Beyond Cost-Benefit Analysis. A Methodological Approach to Access Transport Infrastructure Investments

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Abstract. European Union (EU) cohesion policy pursues the strengthening of economic, social and territorial cohesion between the different regions of the Member states. To this end, EU supports actions aimed at developing to climate-neutral economy (European Green Deal) and just and inclusive society (European Social Pillar), in the broader context of the UN 2030 Agenda for Sustainable Development. However, the choice of high-quality projects, which mainly guarantee the best cost-benefit ratio, often does not respond to the greatest impact on development and employment, and more generally the problems of marginalization and phenomena of demographic decline typical of the insular and internal areas of Italy highlighted by the National Strategy for Internal Areas (SNAI), effectively reducing the success of the overall strategy. From this perspective, the evaluation of projects based on Cost-Benefit Analysis (CBA) with the related Risk Sensitivity Analysis (EU Regulation no. 1303/2013, Annex III), although essential, requires to be associated with other tools evaluation to support the decision-making process, especially for infrastructure projects included in the Operational Programs (OP) of 2021–2027 Programming cycle. This paper fits into this concise framework with the aim of developing a comparative methodological approach of the main complementary methods of CBA. In fact, the demographic challenges, the contrast between global development and local development require a renewed approach for the financial evaluation of mobility infrastructures, in particular with a focus on Sardinia Region (Italy).

Keywords: Cost-benefit analysis · Territorial cohesion · Transport Infrastructure

1 Introduction

European Union (EU) cohesion policy has as its main objective the strengthening of economic, social and territorial cohesion between the different regions of the Member states, to be pursued by supporting economic growth and employment, scientific

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research, innovation and the competitiveness of regional production systems, sustainable development and environmental protection, in order to reduce territorial disparities and improve quality of life citizens.

The EU supports achievement of these objectives through the use of European Structural and Investment Funds (ERDF, ESF+, EMFF, Cohesion Fund, Just Transition Fund - JTF). In 2021–2027 Programming cycle their main objectives are the implementation of interventions aimed at the development of a climate neutral economy (European Green Deal) and a just and inclusive society (European Social Pillar), in the broader context of the UN 2030 Agenda for Sustainable Development. These objectives, in particular, must be achieved by implementing types of actions envisaged by the Regional Programs (PR) and the National Programs (PN) [1], approved by the European Commission (EC) to co-finance development policies on a regional and on a national scale, in line with what is established by the common provisions contained in Regulation (EU) 2021/1060 [2] and to support the 5 strategic objectives defined therein by the EC [2]. General framework of cohesion policies is completed by the Development and Cohesion Fund (FSC), whose additional national financial resources are intended for economic and social rebalancing among different areas of the country, and to support public incentives and investments.

1.1 Sardinia Region: 2021–2027 Programming Scenario

Within this programmatic scenario, the Italian Government has also approved the National Recovery and Resilience Plan (NRRP), which within the Next Generation EU, the program promoted by the EU to encourage the relaunch of the Member States following the Covid-19 pandemic 19, constitutes the set of reforms and investments to be carried out in the period 2021–2026 to pursue the objective of a greener, digital and resilient Europe through the implementation of actions consistent with the three strategic axes identified, digital transition and innovation, ecological transition and social inclusion and territorial rebalancing, on which the articulation [3] of NRRP is developed.

Extraordinary Subsequent paragraphs, however, are indented. Concentration of community and national resources made available by the NRRP and the 2021–2027 Programming, in order to create real development opportunities for the Sardinia Region and allow us to remove the diseconomies that derive from the weak and discontinuous territorial continuity for goods and passengers, presumes the ability to sustain extraordinary investments. It also requires a different approach to the evaluation of interventions to modernize and improve the internal infrastructure network (railway and road), necessary to guarantee territorial cohesion, curb the phenomenon of depopulation and marginalization of internal areas, and to increase accessibility of ports and airports, essential to ensure wider and more reliable connections with the outside world. These conditions appear indispensable to give concrete implementation to the principle of insularity, introduced into the Constitution with the modification of art.119 [4], which constitutes, together with art. 174 of the Treaty on the Functioning of European Union, foundation and legitimation of cohesion policy, since these rules require special interventions to promote harmonious development and to remove economic and social imbalances [5].

In this synthetic framework, multilevel governance supported by different degrees of institutional agreement would make it possible to overcome the use of cost-benefit

analysis (CBA) for the evaluation of the transport infrastructure interventions and the choice of investment priorities.

The aim of this manuscript is to propose a methodological approach to overcome the prevalent use of CBA, comparing with SWOT analysis the main evaluation methods complementary to CBA and evaluating the benefits that are not easily monetizable, deriving from the improvement of accessibility of transport in the framework of the objectives of the 2030 Agenda.

The manuscript is organised as it follows: Sect. 2 Materials and methods; Sect. 2.1 Material and Sect. 2.2 Methodology; Sect. 3 Results; Sect. 4 Discussion and Sect. 5 Conclusion and future development.

2 Materials and Methods

Accessibility and economic development are related to progressive globalization, which is a complex process. In fact, globalization has led to greater interconnection, facilitating single and collective mobility and the exchange of goods and services, helping to make places, goods and services more accessible to a wider audience, even in remote or developing areas. However, the relationship between economic development and accessibility is complex and multi-directional [6–8]. Economic development and accessibility are two interrelated aspects that can reinforce each other. Economic development through investment in transport infrastructure can make spatial contests more accessible and inclusive. Accessibility can foster economic development and lead to greater social inclusion, as well as a better quality of life for local communities and city users. For this reason, it is crucial to view accessibility as an investment rather than a cost [9–11]. In agreement with Rodrigue J. P. (2020) [12] accessibility plays a crucial and decisive role in economic development, equity, inclusiveness and risk management.

An efficient and capillary transport system allows, in fact, the mobility of people and goods, promoting trade, attracting investment and economic development and can also ensure spatial justice and improve the quality of life of local communities [13]. Accessibility is also a key factor in NRRP: both to facilitate trade and investment, promote employment and reduce territorial disparities, bridge the gap between urban and rural areas and improve social cohesion [14].

In particular, the resident population in Sardinia (Italy) represents is about 1 569 832 inhabitants (data updated to 1/01/2024 [15]). Compared to 2011, there was a decrease in population by 3.4%, with a birth rate of approximately 6.4 births per 1 000 inhabitants, and a mortality rate of approximately 9.8 deaths per 1 000 inhabitants. The population appears to be distributed unevenly across Sardinia: in fact the average density is about 68 inhabitants/km^2, with varying values depending on the province. The most populous provinces are the Metropolitan City of Cagliari and Sassari, which together concentrate almost 60% of the Sardinian population.

2.1 Materials

CBA is an evaluation process [16, 17] that compares the costs and benefits associated with construction, operation, and end of life [18, 19]. The CBA plays an important role in policy makers' decision-making process when it comes to prioritizing investment in transportation infrastructure consists of the following steps:

1. definition of the scope of the analysis and identification of relevant costs and benefits;
2. identification of costs and benefits and their units of measurement;
3. quantitative estimation of costs and benefits;
4. monetisation of costs and benefits;
5. intertemporal discount, aggregation of costs and benefits and calculation of the net social benefit of the policy;
6. sensitivity analysis.

However, it is very important to consider the limits of CBA. The CBA outcome can be significantly influenced by the discount rate, which is one of the main methodological limitations. In addition, the CBA adds up the costs and benefits, assuming they are homogeneous. This can be problematic for direct and indirect benefits that are not easily demonstrable from improving the accessibility of transport infrastructure, such as: economic development, equity, inclusion and risk management [20].

In this sense, cost-benefit analysis is complemented by other evaluation methods that are useful for evaluating aspects that are not always easily monetizable. In particularly complex situations, it may be necessary to use complementary methods for the different regulations in force, such as:

1. Cost-Efficiency Analysis (ACE): focuses on minimizing the costs needed to achieve a specific goal, without necessarily considering the benefits in monetary terms. Maximizing resource allocation efficiency can be achieved by using it.
2. Multi-Criteria Analysis (MCA): considers multiple evaluation criteria and assigns them a weight based on importance. It is useful when there are multiple dimensions or goals to consider, but also when you need to compare different alternatives.
3. Environmental Impact Analysis (EIA): assess the environmental effects of a project or infrastructure, focusing on aspects such as air, water and soil pollution, and biodiversity. EIA helps to identify and mitigate negative impacts on the environment.
4. Socio-economic Analysis (SEA): assesses the social and the economic impacts of a project, including job creation, poverty reduction, accessibility to services and the general well-being of the community.
5. Life Cycle Assessment (LCA): LCA examines the entire life cycle of a product or project, from production to use and end of life. It is often used to assess the overall environmental impact.
6. Risk and Uncertainty Analysis: considers the risks associated with a project and evaluates how those risks could impact the results. It is useful for making informed decisions when there is uncertainty.
7. Real Options Analysis (ROA): assesses the options available in the project, taking into account the ability to adapt to future conditions. It can be useful when decision-making flexibility is needed over time.

8. Equity Analysis: Analyze the distribution of a project's impacts on the population, with a focus on justice and equity. Helps identify whether the project benefits or harms specific groups.
9. Geospatial Analysis: uses geographic data and spatial information to analyse the location and impacts of a project in a geographical context. It is useful to assess how the infrastructure affects the surrounding area.
10. Sustainability Assessment: determine the level of economic, social, and environmental sustainability of a project. Consider the balance between the dimensions of sustainability.

2.2 Methodology

The methodology developed consists in the comparison of the main complementary assessment methods (paragraph 2.1) by the construction of SWOT analysis, integrated through two qualitative/quantitative dimensions.

SWOT analysis (Fig. 1) is characterised by a matrix 2 × 2 - exogenous (opportunities and threats) and endogenous (strengths and weaknesses) factors.

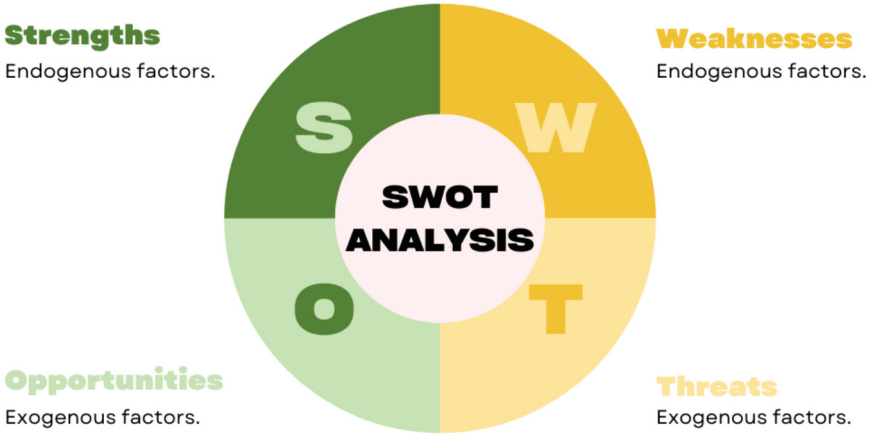

Fig. 1. SWOT analysis matrix.

The qualitative dimension is designed to link the relevant SDGs with every complementary method, while the quantitative dimension is intended to assess the level of integration of the benefits of the project not easily monetizable as: economic development, equity, inclusion and risk management (Table 2) (Fig. 2) (Table 1).



Fig. 2. Key goals not easily monetizable as: economic development, equity, inclusion and risk management (Authors: G. Balletto and M. Sinatra, 2024)

Table 1. Sardinia demography.

Province	N. of municipalities	Population (2024) [15]
Metropolitan City of Cagliari	17	418 761
Nuoro	74	197 003
Oristano	87	149 078
Sassari	92	473 236
Sud Sardegna	107	331 754
Sardinia Region	377	1 569 832

3 Results

The results of the evaluation have been reported in Fig. 3 and Fig. 4. It is highlighted that the SWOT analysis and qualitative/quantitative comparison have not included the Cost-Efficiency Analysis (CEA) method due to the similarity with CBA.

In particular, there are no methods assigned to Level 1; the average positive level (level 2) methods are: Environmental Impact Analysis (EIA) and Socio-economic Analysis (SEA); average critical level (level 3) methods are: Real Options Analysis (ROA), Equity Analysis e Geospatial Analysis: finally, the critical level methods (level 4) are: Multi-Criteria Analysis (MCA), Life Cycle Assessment (LCA), Risk and Uncertainty Analysis and Sustainability Assessment (Fig. 5).

Table 2. Integration levels of infrastructure benefits not easily monetizable from improved accessibility (Authors: G. Balletto, M. Sinatra and M. Naseddu 2024).

Level	Class	Benefits not easily monetizable from improved accessibility
1	1.00	- Economic Development, Equity, Inclusion and Risk Management
2	0.75	- Economic Development, Equity and Inclusion
		- Economic Development, Equity and Risk Management
		- Economic Development Inclusion and Risk Management
		- Equity, Inclusion and Risk Management
3	0.50	- Economic Development and Equity
		- Economic Development and Inclusion
		- Economic Development and Risk Management
		- Equity and Inclusion
		- Equity and Risk Management
		- Inclusion and Risk Management
4	0.25	- Economic Development
		- Equity
		- Inclusion
		- Risk Management

Method	*Strengths*	*Opportunities*	*Weaknesses*	*Threats*
Multi-Criteria Analysis (MCA)	Adaptability	Support for sustainable decisions	Complexity	Risks of misunderstanding
	Completeness	Development of software and tools	Subjectivity	Expert dependence
	Organizing the decision-making process.	Public participation	Data requirements	Challenges in updating data
	Inclusion of stakeholders		Difficulties in communicating the results	
Environmental Impact Analysis (EIA)	Prevention of environmental damage	Sustainable development	time and cost	Legislative changes
	Improvement of planning and design	Technological innovation	Technical complexity	Public opposition
	Stakeholder involvement	Design performance	Data limitations	Financial limitations
	Legislative compliance	Access to funding	Risk of politicisation	Climatic and environmental unpredictability
Socio-economic Analysis (SEA)	Holistic approach	Identifying new trends and patterns	Data complexity	Political and economic changes
	Basis for the decision	Promotion of social inclusion	Bias e Data limitations	Financial limitations
	Flexibility	Inter-sectoral cooperation	Required resources	Evolution of Social Crises
Life Cycle Assessment (LCA)	Structured approach	Innovation and Adaptation	Limitations in Forecasting	Speed of Environmental Change
	Process improvement	Cooperation	Subjectivity in the Analysis	Complexity and Interdependence
	Decision-making Management of Priorities	Technology and Big Data	Costs and resources	Information overload
Risk and Uncertainty Analysis	Experience in Managing Uncertainty	Emerging technologies	Limiti nella Previsione	Unpredictable Environmental and Socio-political Changes
	Advanced analytical tools	Collaboration and sharing knowledge	Limits in the Forecast	Increasing complexity
	Data Based Decision-Making	Innovation in Risk Assessment Processes	Poor Ability to Adapt	Resistance to change
Real Options Analysis (ROA)	Flexibility in Decisions	Innovation and growth	Complexity	Evolution of Financial Models
	Risk management	Portfolio diversification	Data's availability and quality	Perception of Complexity
	Evaluation of Innovative Projects	Adaptability	Subjectivity in the Estimates	Unforeseeable Market Risks
Equity Analysis	Commitment to diversity and inclusion	External collaborations	Lack of representation	Regulatory changes
	Inclusive Leadership	Innovation	Systemic barriers	Public opinion
	Education and development	Favorable legislation	Resistance to change	Growing inequalities
Geospatial Analysis	Accuracy and detail	Technological development	Technical complexity	Evoluzione Rapida delle Tecnologie
	Decision support	Interdisciplinary collaborations	Implementation costs	Data interoperability
	Innovative technologies	Growth of the Geospatial Market	Privacy and security issues	Competition and Overlap
	Multidisciplinary Applications	Sustainability and Resources Management	Data Dependence	Legal and regulatory issues
Sustainability Assessment	Commitment to reducing the environmental impact	Growth of the green market	High initial costs	More stringent environmental regulations
	Innovation	Government incentives	Internal conflicts	Volatility of resource prices
	Design performance	Collaborations and partnerships	Technological limitations	Competitive pressure

Fig. 3. Results of qualitative and quantitative evaluations - SWOT Analysis.

Metodo	*Benefits not easily monetized from improved accessibility*	*Level*	*Class*	*SDGs*
Multi-Criteria Analysis (MCA)	Inclusion	4 - Critical	0.25	3, 4, 6, 7, 8, 11, 12 e 16
Environmental Impact Analysis (EIA)	Economic Development Inclusion Risk Managment	2 - Average positive	0.75	3, 4, 6, 7, 8, 9, 11, 12, 13, 14, 15 e 16
Socio-economic Analysis (SEA)	Economic Development Equity Inclusion	2 - Average positive	0.75	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15 e 16
Life Cycle Assessment (LCA)	Risk Managment	4 - Critical	0.25	7, 12, 13, 14 e 15
Risk and Uncertainty Analysis	Risk Managment	4 - Critical	0.25	7, 12, 13, 14 e 15
Real Options Analysis (ROA)	Economic Development Risk Managment	3 - Average Critical	0.50	7, 8, 9, 11, 12, 13, 14 e 15
Equity Analysis	Equity Inclusion	3 - Average Critical	0.50	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12 e 16
Geospatial Analysis	Economic Development Risk Managment	3 - Average Critical	0.50	7, 8, 9, 11, 12, 13, 14 e 15
Sustainability Assessment	Economic Development	4 - Critical	0.25	7, 8, 9, 11, 12, 13, 14 e 15

Fig. 4. Results of qualitative and quantitative evaluations.

Level	*Class*	*Benefits not easily monetized from improved accessibility*
1 - Positive	1.00	- Economic Development, Equity, Inclusion and Risk Management.
2 - Average positive	0.75	- Economic Development, Equity and Inclusion - Economic Development, Equity and Risk Management - Economic Development, Inclusion and Risk Management - Equity, Inclusion and Risk Management
3 - Average critical	0.50	- Economic Development and Equity - Economic Development and Inclusion - Economic Development and Risk Management - Equity and Inclusion - Equity and Risk Management - Inclusion and Risk Management
4 - Critical	0.25	- Economic Development - Equity - Inclusion - Risk Management

Fig. 5. Legend of quantitative evaluations.

4 Discussion

The role of 2030 Agenda Goals, adopted by the 193 UN member countries in 2015, represents an ambitious action plan to improve the lives of communities. The 17 Sustainable Development Goals (SDGs), divided into 169 targets and 232 monitoring indicators, constitute the main framework that must also guide the design of infrastructure. The proposed qualitative dimension - SDG - allows us to obtain a picture of the sustainability objectives associated with the 10 selected evaluation methods. The proposed quantitative dimension - Level - instead allows us to obtain a picture of the levels of

integration of the main benefits (direct and indirect) deriving from the improvement of accessibility associated with the infrastructure: economic development, inclusion, equity and risk management.

From the analysis conducted, the need emerges to build a set of indicators to be associated with the development dynamics of the territory useful for evaluating the economic and social well-being of communities, which can arise from the choice of transport infrastructure projects aimed at generating development opportunities (complementary "strategic generative" evaluation methods) or defence of the needs and requirements of services ("strategic conservative" evaluation methods) for territories characterised by obvious disadvantages (geographical, demographic, etc.).

5 Conclusions and Future Development

The evaluation of the non-monetizable benefits of CBA, such as economic development, equity, inclusion and risk management was the subject of the authors' research [21]. In particular, how a transport infrastructure can bring benefits that cannot always be monetized to certain groups or regions to the detriment of others, generating differentials in economic development, equity, inclusiveness and risk management. Furthermore, it is difficult to accurately predict the future costs and benefits of a project, especially in the long term. Estimates can be affected by many variables. Decisions regarding infrastructure projects can also be influenced by political aspects, leading to choices that are not optimal from an economic point of view. Technological and social-demographic changes, the digital and energy transition [22] could also further contribute to making infrastructure projects obsolete sooner than expected, thus invalidating the CBA.

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