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Optimizing public investments: A Sustainable Economic, Environmental, and Social Investment Multi-criteria Decision Model (SEESIM)

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ABSTRACT

One of the most important aspects for the economic and social growth of a country is high efficiency of public investments. This imperative has never been more critical, especially in the context of Europe and Italy, where the integration of environmental, economic, and social goals is essential to address the multifaceted challenges of the 21st century. This research introduces the Sustainable Economic, Environmental, and Social Investment Model (SEESIM), a novel multi-criteria decision-making framework designed to ensure the sustainability of projects as their validity over time, especially from a National Recovery and Resilience Plan perspective. Utilizing the Analytic Hierarchy Process (AHP), SEESIM integrates environmental, economic, and social criteria as useful tool to evaluate a project in the post-funding phase, ensuring a balanced approach to efficiency and sustainability. The model is adaptable to various regional contexts, providing a transparent and replicable methodology for assessing the impacts and costs of public investments. An experimental scenario demonstrates SEESIM's utility in guiding investment decisions, highlighting its potential to significantly enhance the effectiveness of public resources in achieving long-term sustainability goals. SEESIM represents a pivotal advancement in sustainable development strategies, offering a comprehensive tool for integrating multi-dimensional sustainability criteria into public investment decisions.

1. Introduction

The pursuit of sustainable development has become a cornerstone in shaping public policies within Italy and across Europe (Ummalla et al., 2023). As nations grapple with the multifaceted challenges posed by climate change, resource depletion, and social inequality, the urgency for adopting and implementing strategies that ensure environmental, economic, and social sustainability has never been more pronounced (Cerniglia, et al., 2023). This imperative is especially relevant in the realm of public investments, where decisions have far-reaching implications for the welfare of current and future generations (Heijdra and Meijdam, 2002). Europe, with its rich history of industrial development and its diverse regional contexts, stands at a critical juncture (Cepparulo et al., 2024). The continent's commitment to sustainable development is evident in numerous policy frameworks and initiatives at both the European Union (EU) level and within individual member states like Italy. The EU's European Green Deal, for instance, represents an ambitious blueprint for transforming the Union into a modern, resource-efficient, and competitive economy, with the overarching goal of achieving climate neutrality by 2050 (Ciarini et al., 2023). Similarly, Italy has embarked on significant reforms and investments aimed at transitioning to a green economy, underscored by initiatives such as the National Recovery and Resilience Plan (NRRP), which allocates substantial funds towards sustainability projects (Busemeyer and Beiser-McGrath, 2024). However, the effective allocation of public investments in this direction necessitates a delicate balance between immediate economic needs and long-term environmental objectives (Baffo et al., 2023). Moreover, the regional impact and the associated costs of such investments are complex and multifaceted, varying significantly across different geographical and socio-economic contexts within Italy

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and Europe at large (Rouyre et al., 2024). This variability underscores the importance of developing robust, flexible, and transparent decision-making models that can adapt to diverse regional needs while optimizing the impact of public investments on sustainable development (Cucchiella et al., 2023). In response to these challenges, the proposed manuscript aims to introduce an innovative Sustainable Economic, Environmental, and Social Investment Model (SEESIM), based on Analytic Hierarchy Process (AHP) a multi-criteria decision-making technique (Saaty, 2016). This model seeks to guide public investment choices by integrating a comprehensive set of criteria that reflect the core pillars of sustainability: environmental impact, economic viability, and social acceptability. By offering a systematic framework for evaluating and prioritizing proposed plans, programs, and projects, the model addresses a critical gap in current public policy-making processes. It promises not only to enhance the efficiency and effectiveness of public investments but also to ensure that such investments are aligned with the long-term sustainability objectives that Italy and Europe are committed to achieving (Magnussen and Olsson, 2006). This model is distinct in its comprehensive integration of environmental, economic, and social criteria, thus offering a holistic framework for evaluating and prioritizing sustainable development initiatives (Bulathsinhala, 2015). Unlike existing models, which often focus on single aspects of sustainability or lack adaptability to diverse regional contexts, the proposed model emphasizes a balanced consideration of sustainability dimensions and is designed to be flexible across different geographical settings (Maude Brunet and Monique Aubry, 2018). By providing a transparent and replicable decision-making process, the model aims to optimize public investments, ensuring they are not only efficient in resource utilization but also effective in contributing to the overarching objectives of sustainable development. Furthermore, the manuscript aims to delineate how this model surpasses current methodologies by facilitating a more nuanced understanding of the regional impacts and costs associated with public investments. In doing so, it seeks to address a critical gap in the literature and practice, offering practitioners and academics alike a valuable tool for guiding public investment choices towards achieving environmental sustainability, economic resilience, and social acceptance. Through its innovative approach and practical applicability, the manuscript aims to set a new benchmark in the field of sustainable development, particularly in the context of public investments in Italy and Europe. The *novelty* of this manuscript lies in its application of the AHP method to create a transparent, replicable, and adaptable decision-making framework tailored to the diverse regional contexts of Italy and Europe at large (Saaty, 1979). This model stands as a testament to the potential of AHP in optimizing the use of public resources, ensuring that investments are not just judiciously allocated but are also potent contributors to the sustainability agenda (Lbahar et al., 2022). In delineating a path forward, this manuscript aims to contribute a *valuable tool for policymakers*, *stakeholders*, and *academics* alike, facilitating informed decision-making that is grounded in a comprehensive understanding of the multifaceted dimensions of sustainable development (Edelenbos and Klijn, 2006). Through this work, we seek to catalyze a paradigm shift in how public investments are conceptualized, evaluated, and implemented, paving the way for a future where sustainability is not just an aspiration but a tangible reality. The relevance of this work lies in its potential to inform and transform public investment strategies, making them more aligned with sustainable development goals. It provides policymakers, practitioners, and academics with a practical tool for navigating the complexities of sustainable development, enabling more informed, transparent, and strategic decision-making. Ultimately, by fostering a more sustainable approach to public investments, this model contributes to the broader quest for a resilient, inclusive, and sustainable future for Italy, Europe, and beyond.

The rest of the manuscript is organized as follows: Section 2 intends to provide an overview on public investments and political strategies; Section 3 summarizes materials and methods applied in the proposed model; Section 4 presents the SEESIM model for Sustainable and Transparent Decision-Making in Public Investments; Sections 5 and 6 summarize the main results and discussions, respectively. Finally, the main contribution and future development of the research is outlined in Section 7.

2. Overview on public investments and political strategies

2.1. Importance of public investments and evolution of political strategies over time

Public investments play a pivotal role in the economic and social development of countries, acting as a catalyst for growth, innovation, and well-being. In Italy and Europe, the landscape of public investment has evolved significantly over time, reflecting changes in economic priorities, political landscapes, and societal needs (Del Bo et al., 2023). This evolution can be understood in several *key phases*, highlighting the importance of public investments in shaping the region's development. In the aftermath of World War II, Europe, including Italy, faced the colossal task of rebuilding destroyed infrastructure and economies. Public investment was crucial in this phase, with significant resources allocated to reconstructing cities, industries, and transportation networks. The Marshall Plan, a significant American initiative, provided substantial aid to Western European countries, facilitating recovery and laying the groundwork for future prosperity (Eick et al., 2023). This period saw a strong belief in the power of government intervention and public investment to drive economic growth and modernization. From the 1950s to the early 1970s, Europe experienced a period of rapid economic growth and expansion, often referred to as the "*Golden Age*". During this time, public investment expanded beyond infrastructure into social services, education, and health, reflecting the establishment and expansion of welfare states, particularly in Northern and Western Europe (Brasili, et al., 2021). Italy, under the "*Italian economic miracle*", saw significant industrial growth and infrastructure development, supported by public investment in industries, housing, and social welfare programs. This era underscored the importance of public investment in creating more equitable and inclusive societies. The late 20th century marked a shift towards neoliberal policies, with a greater emphasis on market mechanisms and privatization. The economic crises of the 1970s and 1980s prompted a reevaluation of the role of the state in the economy across Europe (Carfora et al., 2021). This period saw a reduction in direct public investment in certain sectors, accompanied by the privatization of state-owned enterprises and deregulation of markets (Avdimetaj et al., 2021). In Italy, these trends were mirrored by efforts to reduce public debt and liberalize the economy, though with varying degrees of success and continued debates over the balance between public and private sector roles in investment. The formation and expansion of the European Union (EU) introduced a new dimension to public investment in Europe (Czubak et al., 2021). The EU's cohesion policy, aimed at reducing disparities between regions, became a key vehicle for public investment across member states. Funds allocated through the European Structural and Investment Funds (ESIF) have been instrumental in supporting infrastructure development, innovation, and social inclusion projects. Italy, as a beneficiary, has received significant funding aimed at boosting economic development, particularly in its less developed southern regions. The 21st century has seen a renewed focus on public investment as a tool for addressing contemporary challenges such as climate change, digitalization, and social inequality (Deleidi et al., 2020). The European Green Deal and the Next Generation EU recovery plan, including the Recovery and Resilience Facility (RRF), represent landmark initiatives directing public investment towards sustainable development, digital transformation, and resilience building. Italy's National Recovery and Resilience Plan (NRRP) under Next Generation EU is a prime example, targeting investments in green transition, digital innovation, infrastructure, education, and health (Archibugi et al., 2020). Fig. 1 highlights the shifting focus and strategies of public investments in Italy and Europe, from post-war recovery

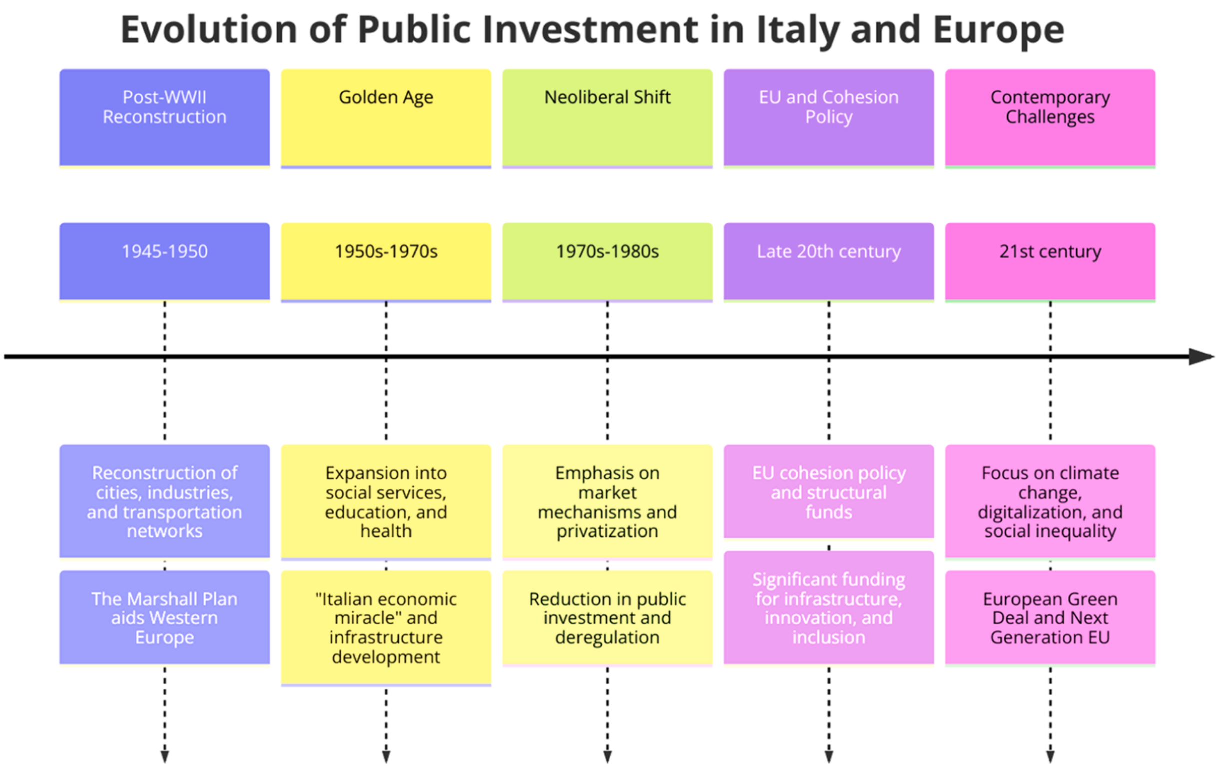

Fig. 1. Timeline on the evolution of public investment in Italy and Europe (Author's elaboration).

efforts to addressing modern challenges like sustainability and digital transformation.

The evolution of public investments in Italy and Europe reflects broader economic and societal shifts, from post-war reconstruction to the challenges of sustainable development and digitalization. These investments have been crucial in driving economic growth, reducing disparities, and adapting to new global challenges (Psycharis et al., 2020). As Europe faces the future, the importance of public investment - in shaping resilient, sustainable, and inclusive economies - remains as relevant as ever.

2.2. *Importance of evaluation of public investments*

The correct evaluation of public investments is crucial for several reasons, each underpinning the broader objective of ensuring that these investments deliver maximum benefit to society while efficiently utilizing scarce resources (Caragliu and Del Bo, 2020). This process involves assessing the economic, social, environmental, and financial impacts of investment projects before, during, and after their implementation (Bubbico et al., 2020). The importance of this evaluation can be distilled into six key aspects, as shown in Table 1. It is important to specify that the 6 Key Attributes (KA) presented in Table 1 were selected based on the extensive experience of the authors in the field of public project evaluation and strategic planning. This experience, accumulated through years of research, consulting, and project implementation, has enabled the authors to identify the most critical attributes for measuring the effectiveness, efficiency, and sustainability of funded interventions. While the selection of attributes may be considered subjective, it is not arbitrary. The authors employed a rigorous methodology based on empirical evidence, that is, data collected through case studies, statistical analyses, and direct field observations, to determine which attributes to include. This approach ensures that the evaluations are comprehensive, relevant, and grounded in a solid theoretical and practical foundation.

By focusing on economic efficiency, sustainable development, social equity, risk management, accountability, and informed decision-making, public authorities can maximize the benefits of investments for society as a whole (Staehr and Urke, 2022). This not only enhances the immediate outcomes of specific projects but also contributes to the long-term resilience and prosperity of communities and nations (Masten and Grdović Gnip, 2019). The monitoring and evaluation of a project is based on a predefined logical/causal sequence of actions (process), even if potentially subject to updates (Randjelovic, 2020). The logic that governs the process is systemic, that is, it places each phase in continuous interaction, creating feedback between the different components with a view to continuous learning, as shown in the Fig. 2.

The approach adopted applies the so-called impact value chain which is explained schematically the process of generating value through the chaining of inputs, outputs, outcomes and impacts (Saccone et al., 2022). If appropriately implemented, this model helps to achieve three important objectives:

– monitor the results achieved by projects during their life cycle to verify the use of resources is producing the expected results.
– evaluate whether the projects have contributed to the achievement of strategic objectives and, more generally, to character improvements economic, social and environmental.
– calibrate and update strategy and intervention methods, favoring actions that generate better impacts and optimizing over time the use of financial resources itself.

On this logical basis, this research proposes a model to incentivize interventions considered strategic for Italy in a European context by providing a robust framework for evaluating and enhancing funded projects. The SEESIM model serves as a vital tool in the post-funding phase, ensuring that the projects not only align with strategic goals but also deliver the intended benefits effectively. The logic behind the model is summarized below:

Table 1
Six key aspects of the importance of evaluation of public investments (Author's elaboration).

Key aspects	Description
KA#1 Ensuring Economic Efficiency	Correct evaluation ensures the allocation of public funds to projects with optimal value for money. This involves analyzing the cost-effectiveness of different investment options and selecting projects that maximize social and economic returns relative to their cost. Limited public resources require careful consideration of opportunity costs.
KA#2 Promoting Sustainable Development	Evaluating public investments from an environmental perspective ensures alignment with sustainable development goals. This includes assessing potential environmental impacts, such as carbon footprint and effects on biodiversity, to comply with environmental sustainability principles and regulations.
KA#3 Enhancing Social Equity	Public investments aim to promote social equity by improving access to essential services (healthcare, education, transportation). Correct evaluation assesses social impacts, focusing on reducing inequalities and enhancing the quality of life for all population segments, particularly the most vulnerable.
KA#4 Risk Management	Evaluation involves identifying and managing financial, operational, and environmental risks associated with projects. This includes addressing cost overruns, delays, and potential negative impacts. Proper risk assessment and management increase the likelihood of projects being completed on time, within budget, and achieving intended outcomes.
KA#5 Facilitating Accountability	Thorough evaluation processes enhance accountability and transparency in public fund utilization. Clear criteria for project selection and performance assessment allow public authorities to demonstrate that investments serve the public interest and meet intended objectives. This fosters public trust and support for investment programs.
KA#6 Informing Policy and Decision-Making	Correct evaluation of public investments generates valuable data and insights to inform future policy and investment decisions. Lessons learned from past projects contribute to improving the design and implementation of future investments, ensuring they are more effective in achieving their goals.

1. **Post-Funding Phase Application**: The SEESIM model is applied after the initial funding and implementation of projects. In this phase, the model helps monitor, evaluate, and optimize the outcomes of funded projects. This ongoing evaluation ensures that projects continue to meet strategic objectives and deliver expected benefits.
2. **Enhancing Project Outcomes**: By providing a structured evaluation framework, the SEESIM model enables stakeholders to assess the performance of projects across multiple criteria, including economic impact, environmental sustainability, and social benefits. This assessment helps identify areas where projects may need adjustments or additional support to achieve their goals fully.
3. **Incentivizing Strategic Interventions**: The model incentivizes strategic interventions by highlighting successful projects and best practices that align with national and European priorities. This recognition can encourage the replication of successful approaches in future projects, fostering a culture of continuous improvement and strategic alignment.
4. **Continuous Improvement**: By using the SEESIM model in the post-funding phase, stakeholders can gather valuable insights and data on project performance. These insights inform future funding decisions, helping to refine criteria and improve the selection process for new projects. This feedback loop ensures that public investments are continually optimized for maximum impact.

The SEESIM model is applied during the post-funding phase to:

- **Monitor**: Track the progress of funded projects against predefined criteria.
- **Evaluate**: Assess the effectiveness and impact of projects based on economic, environmental, and social metrics.
- **Optimize**: Provide recommendations for improvements and adjustments to enhance project outcomes.
- **Report**: Generate detailed reports on project performance to inform stakeholders and guide future investments.

By utilizing the SEESIM model in the post-funding phase, stakeholders can ensure that public investments are not only strategically targeted but also effectively managed to deliver sustained benefits. This approach maximizes the return on investment and supports long-term sustainable development.

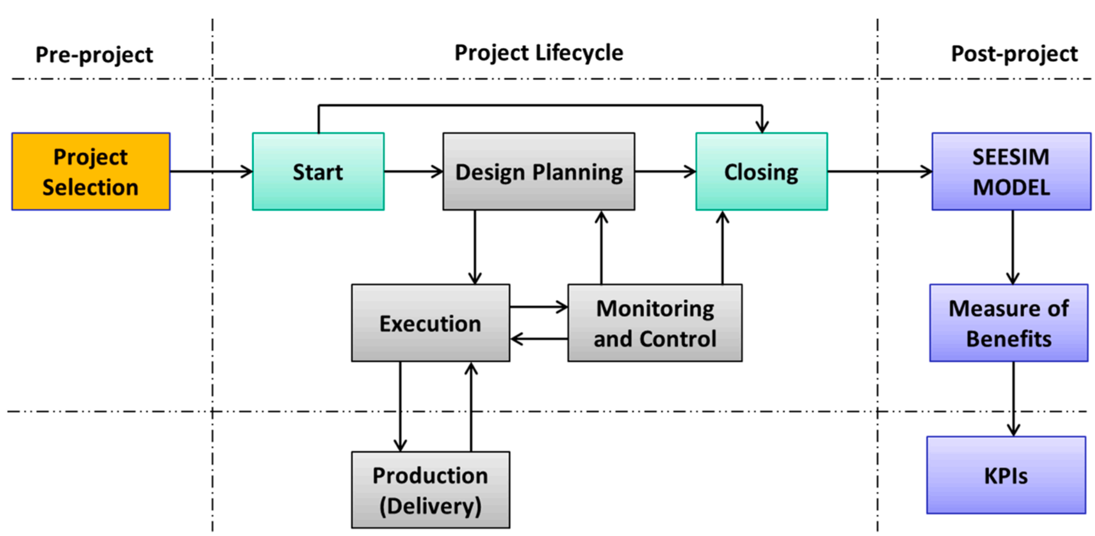

Fig. 2. Systematic scheme characterizing the management of a project (Author's elaboration).

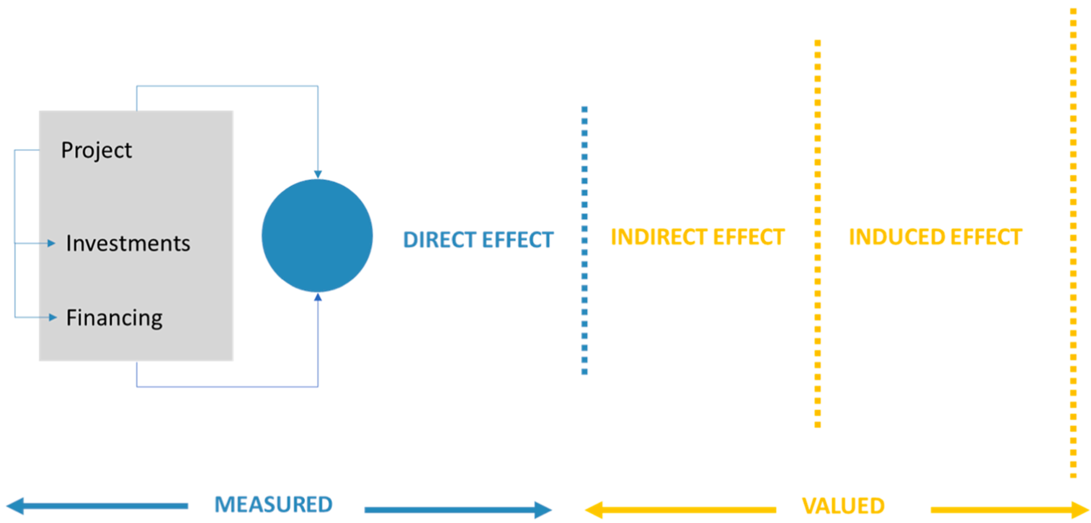

Fig. 3. Estimation of indirect and induced effects (Author's elaboration).

In particular, the result of the model is the definition of key performance indicators (KPIs) for each strategic priority with the aim of monitoring and standardizing the results achieved (Cerniglia, et al., 2021). Using KPIs it is possible to estimate the *direct*, *indirect* and *induced* effects of a certain volume of financing. Fig. 3 illustrates the indirect and induced effects that can be evaluated using the SEESIM model. It is crucial to understand the differences between these effects and how they contribute to a comprehensive evaluation of public investment projects.

2.2.1. 1. Indirect Effects

Indirect effects refer to the secondary economic activities that result from the implementation of a project. These effects are typically observed in industries and sectors that supply goods and services to the project. For example:

- **Supply Chain Impact**: Increased demand for materials and services required for the project, leading to growth in supplier industries.
- **Employment in Supporting Industries**: Creation of jobs in industries that provide inputs to the project, such as construction materials, equipment manufacturing, and professional services.

2.2.2. Induced Effects

Induced effects are the additional economic activities generated by the spending of income earned from the direct and indirect effects of the project. These effects are observed in the broader economy as the increased income leads to higher consumption and further economic activity. For example:

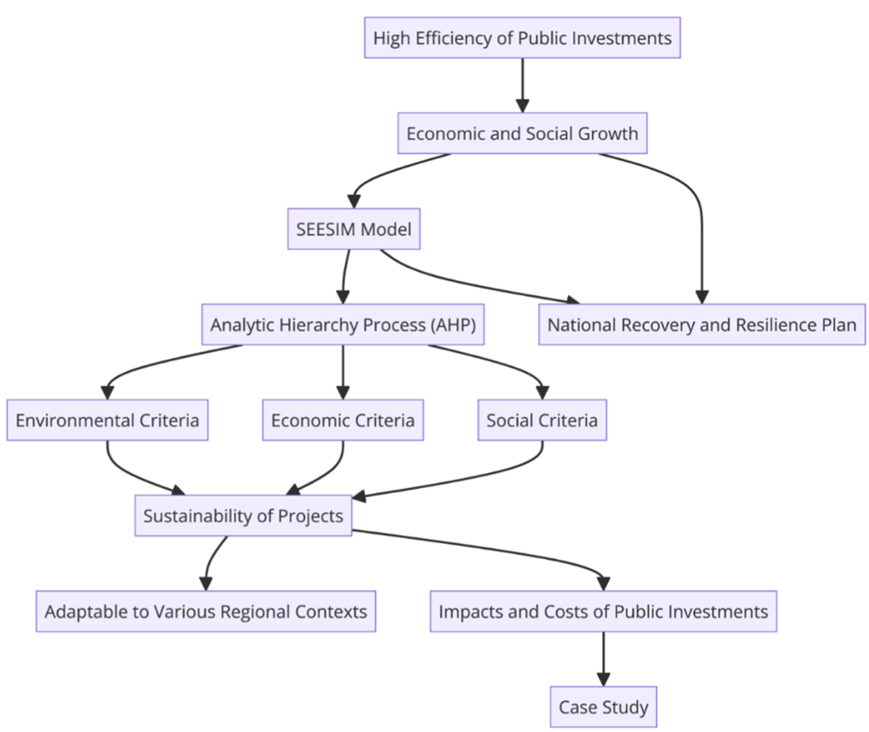

Fig. 4. Logical structure underlying the proposed model (Author's elaboration).

- **Household Spending**: Employees involved in the project and its supply chain spend their earnings on goods and services, stimulating local businesses such as retail, hospitality, and entertainment.
- **Community Benefits**: Improved economic conditions lead to increased tax revenues for local governments, which can be reinvested in public services and infrastructure, enhancing overall community welfare.

By evaluating both indirect and induced effects, the SEESIM model provides a comprehensive assessment of the wider economic impacts of public investment projects. This holistic view helps policymakers understand the full range of benefits and make more informed decisions about resource allocation.

3. Materials and methods

Logical structure underlying the proposed model for evaluating public investments with a focus on efficiency, growth, and sustainability is shown in Fig. 4. The SEEISM Model is influenced by the Analytic Hierarchy Process (AHP) approach, which evaluates investments based on environmental, economic, and social criteria, ensuring project sustainability. This sustainable focus intends to be adaptable and assess the impacts and costs, with the practical application explored through a case study.

3.1. *Multicriteria decision models (MCDMs)*

Public investments wield substantial influence over the trajectory of economies and societies. Whether directed towards infrastructure development, environmental initiatives, or social welfare programs, these investments demand careful consideration of diverse and often conflicting criteria (Yikici and Özçelik, 2023). The multifaceted nature of public investments necessitates a departure from traditional decision-making approaches, where singular criteria may prove inadequate in capturing the intricate interplay of economic, environmental, and social factors (Heidary et al., 2023). Multicriteria Decision-Making Models (MCDMs) emerge as crucial tools in this context, offering decision-makers a systematic framework to grapple with the multifaceted nature of such decisions. This exploration delves into the importance of MCDMs in the realm of public investments, emphasizing their academic and practical relevance (Nesticò et al., 2018). MCDMs, as analytical tools, offer a paradigm shift in decision-making by acknowledging the existence of multiple, diverse criteria. Unlike unidimensional models that often oversimplify complex decision landscapes, MCDMs provide a holistic lens through which decision-makers can comprehensively evaluate and compare various alternatives. This holistic perspective aligns with the intricate nature of public investments, which inherently involve considerations spanning economic viability, environmental impact, social equity, and alignment with broader policy objectives (Carboni, 2017). At the core of MCDMs is the evaluation and comparison of different decision alternatives or options. Decision-makers must consider the performance of each alternative across the specified criteria, aiming to identify the most suitable course of action (Beuthe et al., 2000). The versatility of MCDMs extends beyond theoretical frameworks, finding practical applications across diverse sectors. In the context of public investments, MCDMs prove invaluable in project selection, resource allocation, and policy formulation (Lombardi Netto et al., 2021). Their adaptability to different decision contexts allows decision-makers to tailor the model to the specific nuances of each investment, contributing to a more nuanced and contextualized decision-making process (Cobacho et al., 2010). Transparency and accountability are foundational principles in public governance. MCDMs, with their structured approach and explicit consideration of multiple criteria, enhance transparency in decision-making processes related to public investments. The hierarchical structure of these models facilitates clear documentation of criteria, weights assigned to each criterion, and the rationale behind decision outcomes. This transparency not only builds trust among stakeholders but also establishes a foundation for greater accountability in the allocation of public funds (De Felice et al., 2021).

3.2. *Analytic Hierarchy Process (AHP)*

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s (Saaty, 1978). Fig. 5 shows the logical diagram of the AHP method.

AHP has been used extensively in various decision-making situations, including those in business, government, and education (Abdulkareem et al., 2022). Analyzing the key components of the AHP (Vargas and Saaty, 1981) reveals a systematic and structured decision-making methodology, as follows (Table 2):

With reference to the *construct a set of pairwise comparison matrices* it is important to point out that the Pairwise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion. Saaty suggested a scale of 1–9 when comparing two components as shown in Table 3 (Saaty, 1982). For example, number 9 represents extreme importance over another element. And number 8 represents it is between "*very strong important*" and "*extreme importance*" over another element (Saaty, 1986).

Let $A_1, A_2,\ldots,A_m$ denote the set of elements, while a_{ij} represents a quantified judgment on a pair of A_i, A_j. Through the 9-value scale for pairwise comparisons, this yields an [m x m] matrix A as follows:

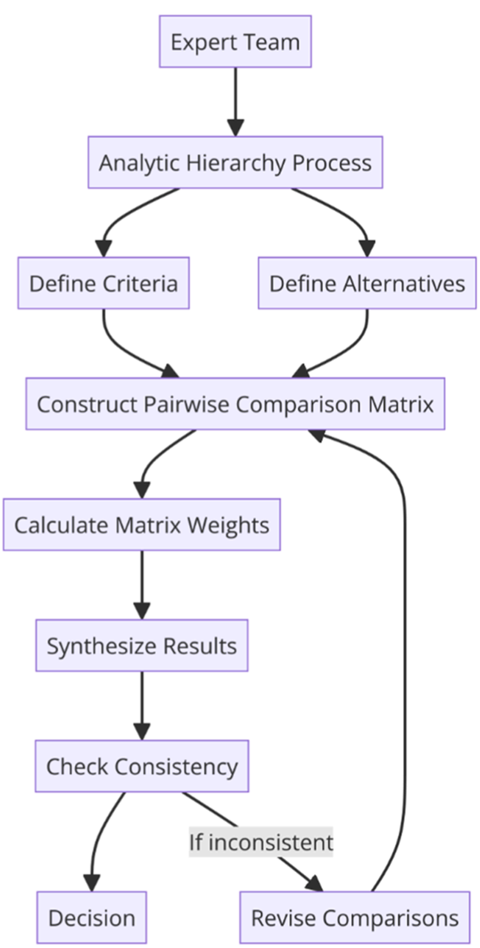

Fig. 5. Logical diagram of the AHP method (Author's elaboration).

Table 2
Descriptive detail of the main steps of AHP.

Step		Description
#1	Define the Problem and Determine the Goal	Clearly articulate the decision problem and specify the desired outcomes or goals.
#2	Structure the Hierarchy	Decompose the decision problem into a hierarchical structure, beginning with the overarching goal at the top. Subsequent levels include objectives, criteria, sub-criteria, and alternatives. This hierarchical breakdown facilitates a systematic analysis of the decision landscape.
#3	Construct a Set of Pairwise Comparison Matrices	For each level in the hierarchy, conduct pairwise comparisons between elements to assess their impact on the element directly above them. Create matrices to capture these comparisons, ensuring a comprehensive evaluation of relationships within the decision framework.
#4	Calculate Weights and Consistency Ratio	Derive priority scales from the pairwise comparisons to assign relative weights to criteria and alternatives. Perform consistency ratio calculations to assess the reliability of judgments. If consistency is below acceptable levels, reconsider and refine judgments for improved reliability.
#5	Aggregate the Weights to Determine an Overall Ranking	Aggregate the assigned priorities across all levels of the hierarchy. This cumulative process yields an overall ranking of the alternatives. The aggregation provides a synthesized view of the decision landscape, aiding decision-makers in identifying and prioritizing the most favorable alternatives.

Table 3
Semantics scale of Saaty.

Intensity of importance a_{ij}	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

$$
A = a_{ij} = \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{array} \left| \begin{array}{cccc} A_1 & A_2 & \cdots & A_m \\ 1 & a_{12} & \cdots & a_{1m} \\ 1/a_{12} & 1 & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{1m} & 1/a_{2m} & \cdots & 1 \end{array} \right|
$$

where $a_{ij} > 0$ (i, j = 1, 2,.,m), $a_{ii} = 1$ (i = 1, 2,…,m), and $a_{ij} = 1/a_{ji}$ (1; 2;…,m). A is a positive reciprocal matrix.

The result of the comparison is the so-called dominance coefficient a_{ij} that represents the relative importance of the component on row (i) over the component on column (j), i.e., $a_{ij}=w_i/w_j$. The pairwise comparisons can be represented in the form of a matrix. The score of 1 represents equal importance of two components and 9 represents extreme importance of the component i over the component j (Basak and Saaty, 1993).

In matrix A, the problem becomes one of assigning to the m elements A_1, A_2,…,A_m a set of numerical weights w_1, w_2,…,w_m that reflects the recorded judgments. If A is a consistency matrix, the relations between weights w_i, w_j and judgments a_{ij} are simply given by $a_{ij} = w_i/w_j$ (for i,j = 1, 2, …, m) and

$$
A = \begin{array}{c} A_1 \\ A_2 \\ \cdots \\ A_m \end{array} \left| \begin{array}{cccc} w_1/w_1 & w_1/w_2 & & w_1/w_m \\ w_2/w_1 & w_2/w_2 & & w_2/w_m \\ \cdots & \cdots & \cdots & \cdots \\ w_m/w_1 & w_m/w_2 & \cdots & w_m/w_m \end{array} \right|
$$

If matrix w is a non-zero vector, there is a λ_{max} of $Aw = \lambda_{max}w$, which is the largest eigenvalue of matrix A. If matrix A is perfectly consistent, then $\lambda_{max}w = m$. But given that a_{ij} denotes the subjective judgment of decision-makers, who give comparison and appraisal, with the actual value (w_i/w_j) having a certain degree of variation. Therefore, $Ax = \lambda_{max}w$ cannot be set up. So the judgment matrix of the traditional AHP always needs to be revised for its consistency. After all pairwise comparison is completed, the priority weight vector (w) is computed as the unique solution of $Aw = \lambda_{max}w$, where λ_{max} is the largest eigenvalue of matrix A (Saaty, 2005).

Regarding the Consistency index estimation Saaty (1990) proposed utilizing consistency index (CI) to verify the consistency of the comparison matrix. The consistency index (CI) of the derived weights could then be calculated by: $CI = (\lambda_{max} - n)/ n-1$. In general, if CI is less than 0.10, satisfaction of judgments may be derived.

AHP has found applications in various fields, including business, engineering, healthcare, and public policy. Its versatility and ability to handle both quantitative and qualitative data make it particularly suitable for complex decision environments. Advantages of AHP (Niemira and Saaty, 2006):

- Structured Approach: AHP provides a systematic and organized framework for decision-making.
- Quantitative and Qualitative Integration: AHP allows the integration of both quantitative and qualitative data.
- Transparency: The hierarchical structure and pairwise comparisons enhance transparency in decision processes.

4. SEESIM model for sustainable and transparent decision-making in public investments

4.1. *The scenario under study on Italian small municipalities*

The scenario under study is related to National plan for the redevelopment of *small municipalities* in Italy for the design of environmental protection, economic development, mitigation of hydrogeological risk. The tender is intended to finance projects for the valorization of municipalities with a population of less than **5000** inhabitants. The motivation behind the plan is the promotion of the economic, social, environmental and cultural development of rural areas, to counteract depopulation and encourage the conservation and valorization of the territory.

In this context the implementation of the SEESIM model and the subsequent synthesis of its results into a monitoring dashboard is a tool useful in the *post-funding* project verification phase. This crucial step aims to validate the actual impact of the funded projects, ensuring they effectively contribute to the structural, economic, and social development of the involved small municipalities. The model aims to provide a structured mechanism to assess and compare the different impact dimensions of the projects, based on predetermined criteria that reflect the objectives of the call. Through this analytical methodology, it is possible to quantify and prioritize the critical aspects of each project, from environmental sustainability to technological innovation, and from economic impact to social benefits. The derived dashboard facilitates an intuitive visualization of the results, offering stakeholders an immediate overview of the performance of the funded projects. Using graphical representations, such as radar charts, the dashboard allows for the visual identification of strengths and areas for improvement, thus supporting informed decisions on future resource allocation and development policy orientation. Definitively, employing the SEESIM model in the post-funding verification phase emerges as an innovative approach to ensure that public investments are directed towards initiatives that maximize the well-being of the target communities and promote sustainable development. This strategy not only increases the transparency and accountability of the evaluation process but also encourages a deeper reflection on the long-term impacts of the funded projects.

4.2. Construction of the SEESIM model

The proposed model it was designed with the purpose to be particularly useful for public sector decision-makers, policy analysts, urban planners, environmental agencies, and non-profit organizations focused on sustainable development (Carvelli, 2024). It provides *a structured framework* for assessing the *multi-dimensional* impacts of public investments, helping to ensure that projects are not only economically viable but also socially beneficial, environmentally sustainable, and technologically forward-thinking (Gupta and Sharma, 2023). The decision-making criteria and sub criteria for the application of the model were defined through a methodical approach that included an in-depth analysis of existing literature and the accumulated experience of the research team. This process ensures that the chosen criteria are both theoretically grounded and practically applicable to the specific context of the decision (Paczos et al., 2023). In this context it is good to remember that the SEESIM model, applied in the post-funding phase, focuses on evaluating the efficiency and effectiveness of the use of public funds rather than comparing initial project costs. This phase is crucial as it provides insights into real-world project performance, ensuring that allocated funds are used optimally, and projects achieve their intended outcomes. The SEESIM model assesses cost efficiency, project effectiveness, and impact across economic, environmental, and social metrics. It monitors progress, evaluates performance, optimizes outcomes, and generates detailed reports to inform stakeholders and guide future investments. This approach maximizes return on investment and supports long-term sustainable development. In accordance with these considerations Table 4 summarizes the decision criteria, with their respective sub criteria. A brief description is provided for each.

While Fig. 6 shows a graphical representation of the decision-making model in hierarchical form.

One of the most delicate steps in the application of the AHP method is the choice and *selection of the group of decision makers*. The main variables, subject to greater attention and study in this phase, are the size of the sample and the characteristics that distinguish the interviewees: both are strongly influenced by the context in which the AHP is applied. It should also be specified that the term expert refers to an individual who knows the topic on which pairwise comparisons will be conducted and who is able to express an evaluation between pairs of related criteria (Ivanov et al., 2024; Bremer, et al., 2023). In particular, in this pilot case study, *6 experts* were selected as follows: 1 Engineer expert in urban planning, 1 Environmental Engineer, 1 Management Engineer, 2 Economist, 1 Expert in AHP. Table 5 summarizes the profile for each expert.

In order to facilitate data collection, periodic meetings were organized, and a survey was administered to the 6 experts through an online interview via Microsoft form. An example is shown in Fig. 7.

Table 4
Decision-making criteria and respective sub-criteria.

#	Criteria	Sub Criteria
1	**C1.** **Efficiency (EF)** *Evaluates the project's ability to be realized within predetermined timelines and budgets, maintaining high quality standards and effective resource management.*	**SC1.1 Timelines:** Meeting project deadlines **SC1.2 Budget:** Completion within the forecasted cost limits **SC1.3 Quality:** Excellence level in project completion **SC1.4 Resource:** Optimization of available resources usage
2	**C2.** **Economic Impact (EI)** *Measures the project's contribution to the local economy through job creation, GDP increase, attraction of private investments, and support for industrial development*	**SC2.1 Job Creation:** Generation of new employment opportunities **SC.2.2 Increase GDP:** Enhancement of economic value in the region **SC2.3 Private Investments:** Stimulation of non-governmental capitals **SC2.4 Local Industrial Sector:** Growth and strengthening of regional industries
3	**C3.** **Social Benefits (SB)** *Examines the project's effects on society, including improved access to services, enhanced quality of life, reduced disparities, and empowerment of local skills*	**SC3.1 Access to Services:** Easier access to essential services. **SC3.2 Quality of Life:** Enhancements in overall well-being. **SC3.3 Social Disparities:** Decrease in inequalities among social groups. **SC3.4 Local Skills:** Enhancement of local abilities and knowledge.
4	**C4.** **Sustainability (SS)** *Assesses the project's commitment to minimizing negative environmental impacts, promoting sustainable practices such as emissions reduction, conservation of natural resources, and waste management*	**SC4.1 CO_2 Emissions:** Decrease in carbon footprint **SC4.2 Natural Resources:** Protection of resources like water and soil **SC4.3 Biodiversity:** Rise in the variety of living species **SC4.4 Waste Management:** Reduction, recycling, and reuse of waste
5	**C5. Innovation and Technology (IT)** Considers the project's contribution to technological innovation, evaluating the adoption of new technologies, improvement of IT infrastructure, development of innovative solutions, and collaboration with research entities	**SC5.1 New Technologies:** Introduction of advanced technological solutions **SC5.2 IT Infrastructure:** Development of technological architecture **SC5.3 Innovative Solutions:** Creation of new methods or products **SC5.4 Research Institutions:** Synergies with research entities for innovation

5. Results of the SEESIM Model

5.1. Aggregate and global results

The SEESIM Model's results reveal criteria's relative importance. The data collected represents experts' preferences regarding comparisons between different criteria, expressed in terms of relative importance. The data were "translated" into numerical judgments with a view to the judgment matrix as established by the AHP method, assigning numerical values to the categories of importance as detailed below (according to Saaty's Scale): *Equal importance: 1; Weak importance: 3; Strong Importance: 5; Of proven importance: 7; Absolute importance: 9*. The findings offer an interesting insight into how experts perceive the relative importance of different aspects of each dimensions. Through data analysis it is possible to identify the priorities considered strategic for the 6 experts. This global vision is of crucial importance to identify universally relevant decision-making criteria and to establish a shared strategic framework. By analyzing this data from an aggregate perspective, we can identify convergences that can inform globally accepted decisions, promoting the effectiveness of public Investments within a broader context. Fig. 8 presents a comprehensive overview of the aggregated expert evaluations for each main criterion. It enables a comparison across criteria such as Efficiency, Economic Impact, Social Benefits, Sustainability, and Innovation and Technology, highlighting the consensus or divergence among experts' views.

Fig. 8 shows that *C1. Efficiency (EF)* project's maintaining high quality standards and effective resource management is considered one of the most important parameters in the post evaluation phase of the project. Similarly, the *C4. Sustainability (SS)* project's commitment to

Fig. 6. Examples of small municipalities in Italy (Author's elaboration).

Table 5
Qualifications and skills for each expert.

Expertise	Areas of professional activity	Experience	Degree	Hard Skills	Soft Skills
Exper#1 Engineer in Urban Planning	Public Administration	10 years	Master's in Urban Planning	Urban design, Planning regulations, GIS	Problem-solving, Communication
Exper#2 Environmental Engineer	Public Administration	8 years	Master's in Environmental Engineering	Waste management, Environmental assessment	Teamwork, Analytical thinking
Exper#3 Management Engineer	Project Management	7 years	Master's in Management Engineering	Project management, Optimization	Leadership, Decision-making
Exper#4 Economist (1)	Economics	12 years	PhD in Economics	Economic modeling, Statistical analysis	Critical thinking, Detail-oriented
Exper#5 Economist (2)	Economics	9 years	Master's in Economics	Financial forecasting, Market analysis	Creativity, Strategic planning
Exper#6 Expert in AHP	Academic facilitator	15 years	PhD in Decision Sciences	AHP methodology, Multi-criteria decision making	Logical reasoning, Persuasiveness

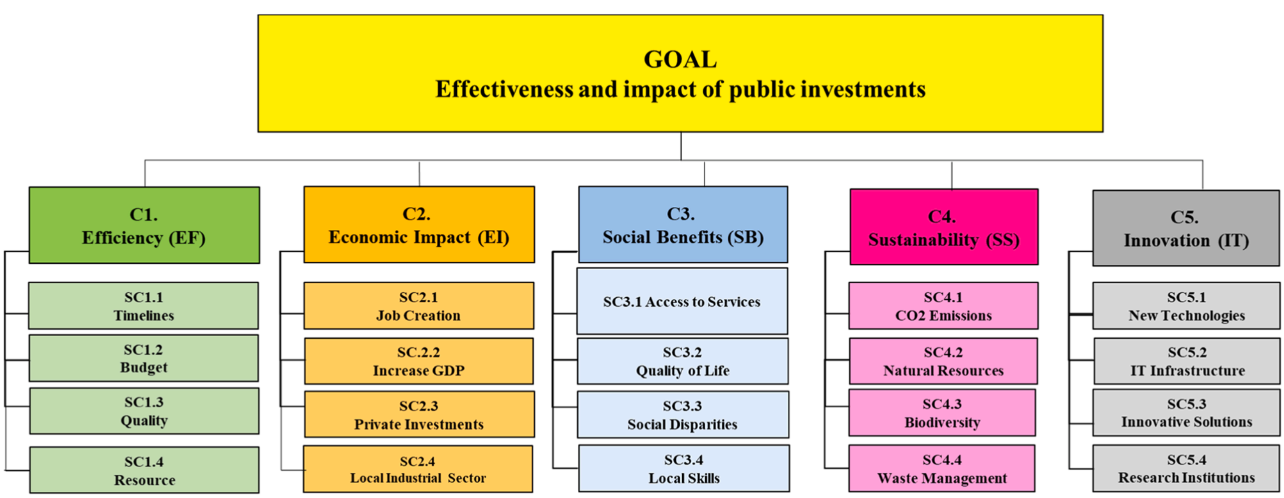

Fig. 7. AHP Decision Model (Author's elaboration according to the expert team).

minimizing negative environmental impacts is confirmed as a priority.

Below are the results corresponding to each dimension analyzed, divided by the different experts involved. The detailed analysis of this data is of fundamental importance as it provides in-depth insight into the priorities, perspectives and evaluations of each actor involved in the decision-making process. These diagrams not only highlight differences in perceptions, but also convergences that can guide the formulation of well-considered strategies and decisions, ensuring a balanced and

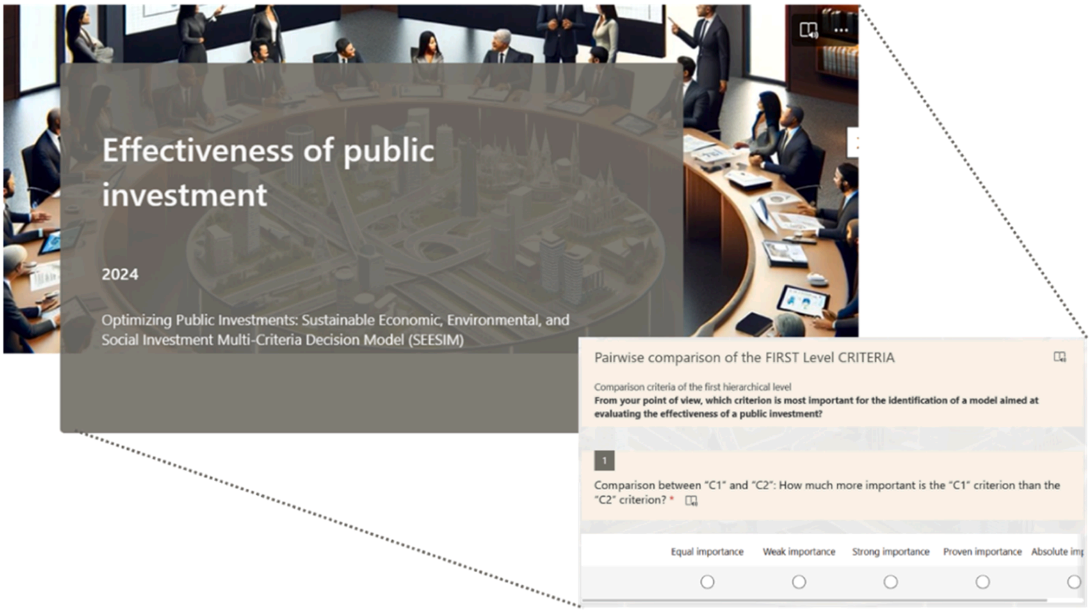

Fig. 8. Online interview via Microsoft form (Author's elaboration).

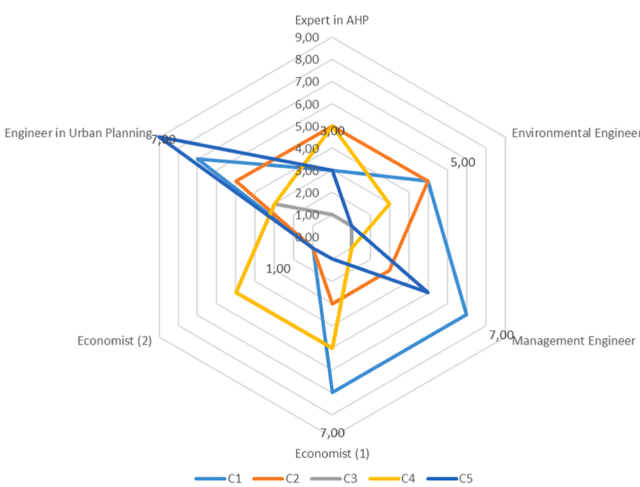

Fig. 9. Aggregated evaluation results for each criterion for the 6 experts.

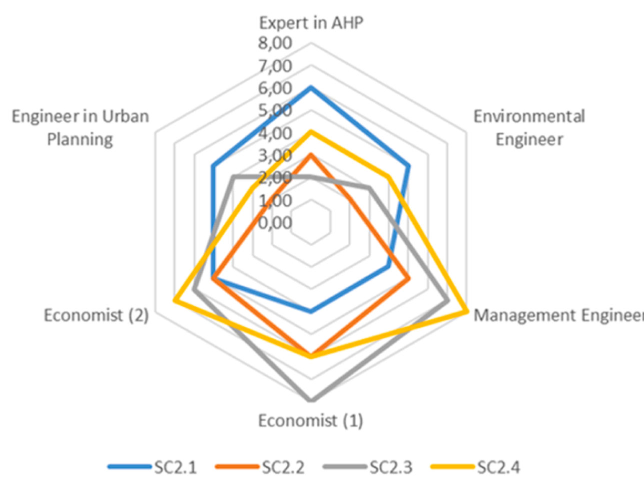

Fig. 11. Aggregated Results for C2.

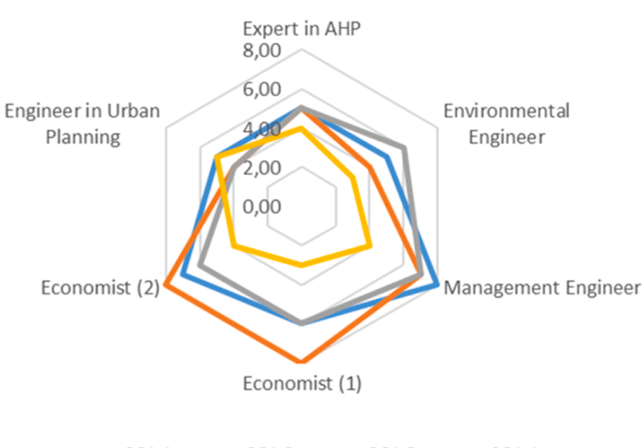

Fig. 10. Aggregated Results for C1.

Fig. 12. Aggregated Results for C3.

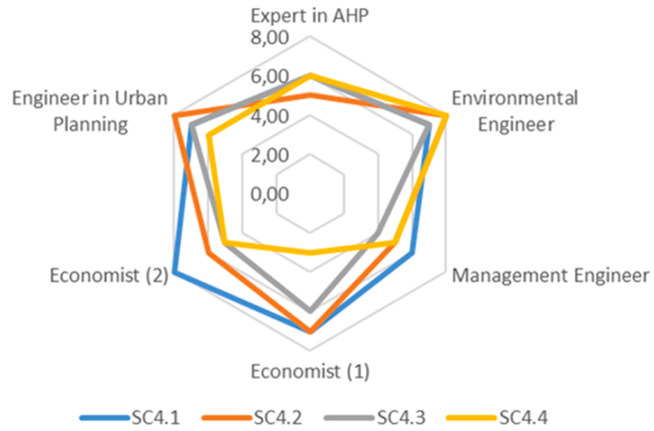

Fig. 13. Aggregated Results for C4.

inclusive approach in defining solutions. Figs. 9–13 dive deeper into the sub-criteria levels, offering an aggregated perspective on how each sub-criterion is evaluated by the experts. This detailed breakdown helps in understanding the nuanced views of the experts on specific aspects of the criteria, such as timelines, budget, quality, job creation, GDP increase, access to services, CO_2 emissions reduction, and technological innovation. The analysis of each figure facilitates an analysis of which sub-criteria are deemed most critical by the experts, reflecting their priorities and concerns.

Fig. 9 shows that the Management Engineer believes it is important to keep the *SC1.1 Timelines* under control. While the two economists show particular attention to monitoring the *SC1.2 Budget*. On the other hand, Fig. 10 shows that the Management Engineer believes it is important to keep the *SC2.3 Private Investments* and *SC2.4 Local Industrial Sector* under control. Similarly, this attention is confirmed by the two Economist. Further analysis shown in Fig. 11 highlights that Engineer in Urban Planning believes it is important to keep *SC3.1 Access to Services* under control. While the economist (2) focuses on *SC3.2 Quality of Life*. As regards the *C4 Sustainability* criterion, the attention on the part of all the experts for SC4.1 CO_2 Emissions followed by *SC4.2 Natural Resources* and *SC4.4 Waste Management* appears clear. Obviously, also *SC4.3 Biodiversity* is worth paying attention to (Fig. 12). Finally, in the evaluation of criterion *C5. Innovation*, Management Engineer and Economist (1) consider it very important to monitor *SC5.1 New Technologies*. Engineer in Urban Planning shows particular attention to *SC5.2 IT Infrastructure*. Environmental Engineer points out attention on *SC5.4 Research Institutions* (Fig. 13).

The AHP experts in all evaluations has a moderate profile, more attentive to evaluating the scientific rigor of the model overall.

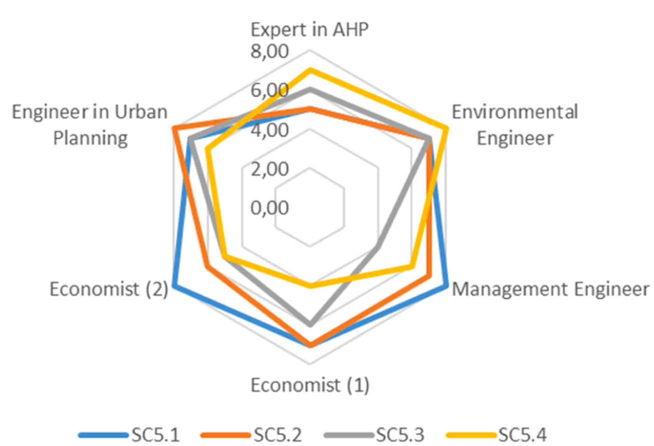

Fig. 14. Aggregated Results for C5.

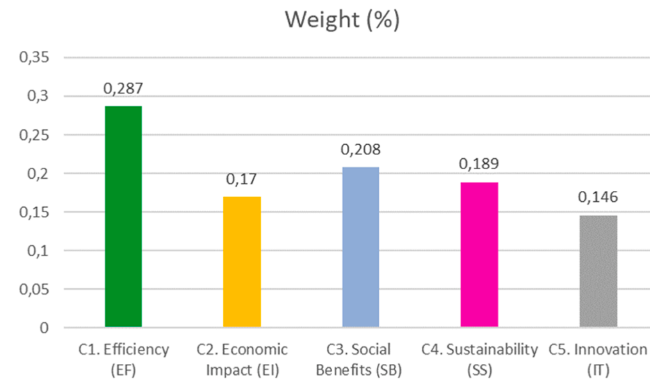

Fig. 15. Final ranking for each criterion.

While Fig. 14 shows the final ranking for each criterion and sub-criterion showcasing the hierarchy of importance assigned to each criterion and sub-criterion by the experts. It encapsulates the outcome of the multi-criteria decision-making process, providing a clear hierarchy of priorities for sustainable and transparent decision-making in public investments. It emerged that *C1. Efficiency* has a higher priority than the other criteria with a percentage of *28.7 %* followed by *C3. Social Benefits* with a score of 20.8 %.

Fig. 15 points out the weights for each criterion. It emerges that *SC5.2 IT Infrastructure* is the one of the most relevant sub criteria with a score of 38,3 % followed by *SC3.2 Quality of Life* (32,4 %) and by *SC1.1 Timelines* (32,1 %) (Fig. 16).

The final ranking represents the starting point for monitoring the project in its post-evaluation phase through the definition of some KPIs described in the Section 5.2.

5.2. SEEMIM model & KPIs

The definition of monitoring KPIs is a factor of fundamental importance both to reflect the expected results in the best possible way from the financing and to be able to conduct the impact analysis according to *strategic priorities*. However, the choice must consider not only possible limitations or constraints in the availability of data, but also of the potential costs in the production of the information itself by the counterparties. In general, in the proposed model, the choice of KPIs followed the *SMART approach*, according to which the indicators must be specific, measurable, reachable, relevant and traceable (Liu et al., 2024). Table 6 shows some KPIs, selected with the group of experts, that could be useful to monitor the effectiveness of a project.

Monitoring takes place throughout the entire execution phase of the project and is aimed at continuously collecting and systematic information on the progress of the individual project, the results of which constitute the information basis for the subsequent and complementary one ex-post evaluation activities. To offer greater support to the *medium* and *long-term impact analysis*, it is expected that the interventions are monitored even after the end of the financing/investment period (Latupeirissa and Arrang, 2024). During the project execution phase, therefore, the counterparty should be asked to periodically communicate the *progress* of the KPIs defined at the time of granting public funding. In this regard, the SEESIM model involves the use of a *strategic coherence evaluation grid*. The grid is intended to be a tool through which the expected impact of a project is assessed single operation responds to strategic objectives. The use of the grid is based on the following steps:

– for each operation to be financed, identification of one or more fields of intervention to which the project can refer and, therefore, of one or more focus areas and one or more strategic priorities.
– for each of the strategic priorities identified, identification of the relevant investment or financing quotas.

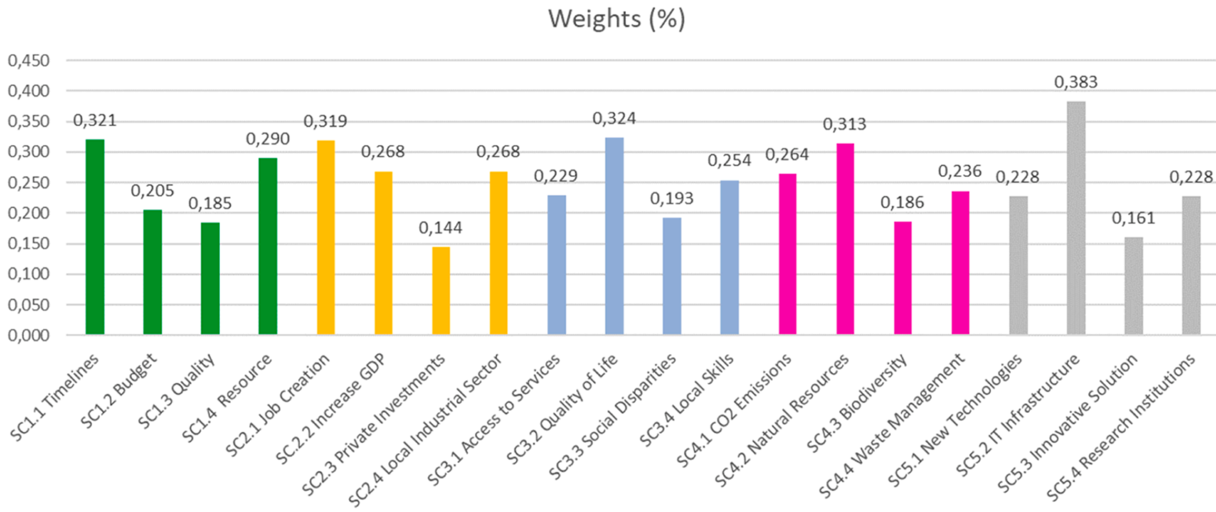

Fig. 16. Final ranking for each sub criterion.

Table 6
KPIs definition.

Criteria	Strategic priorities/SDGs	KPIs	Description
C1. **Efficiency (EF)**	Ensure efficient and effective use of public resources to achieve project goals within set timelines and budget 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	KPI#1 On-time Completion Rate KPI#2 Budget Variance	Percentage of project tasks completed by their due dates. Difference between the budgeted and actual costs.
C2. **Economic Impact (EI)**	Ensure that the territory grow through the creation of new jobs 8 DECENT WORK AND ECONOMIC GROWTH	Number of Jobs Created GDP Growth Rate	Total jobs created directly by the project. Annual percentage increase in local GDP attributable to the project.
C3. **Social Benefits (SB)**	Ensure the territory is improved by creating services for citizens and enhancing life quality socially, economically, and environmentally 3 GOOD HEALTH AND WELL-BEING 4 QUALITY EDUCATION 11 SUSTAINABLE CITIES AND COMMUNITIES	Service Accessibility Index Quality of Life Score	Measure of the change in access to essential services. Composite index based on health, education, and income indicators.
C4. **Sustainability (SS)**	Ensure valorisation of the territory by guaranteeing less pollution, waste and conservation of biodiversity 13 CLIMATE ACTION 14 LIFE BELOW WATER 15 LIFE ON LAND	CO_2 Emission Reduction Percentage Resource Conservation Rate	Year-over-year percentage decrease in CO_2 emissions. Percentage reduction in the use of key natural resources.
C5. **Innovation and Technology (IT)**	Ensure collaboration with all interested parties in the area with a view to expected benefits for the local community 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 17 PARTNERSHIPS FOR THE GOALS	Technology Adoption Rate Research Collaborations	Number of new technologies implemented as part of the project. Number of partnerships or projects undertaken with research institutions.

Based on the combination of the financing/investment strategic priorities and the respective degree of relevance (defined by the AHP model), the grid returns a numerical value that summarizes the degree of relevance of each intervention. Table 7 shows the global evaluation grid highlighting possible KPIs and target values. The grid was developed with the team of experts.

To provide a synthetic and transparent evaluation of the overall effectiveness and efficiency of public investments, a *global index* of effectiveness and efficiency the "*SEESIM Overall Effectiveness and Efficiency Index*" is formulated. The index is critical for driving informed decisions, improving accountability and optimizing resource allocation to maximize the socio-economic and environmental impact of projects. To formulate a global index of effectiveness and efficiency, a systematic approach is proposed that integrates the scores of the KPIs with the

Table 7
Global evaluation grid.

% Criteria	Subcriteria	%	KPIs	Target of strategic coherence/ score
C1. Efficiency (EF) 28,7 %	SC1.1 Timelines SC1.2 Budget	32,1 % 20,5 %	**KPI#1** *On-time Completion Rate* = % of project tasks completed by their due dates	3: Target < 50 % 6: Target 60–50 % 8: Target = 70 – 90 % 10: Target = 100 %
	SC1.3 Quality SC1.4 Resource	18,5 % 29,0 %	**KPI#2** *Budget Variance* = Difference between the budgeted and actual costs	
C2. Economic Impact (EI) 17 %	SC2.1 Job Creation SC.2.2 Increase GDP	31,9 % 26,8 %	**KPI#3** *Number of Jobs Created* = Total jobs created directly by the project	3: < 50 % new jobs 6: 60–50 % new jobs 8: 70 – 90 % new jobs 10: 100 % new jobs
	SC2.3 Private Investments SC2.4 Local Industrial Sector	14,4 % 26,8 %	**KPI#4** *GDP Growth Rate* = Annual % increase in local GDP attributable to the project.	3: Negative GDP growth rate 6: Moderate GDP growth rate 9: High GDP growth rate 10: Exceptional GDP growth rate
C3. Social Benefits (SB) 20,8 %	SC3.1 Access to Services SC3.2 Quality of Life	22,9 % 32,4 %	**KPI#5** *Service Accessibility Index* = % of new essential services	3: < 30 % new services 6: 40 – 50 % new services 8: 70 – 80 % new services 10: > 80 % new services
	SC3.3 Social Disparities SC3.4 Local Skills	19,3 % 25,4 %	**KPI#6** *Quality of Life Score* = Access to cultural and entertainment opportunities	3: < 30 % poor 6: 40 – 50 % limited 8: 70 – 80 % goog 10: > 80 % excellent
C4. Sustainability (SS) 18,9 %	SC4.1 CO_2 Emissions SC4.2 Natural Resources	26,4 % 31,3 %	**KPI#7** *CO_2 Emission Reduction* = % Year-over-year percentage decrease in CO_2 emissions	3: Minimum reduction in CO_2 (0–20 %). 6: Moderate reduction in CO_2 (20–40 %). 8: Significant reduction in CO_2 (40–60 %). 10: Excellent reduction of CO_2 (60–100 %).
	SC4.3 Biodiversity SC4.4 Waste Management	18,6 % 23,6 %	**KPI#8** *Resource Conservation Rate* = % reduction in the use of natural resources	3: Minimum reduction (0–20 %) 6: Moderate reduction (20–40 %) 8: Significant reduction (40–60 %) 10: Excellent (60–100 %)
C5. Innovation and Technology (IT) 14,6 %	SC5.1 New Technologies SC5.2 IT Infrastructure	22,8 % 38,3 %	**KPI#9** *Technology Adoption Rate* = Number of new technologies implemented as part of the project	3: Minimal adoption (0–30 % of users) 6: Moderate adoption (30–60 % of users) 8: Good adoption (60–80 % of users) 10: Excellent adoption (80–100 % of users)
	SC5.3 Innovative Solution SC5.4 Research Institutions	16,1 % 22,8 %	**KPI#10** *Research Collaborations* = Number of partnerships or projects undertaken with research institutions	3: < 30 % new collaborations 6: 40 – 50 % new collaborations 8: 70 – 80 % new collaborations 10: > 80 % new collaborations

relative weights of the criteria and sub-criteria. The proposed formula (Equation 1) calculates the contribution of each KPI to the overall score of the project, taking into account the percentage weight of each criterion and sub-criterion.

SEESIM Index $= \sum_{i=1}^{n}\left(W_{C_i} * \sum_{j=1}^{m_i}\left(W_{SC_{ij}} * \mathit{Normalized\ Score}_{KPI_{ij}}\right)\right)$ Eq. 1

Where:

- *WCi* represents the weight of the criterion *i* th.
- *WSCij* represents the weight of the sub-criterion *j*-th under the criterion *i*-Th.
- Normalized Score*KPIij* is the normalized KPI score associated with the sub-criterion *j*-th under the criterion *i*-Th.
- *n* is the total number of criteria.
- *mi* is the number of sub-criteria under the criterion *i*-esimo.

The normalized score (Eq. (2)) of each KPI can be calculated as follows, based on the scale (3, 6, 8, 10):

$$\text{Normalized Score} = \frac{(\text{Real ScoreKPI})}{(\sum_{3}^{10} \mathit{Score}\ \text{max}} \tag{2}$$

Where:

- Real Score Real Score$_{KPI}$ is the score assigned to the KPI based on the results obtained.
- Maximum Score is the sum of scores on the KPI scale (in the example, 3, 6, 8 and 10).

Table 8 shows an example calculation for project monitoring for C1. Efficiency (EF). Similarly, it is constructed for the other criteria and

Table 8
Example of calculation for project monitoring.

% Criteria	Subcriteria	%	$\sum_{j=1}^{m_i}(W_{SC_{ij}})$	KPI#1 (t=6 months)			
				3 (min)	6	8	10 (max)
C1. Efficiency (EF) 28,7%	SC1.1 Timelines	32,1%	**38%**	**4,22%**	**8,45%**	**11,26%**	**14,8%**
	SC1.4 Resource	29,0%		**Weak [<5%]**	**Moderate [<10%]**	**Good [>10%]**	**Optimal [≈15%]**
	SC1.2 Budget	20,5%	**32,5**	**3,61%**	**7,22%**	**9,63%**	**12,03%**
	SC1.3 Quality	18,5%		**Weak [<5%]**	**Moderate [<10%]**	**Good [>10%]**	**Optimal [≈15%]**

KPIs. The score is calculated based on the assigned weight and the rating scale used. The different scales (3−6−8−10) represent different levels of granularity in rating the performance of a project.

For each KPI, we calculate the normalized score and then apply sub criteria and criterion weights as specified. We then add the contributions of all the criteria to obtain SEESIM Index. The index offers an overall picture of the effectiveness and efficiency of a public investment, allowing a holistic evaluation that integrates different aspects of the project. It can be adapted and refined based on the specific needs and priorities of the project or the organization managing it. Additional KPIs can be included or to change weights based on new political or economic priorities. The model allows KPI scores to be adjusted over time, offering a dynamic assessment of the project's effectiveness. It is important to note that the SEESIM model is inherently dynamic, as it relies on comparative evaluations of criteria by experts. These experts can account for the difficulty of measuring changes in complex parameters such as GDP growth on a case-by-case basis. This flexibility allows the model to adapt to the specific characteristics and challenges of each project, providing a more accurate and contextualized assessment. Furthermore, SEESIM encourages the use of a combination of quantitative and qualitative methods to offer a more comprehensive evaluation of project outcomes, considering the broader economic context. This approach ensures a more nuanced understanding of the model's capabilities and limitations in measuring the true impact of public investments.

6. Discussion

6.1. General considerations

The development of a multi-criteria decision-making model tailored for sustainable development, as presented in this study, marks a significant advancement in the arena of public investment decisions. This model stands out by offering a versatile framework that serves various stakeholders involved in sustainable development projects, including decision-makers in the public sector, urban and regional planners, non-governmental organizations (NGOs), financing entities, researchers, public policy consultants, and the local communities themselves. Our findings underscore the critical need for a holistic approach to sustainable development, one that harmoniously integrates economic, environmental, and social considerations. The model's robustness lies in its capacity to facilitate informed and sustainable decision-making processes, particularly in the public sector, where the balancing act between competing objectives and interests is a common challenge. By employing a structured framework like the Analytic Hierarchy Process (AHP), decision-makers are better equipped to evaluate the long-term impacts of their proposals, ensuring alignment with sustainability goals. The experimental scenario applied within this research demonstrates the model's effectiveness in real-world scenarios, offering a concrete example of how it can guide the allocation of public investments towards initiatives that promise sustainability and resilience. This research demonstrates the SEESIM model's effectiveness in real-world scenarios, offering a concrete example of how it can guide the allocation of public investments towards initiatives that promise sustainability and resilience. This practical application not only validates the model's utility but also highlights its potential to transform public investment strategies by embedding sustainability at their core. Moreover, the engagement of diverse stakeholders through this model fosters a more transparent and participatory decision-making process. By delineating clear criteria and providing a mechanism for their evaluation, the model empowers communities and local actors to have a say in the investments that affect their environment and well-being. This inclusivity is paramount for the success and acceptance of sustainable development projects. However, the application of this model is not without challenges. The integration of multiple criteria and the need for comprehensive data collection can pose significant hurdles, particularly in contexts where resources and information may be scarce. Additionally, the subjective nature of some criteria and the potential for biases in weighting and evaluation underscore the need for careful consideration and validation of the inputs into the model. Future research should focus on further refining the model, exploring its applicability across different regional contexts, and incorporating advanced technologies for data analysis and stakeholder engagement. As sustainability challenges become increasingly complex, the development of adaptable, transparent, and inclusive decision-making tools like the one presented in this study will be crucial for guiding public investments towards a more sustainable future.

6.2. Ex-post and on-going phase application

The SEESIM model is primarily designed to be applied in the post-funding or ongoing phases of projects. This phase is crucial for evaluating the actual performance and impact of projects, rather than merely selecting projects based on forecasts and proposals. In this regard it is worth providing some clarifications as follows. For example, if there is a:

- Budget Variance: the SEESIM model assesses whether projects are completed within the forecasted cost limits. This criterion helps in understanding the financial efficiency of a project and is applicable in the ex-post or ongoing phase, as it requires real expenditure data.
- Number of Jobs Created: Similarly, the impact of a project on job creation can only be accurately measured during or after the project's implementation. This provides concrete data on the project's economic and social benefits, further reinforcing the model's utility in evaluating completed or ongoing projects.

By focusing on the post-funding phase, the SEESIM model ensures that public funds are used effectively and that projects deliver their promised benefits. This phase allows for a thorough assessment of project outcomes, including:

- Effectiveness: Evaluating whether the project meets its intended goals and delivers anticipated benefits.
- Efficiency: Analyzing how resources are utilized and whether the project stays within budget and time constraints.
- Sustainability: Assessing the long-term impacts on economic growth, environmental health, and social well-being.

The insights gained from the SEESIM model during the ex-post or ongoing phase are invaluable for informing future policy and investment decisions. By providing a detailed evaluation of completed projects, the model helps identify best practices, common challenges, and areas for improvement. This feedback loop enhances the strategic planning and allocation of public investments, ensuring that future projects are better aligned with sustainability and resilience goals.

While the SEESIM model excels in post-funding evaluation, it also supports continuous monitoring and mid-course corrections for ongoing projects. This dynamic application allows stakeholders to:

- Monitor Progress: Regularly track project milestones and performance indicators.
- Identify Issues: Detect and address potential problems early, ensuring projects stay on track.
- Optimize Outcomes: Make informed adjustments to improve project efficiency and effectiveness.

In other words, the SEESIM model is a robust tool for evaluating and enhancing the impact of public investments. Its application in the ex-post and ongoing phases provides a comprehensive understanding of project performance, guiding future investment decisions towards more sustainable and resilient outcomes. By emphasizing the importance of post-implementation evaluation, this research highlights the model's role in fostering accountability, transparency, and continuous improvement in public sector investments.

6.3. Spatial/territorial dimension and influence on the method

The manuscript describes the development and application of the Sustainable Economic Environmental and Social Investment Model (SEESIM), a multi-criteria decision-making framework to ensure the sustainability of public investment projects. Utilizing the Analytic Hierarchy Process (AHP), SEESIM integrates environmental, economic, and social criteria to evaluate projects in the post-funding phase, ensuring a balanced approach between efficiency and sustainability. It is adaptable to various regional contexts, offering a transparent and replicable methodology for assessing the impacts and costs of public investments.

Regional Adaptability: SEESIM is designed to be flexible and applicable across different regional contexts. This feature is crucial because the challenges and opportunities related to sustainable development vary greatly across different geographical areas. For example, environmental, economic, and social priorities can differ between densely populated urban regions and less developed rural areas. The model's adaptability allows it to account for these spatial/territorial differences in the allocation and assessment of public investments.

Regional Impact Evaluation: The model emphasizes the importance of developing robust, flexible, and transparent decision-making models that can adapt to diverse regional needs, optimizing the impact of public investments on sustainable development. This implies that SEESIM not only considers the territorial dimension in the application of the method but actively seeks to model and respond to regional specificities to maximize the effectiveness of investments.

Local Sustainability and Community Benefits: Through the use of specific Key Performance Indicators (KPIs), SEESIM aims to monitor and evaluate the effectiveness of public investments in terms of local environmental, economic, and social outcomes. This includes assessments of the impact of specific projects on local communities, ensuring that investments contribute positively to the quality of life, conservation of natural resources, CO_2 emission reduction, and the promotion of innovation and technology at the territorial level.

Case Study on Small Italian Municipalities: The experimental application of the SEESIM model included a specific scenario focused on supporting and enhancing small municipalities in Italy, demonstrating how the model can guide investment decisions that directly influence economic and social development at the local level. This further underscores how the model accounts for the territorial dimension, facilitating public investment decisions that are directly relevant and beneficial to local communities.

SEESIM embraces a holistic view of public investment, explicitly incorporating the spatial/territorial dimension both in the impact evaluation and in the adaptability of the method to different contexts. This approach ensures that public investment decisions not only pursue global sustainability objectives but are also sensitive to the specific needs and characteristics of different regions and communities.

6.4. Model's impact

The SEESIM model presents a transformative approach to evaluating public investments by addressing the intricate balance between economic efficiency, environmental sustainability, and social equity. Its impact is multifaceted, providing a robust framework that not only assesses projects' immediate benefits but also their long-term viability and contribution to sustainable development goals. By employing the Analytic Hierarchy Process (AHP), SEESIM enhances decision-making clarity and transparency, enabling policymakers to systematically weigh diverse criteria and make informed choices that align with national and regional priorities. Its adaptability across different regional contexts ensures that SEESIM can be tailored to meet local needs and challenges, promoting equitable resource distribution and targeted impact. Furthermore, the model's emphasis on the post-funding phase helps to monitor and optimize project outcomes over time, fostering accountability and continuous improvement. Ultimately, SEESIM's integration of comprehensive sustainability metrics supports more resilient and inclusive public investment strategies, driving progress towards a more sustainable and equitable future.

6.4.1. Economic impact

The SEESIM model significantly enhances economic outcomes by guiding public investments towards projects that demonstrate high economic returns. The data shows that municipalities using SEESIM experience higher growth rates and improved economic stability. Specifically, the model's focus on efficiency and economic viability ensures that public funds are allocated to projects that offer substantial economic benefits, reducing waste and maximizing the impact of each investment.

6.4.2. Environmental impact

Environmental sustainability is a core criterion in the SEESIM model. The quantitative data illustrates a notable reduction in CO2 emissions and other environmental benefits, such as increased green spaces and improved waste management practices. This alignment with Italy's environmental goals not only helps in meeting regulatory requirements but also contributes to global efforts to combat climate change.

6.4.3. Social impact

The SEESIM model places a strong emphasis on social equity, ensuring that public investments contribute to improved social outcomes. The model's application has resulted in significant social benefits, including enhanced access to essential services like healthcare and education, increased local employment, and overall improved quality of life. The qualitative feedback from stakeholders supports these findings, highlighting the model's role in fostering inclusive and equitable development.

6.4.4. Policy and decision-making impact

The SEESIM model provides a transparent and replicable decision-making framework, which has been praised by policymakers and project managers. The model's structured approach facilitates better resource allocation and enhances accountability in public investment decisions. By integrating multiple criteria, the model supports more informed and strategic decision-making, contributing to more sustainable and resilient development policies.

7. Conclusions

The proposed study presented a comprehensive exploration of a multi-criteria decision-making model, the SEESIM model, emphasizing its application in evaluating and guiding sustainable public investments. Through the meticulous integration of the Analytic Hierarchy Process (AHP), this model affords a structured and systematic approach to assess investments across a broad spectrum of criteria, including economic viability, environmental sustainability, and social equity. The application of the SEESIM model to the context of Italian small municipalities underscored its potential to significantly impact the decision-making process in public investments. By providing a clear, hierarchical evaluation of various criteria and sub-criteria, the model facilitates informed and balanced decision-making. The adoption of this model can lead to more transparent, accountable, and effective allocation of public resources, ensuring that investments not only yield immediate economic benefits but also contribute to long-term sustainability and social well-being. Furthermore, the incorporation of KPIs derived from the model's outcomes emphasizes the importance of ongoing monitoring and evaluation in the lifecycle of public investments. This approach enables stakeholders to track the performance of investments against defined sustainability and efficiency objectives, thereby fostering a culture of continuous improvement and learning. The implications of this research extend beyond the specific case study, offering valuable insights for policymakers, urban planners, and sustainability advocates across different regions and contexts. The SEESIM model represents a significant step forward in the pursuit of sustainable development, providing a robust framework for making complex investment decisions that account for the multifaceted challenges of modern societies. As we look to the future, it is clear that the principles of sustainability, transparency, and inclusivity must be at the heart of public investment decisions. Models like SEESIM, which incorporate these principles through structured and analytical methodologies, are essential tools in this endeavor. They not only aid in navigating the complexities of sustainable development but also in realizing the vision of a more equitable, resilient, and sustainable world. In conclusion, this research contributes to the ongoing dialogue on sustainable development, offering a practical solution for enhancing the decision-making process in public investments. The SEESIM model stands as a testament to the power of structured, criteria-based evaluation in achieving sustainable outcomes and paves the way for further innovations in this critical field.

CRediT authorship contribution statement

Vincenzo D'Alberti: Writing – original draft, Methodology, Conceptualization. **Marco Leonardi:** Writing – original draft, Methodology, Conceptualization. **Ilaria Baffo:** Writing – original draft, Methodology, Conceptualization. **Antonella Petrillo:** Writing – original draft, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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