evaluation.

The proposed model provides a decision-making tool that supports the evaluation and adoption of innovative technologies, such as pyrolysis, by demonstrating their long-term sustainability benefits. Thus, it enables the development of targeted solutions to address challenges at different levels, micro (e.g. companies), meso (e.g. partnerships, association, etc) and macro (e.g. Cities, Regions) promoting policies that address both upstream and downstream impacts of waste management practices. By aligning financial and non-financial criteria, the model enables organisations and policymakers to make informed, long-term investment decisions. This approach is particularly valuable in contexts that require alignment with SDGs, addressing sustainability challenges comprehensively and prioritising holistic outcomes over isolated considerations.

On a societal level, the model highlights the broader benefits of sustainable waste management, including job creation and public health protection. By reducing marine plastic pollution, it contributes to the health and resilience of marine ecosystems, which are vital for the economic sustainability of fisheries and tourism industries.

However, the study also acknowledges certain limitations. The complexity of the model requires a substantial amount of data and stakeholder input, which may pose challenges in other contexts where data availability or stakeholder engagement is limited. Additionally, while the model offers a comprehensive evaluation, the final decision still involves trade-offs, requiring decision-makers to balance competing priorities and interests. This challenge is in line with the observations made by Babashamsi *et al.* (2016), who noted the difficulties in monetising intangible aspects and quantifying environmental costs in conventional CBAs.

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Further reading

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Corresponding author

Michele Guidi can be contacted at: m.guidi@univpm.it

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