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abstract

Critical Review of Cost-Benefit Analysis for Climate-Neutral Infrastructure: Addressing Policy Challenges in Europe

Alessio D'Auria, Irina Di Ruocco

Abstract

Climate change makes infrastructure less resilient, thus projects that mitigate environmental effects are required.

Traditional cost-benefit analysis (CBA) often inadequately assesses long-term sustainability. In Europe, despite academic discussions, regulatory frame- works and CBAs frequently overlook these aspects. This paper identifies legislative gaps in evaluating infrastructure projects' economic and environmental impacts, advocating for improved methodologies that integrate climate resilience and long-term sustain- ability. It also recommends using variable discount rates to better assess environmental impacts, highlighting the need for strategic policies tailored to the European context.

Keywords:
Cost-Benefit Analysis; Resilient infrastructures; Climate Neutral Development; En-

vironmental Impacts; European Policies

Revisione critica dell'analisi costi-benefici di infrastrutture ad impatto climatico zero: Affrontare le sfide politiche in Europa

Il cambiamento climatico mette alla prova la resilienza delle infrastrutture, richiedendo progetti che mitigano gli impatti ambientali. L'analisi costi-benefici (ACB) tradizionale spesso non valuta adeguatamente la sostenibilità a lungo termine. In Europa, nonostante le discussioni accademiche, le normative spesso trascurano questi aspetti. Questo paper evidenzia lacune legislative nella valutazione economica e ambientale dei progetti infrastrutturali, proponendo metodologie che integrino resilienza climatica e sostenibilità. Raccomanda anche l'uso di tassi di sconto variabili per valutare meglio gli impatti ambientali, sottolineando la necessità di politiche strategiche adeguate al contesto europeo.

Parole Chiave:

Analisi costi-benefici; infrastrutture resilienti; sviluppo a impatto climatico zero; impatti ambientali; politiche europee

Critical Review of Cost-Benefit Analysis for Climate-Neutral Infrastructure: Addressing Policy Challenges in Europe

Alessio D'Auria, Irina Di Ruocco

1. Introduction

Transportation infrastructure offers substantial benefits, including improved logistics, job creation, and enhanced connectivity, but it also presents challenges like resource overuse and increased greenhouse gas emissions, which significantly affect natural environments. Climate change intensifies these issues, threatening the resilience and effectiveness of transportation systems. Then, climate considerations must be incorporated into infrastructure development at every level, especially during periods of extreme weather (IPCC, 2014; Wamsler et al., 2013). The move towards Environment, Social, and Governance (ESG) criteria in infrastructure investments reflects a growing focus on sustainability, aiming to enhance the risk-return profile while addressing climate change, social welfare, and economic competitiveness (Ansar et al., 2016). The UN's Principles for Responsible Investment (PRI) have been pivotal in integrating ESG factors into investment decisions, aligning them with broader societal objectives (Heinkel et al., 2001; Mackey et al., 2007). As climate change increasingly impacts infrastructure, traditional protection methods are being replaced by more flexible, adaptive strategies that consider modern complexities European policies, such as the European Green Deal, emphasize reducing GHG emissions and enhancing sustainability, with significant funding through the Connecting Europe Facility (CEF). The intersection of infrastructure, climate change, and CBA is crucial in modern policymaking. Infrastructure projects contribute to GHG emissions, while climate change threatens their resilience through rising sea levels and extreme weather (IPCC, 2021; World Bank, 2020). However, traditional CBA frameworks are increasingly insufficient for sustainable projects, often overlooking complex climate challenges (Loiseau et al., 2016). Traditional methods that focus on financial metrics and assume a static future need updating to incorporate adaptive decision-making that accounts for future climate scenarios and uncertainties (Giordano, 2012; Hallegatte, 2009; Hallegatte & Corfee-Morlot, 2011). Traditional CBA methods often undervalue long-term benefits due to high discount rates and may not align with actual project timelines (EC, 2021; OECD, 2018). Despite these challenges, CBA is essential for sustainable infrastructure projects as it considers long-term environmental and social impacts that traditional financial analyses might overlook (European Commission, 2015). By incorporating externalities like air and water pollution, CBA offers a more comprehensive assessment of a project's true value. Modern CBA methodologies also utilize adaptive decision-making frameworks to account for various future scenarios, which is crucial for planning resilient infrastructure amid climate uncertainties

Aspect	Description
Holistic Evaluation (Busse et al., 2019)	CBA offers a comprehensive framework for evaluating infrastructure projects by considering not only financial costs and revenues but also environmental and social impacts (OECD, 2018).
Informed Decision-Making (Busse et al., 2019)	CBA guides policymakers in making informed decisions, ensuring efficient resource allocation and prioritizing projects that offer the greatest societal benefits (Boardman et al., 2018).
Incorporating Externalities (NIST, 2019)	CBA incorporates externalities into the analysis, providing a more accurate assessment of a project's true costs and benefits (European Commission, 2015).
Evaluating Long-Term Impacts (Lee et al., 2023)	CBA evaluates the long-term impacts of sustainable by applying appropriate discount rates and considering the project's sustainability and resilience throughout its lifecycle. (Sartori et al., 2015).
Flexibility and Adaptability (Zhou, 2023)	Modern CBA methodologies can incorporate adaptive decision-making frameworks to account for various future scenarios, ensuring that sustainable infrastructure remains resilient to environmental changes and uncertainties (Hallegatte, 2009).
Transparency and Accountability (Articolo & Florio, 2023)	CBA offers a transparent method for comparing projects, enhancing accountability in public spending (Boardman et al., 2018).

Tab. 1 – Critical points of CBA, elaboration of authors

(Hallegatte, 2009). Furthermore, CBA's transparency enhances accountability in public spending by clearly documenting assumptions, data, and methods, thereby fostering trust and support for sustainable infrastructure investments (Boardman et al., 2018).

CBA is essential for evaluating climate-neutral infrastructure, but the uncertainty of climate change complicates accurate forecasting (Table 1). To improve CBA, incorporate scenario-based analyses, varied discount rates, and broader indicators such as ecosystem services and societal well-being. These adjustments help align investments with environmental, social, and economic goals, enhancing CBA's role in sustainable development. This article focuses exclusively on the European context. addresses critical gaps in the application of CBA to infrastructure resilience and sustainability amid climate change, highlighting two main issues: the misalignment between regulatory frameworks and scientific research, and the lack of transparency in CBA rate calculations. The article poses two research questions: (1) *"Are current European regulations sufficient for incorporating climate change complexities into CBA?"* (2) *"Is merely adjusting discount rates or other CBA parameters enough to adapt CBA for climate resilience?"*.

By exploring these questions, the article advocates for a comprehensive approach to CBA that better integrates climate resilience and sustainability into infrastructure planning, responding to the dynamic and unpredictable impacts of climate change. The following sections are so organized: Section 1 is the introduction, Section 2 is the literature review, Section 3 is to discuss the policy analysis, Section 4 is for discussion, and Section 5 is for conclusions and policies recommendation.

2. Literature background

Studies have developed economic methods for adaptation, such as Yi et al. (2010) flood prevention framework and Zhou et al. (2012) damage model for extreme weather. Chinowsky et al. (2013, 2015) examined adaptation costs for roads using traditional economic approaches like net present value (NPV). Sustainable infrastructure integrates renewable energy, eco-friendly materials, and resilience features, aiming for long-term benefits (United Nations, 2015; World Bank, 2017; OECD, 2018). Real Options Valuation (ROV) adds flexibility and accounts for project return volatility. Gersonius et al. (2013) applied ROV to urban drainage, while Woodward et al. (2014) and Kontogianni et al. (2014) used it for flood risk and sea level rise strategies. CBA remains crucial in assessing environmental impacts, but traditional methods often underestimate long-term effects. Recent approaches, like ROA and Life Cycle Analysis (LCA), better address uncertainties and long-term impacts (Schaubroeck, 2019; Hoogmartens et al., 2014). Integrating equity considerations into CBA is essential for addressing impacts on marginalized communities (Paavola & Adger, 2006; Pindyck, 2019), underscoring the need for updated methodologies to better evaluate climate action (Stern, 2007). The scarcity of climate change studies on transport arises from the sector's complexity, with diverse modes (road, rail, air, maritime) each having unique impacts. Data limitations, especially for maritime and air transport, and challenges in integrating various data sources and modeling interactions between technological, behavioral, and policy factors, further complicate analysis (IEA, 2020; European Environment Agency, 2019; Santos, 2017; WHO, 2018). Additionally, an interdisciplinary approach is required, combining engineering, economics, and public policy, which can be difficult to coordinate (Givoni & Banister, 2013). Policies focus often skews toward sectors with more immediate emissions reduction potential, like energy, due to the dispersed emissions sources in transport (IPCC, 2014). Economists have long debated the appropriate societal discount rate for cost-benefit analyses of public projects, with the issue gaining renewed focus in the context of climate change (Tol, 2003). Dennis (2018) underscores the importance of the discount rate in climate policy, noting that higher rates can diminish the perceived significance of long-term climate impacts. Despite extensive discussions and suggestions, including hyperbolic discounting and political economy models, no consensus has been reached, highlighting the ongoing complexity of this issue. Current CBA methods struggle to integrate the inherent uncertainties in climate change, including projections, socio-economic developments, and technological advancements. This results in gaps such as:

I) Valuation of Non-Market Impacts: CBA often undervalues or overlooks non-market impacts like biodiversity loss and ecosystem services, requiring improved methodologies;
II) Adaptation vs. Mitigation: There is a need for more integrated analyses that consider both strategies together to better understand their trade-offs and synergies;
III) Long-Term and Intergenerational Effects: Current models often fail to account for the impacts on future generations and long-term economic sustainability.

The literature review highlights the lack of empirical evidence on the effectiveness of various adaptation policies, suggesting the need for more studies on real-world outcomes and cost-effectiveness. Gaps emerging are related to the barriers to effective policy implementation and the role of governance is crucial, particularly in studying the political economy of climate policy and international cooperation. More research is needed on the economics of technical innovation and the diffusion of environmentally friendly technologies, including the forces driving innovation and factors influencing technology adoption. Key gaps in CBA for climate change include inadequate handling of uncertainty, difficulties in valuing non-market impacts, intergenerational equity issues, and limited attention to distributional impacts (Hallegatte, 2009; Stern, 2007; Tuner, 2007). Valuing non-market impacts, such as biodiversity loss, remains challenging, leading to incomplete assessments (Halvorsen, 1995; Hanley et al., 2009; Dietz et al., 2007). The use of discount rates can undervalue future benefits, raising ethical concerns about intergenerational equity. Traditional CBA also tends to overlook the distribution of benefits and costs across regions and groups, crucial for equitable policy (IPCC, 2014; Markandya et al., 2017), may not fully capture the complex, systemic interactions and feedback loops inherent in climate impacts (Weitzman, 2009; Nordhaus, 2010). The role of institutional factors, which significantly influence climate policy outcomes, is often underappreciated (Stern, 2007; Gillingham & Sweeney, 2010).

3. Materials and Methods

This section critically examines a key aspect of CBA that is often overlooked: the discount rate used for long-term projects. Traditional CBA approach ignores the varying opportunity costs of different policy goals and often relies on market interest rates that may not align with societal preferences, leading to a bias toward short-term gains. The social discount rate (SDR), which accounts for the opportunity cost of public funds and intergenerational equity, is crucial for evaluating long-term projects like green infrastructure but is often neglected (Bauer & Rudebusch, 2020). This review highlights the importance of adopting variable or social discount rates examining the evolution of CBA for climate change from the 1990s to today, emphasizing that lower discount rates are increasingly recommended to align economic evaluations with ecological and social goals, particularly to ensure intergenerational equity (Stern, 2007; Drupp et al., 2018; Howarth & Norgaard, 1992). As discussions on climate change advance, the use of appropriate discount rates will remain critical in policy and green infrastructure development. In Europe, discount rates for CBA vary by country and project type[1]. This flexible approach ensures that economic evaluations reflect the unique risks and benefits of each project (Table 2).

No.	Country Discount	Rate (%)
1	Germany	3.0
2	United Kingdom	3.5
3	France	4.0
4	Italy	3.5
5	Spain	4.0
6	Netherlands	3.0
7	Belgium	4.0
8	Sweden	3.5
9	Denmark	4.0
10	Finland	3.5
11	Portugal	4.0
12	Greece	
13	Ireland	3.5
14	Austria	3.0
15	Poland	5.0
16	Czech Republic	
17	Hungary	
18	Slovakia	
19	Slovenia	4.0
20	Luxembourg	3.0
21	Estonia	5.0
22	Latvia	
23	Lithuania	
24	Malta	4.0
25	Cyprus	
26	Bulgaria	5.0
27	Romania	
28	Croatia	

**The values of SDR are updated to 2024*

Tab. 2 – Social discount rates in selected countries, elaboration of authors

Social discount rates (SDRs) are crucial in evaluating long-term projects, particularly for environmental and climate-related infrastructure. Lower SDRs increase the present value of future benefits, making sustainable projects like renewable energy and climate resilience more attractive. This approach supports investments in green infrastructure, promotes low-carbon technologies, and aligns economic decisions with long-term environmental goals.

The debate on SDRs involves three key points:

- Appropriate Rate: No consensus exists on the "correct" SDR, with some advocating higher rates for market returns and others favoring lower rates to prioritize future generations.
- Ethical Considerations: Lower SDRs are preferred for climate policies, reflecting the importance of intergenerational equity.

Tab. 3 – Comparative Analysis of Social Discount Rates, elaboration of author

Country	SDR Value	Best practices	Challenges	Failures
Germany	3%	Germany's low social discount rate (SDR) underscores its commitment to long-term environmental sustainability, especially in energy efficiency and renewable energy projects.	Balancing economic growth with strict environmental regulations is particularly challenging in industrial sectors.	Projects sometimes encounter delays and increased costs due to lengthy regulatory processes.
United Kingdom	3.5%*	The UK's decreasing social discount rate (SDR) for long-term projects emphasizes future benefits, encouraging investments in climate resilience and sustainable infrastructure.	Political changes and economic uncertainties, such as those following Brexit, can disrupt long-term policy consistency.	Some large infrastructure projects have encountered public opposition and financial overruns, highlighting gaps in stakeholder engagement and planning.
France	4%	France uses a relatively higher social discount rate (SDR) but has successfully funded extensive public transportation and green urban planning initiatives.	Higher SDRs can sometimes undervalue long-term environmental benefits.	There have been instances where financial constraints have limited the scope and scale of environmental projects.
Netherlands	3%	The Netherlands prioritizes water management . A low social discount rate (SDR) supports long-term investments in climate adaptation	The country faces ongoing risks from climate change, requiring continuous and substantial investment in resilience.	Some projects have encountered technical difficulties and unforeseen environmental impacts, highlighting the need for adaptive management
Sweden	3%	Sweden applies its social discount rate (SDR) across various sectors, supporting sustainable forestry, renewable energy, and eco-friendly urban development. This integrated approach aligns SDRs with the country's broader sustainability goals.	Maintaining economic competitiveness while pursuing aggressive environmental targets can be difficult.	Certain initiatives have faced budget cuts and reduced public support, affecting their implementation.
United States	7%	The U.S. approach to social discount rates (SDRs) varies by state and sector, with some states adopting lower SDRs for environmental projects, allowing for tailored regional solutions.	High federal SDRs often undervalue long-term environmental benefits, making it harder to justify investments in climate change mitigation.	Inconsistent application and political opposition have led to the underfunding of crucial infrastructure projects.
China	8-10%	China has aggressively invested in renewable infrastructure. Strategic long-term planning drives large-scale projects despite a relatively high social discount rate (SDR).	High SDRs can undervalue long-term environmental benefits.	Some green projects face financial sustainability issues due to high upfront costs and less emphasis on long-term environmental gains.
India	8-10%	India has promoted renewable energy through initiatives like the National Solar Mission, applying lower regional social discount rates (SDRs) to boost investments in solar and wind energy.	High SDRs pose a challenge in valuing long-term environmental benefits, which is crucial for climate change mitigation.	Financial and technical barriers have limited the expansion of some renewable energy projects and infrastructure development, particularly in rural areas.
Brazil	6-8%.	Brazil has prioritized sustainable agriculture and renewable energy, particularly hydroelectric power to cut urban emissions.	Deforestation and balancing economic development with environmental conservation are significant issues.	Projects aimed at reducing deforestation have often faced setbacks due to political and economic pressures.
South Africa	6-8%.	South Africa has driven renewable energy growth through its Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), attracting substantial private investment.	High SDRs can deter long-term investments in sustainable projects, and there are issues with energy infrastructure and grid reliability.	Political instability and financial constraints have affected the consistency and effectiveness of environmental policies and projects.
Indonesia	6-8%.	Indonesia has focused on sustainable forestry and renewable energy, particularly geothermal power, leveraging its geological advantages.	High SDRs and economic pressures can make long-term environmental projects less appealing.	Deforestation and environmental degradation persist due to the insufficient valuation of long-term benefits.

** For short-term projects, decreasing for longer-term projects.*

• Methodological Differences: Different methods to calculate SDRs, like the Ram- sey equation (Ramsey, 1928) lead to varying suggested rates. Lower SDRs make projects with long- term benefits, such as renewable energy and resilient infrastructure, more financially viable, ensuring that economic decisions support sustainability and intergenerational equity. The Ramsey equation is so described:

$$s=\rho+\mu g \quad (1)$$

The term 's' is the social discount rate, 'ρ' the time preference rate, 'μ' is the elasticity of the marginal utility of income (consumption), 'g' is the mean rate of the income growth.

3.1 The critical review of guidelines

New infrastructure must be planned, designed, and managed with consideration for systemic threats, including climate change, while aligning with sustainable development goals. Specifically, they should contribute to the Sustainable Development Goals (SDG) of the 2030 Agenda, notably SDG 9, which emphasizes building resilient infrastructure and fostering sustainable industrialization and innovation.

Several key technical-policy documents from the European context have been analyzed to understand their approaches to climate-neutral and resilient infrastructure, particularly regarding CBA. These include:

• The Critical Entities Resilience Directive (CER) of the European Union (Directive (EU) 2022/2557);
• "Climate-resilient Infrastructure" (OECD, 2018);
• "Making Critical Infrastructure Resilient" (UNDRR, 2020);
• "Building Community Resilience with Nature-based Solutions" (FEMA, 2021);.
• The EU Commission's "Technical Guidelines for Climate-Proof Infrastructure" for 2021-2027.
• "Engineering for Sustainable Development" (UNESCO, 2021);.
• Regulation (EU) 2022/869 on Guidelines for Trans-European Energy Infrastructure.

Most of these documents do not thoroughly address the economic sustainability of climate-neutral or resilient infrastructure investments. However, assessing economic sustainability is crucial to ensure that such investments not only meet environmental goals but also provide long-term financial benefits. This includes ensuring resource allocation to projects with the highest potential for positive economic and environmental impact, balancing immediate costs with future savings, and mitigating economic risks like cost overruns. Notably, only the "Technical Guidelines for Climate-Proof Infrastructure" explicitly consider the need for enhanced CBA in this context. The Critical Entities Resilience Directive (CER) of the European Union, formally known as Directive (EU) 2022/2557, aims to enhance the resilience of critical entities that provide essential services within the EU. Several studies have analyzed and provided

The Critical Entities Resilience Directive (CER) of the European Union (Directive (EU) 2022/2557)					
Strengths	*Comprehensive Scope*	*Risk-Based Approach*	*Enhanced Coordination and Cooperation*	*Clear Framework for Accountability*	-
	The directive has been praised for its broad scope, covering critical sectors like energy, transport, water, health, and digital infrastructure.	The directive's focus on a risk-based approach has been well-received, as it requires entities to assess risks and implement mitigation measures	The directive's focus on enhanced coordination between member states and public-private sectors is seen as a major advancement	The directive's establishment of clear accountability frameworks, including designating national competent authorities and requiring critical entities	-
Challenges and Areas for Improvement	*Implementation Consistency*	*Resource Allocation*	*Dynamic Threat Landscape*	*Monitoring and Enforcement*	*Interdependency of Critical Entities*
	Some studies express concerns about inconsistent implementation across member states due to differences in capacities, resources	The directive imposes significant obligations on critical entities, requiring substantial investments in resilience.	The rapidly evolving nature of threats, especially in the digital realm, challenges the directive.	Effective monitoring and enforcement are vital for the directive's success.	The interdependency of critical entities is both a strength and a vulnerability.

Tab. 4 – The Strengths and barriers of European Directive CER, elaboration of authors

feedback on the directive, highlighting both its strengths and areas for improvement. Here in Table 4 are summarized the main aspects (barriers and positive feedback) as follows.

The analysis of various documents highlights key strengths and challenges in addressing climate resilience and infrastructure sustainability. The **OECD's 2018 Climate-resilient Infrastructure report** emphasizes comprehensive risk assessments, economic evaluations, and supportive policy frameworks but notes challenges like resource constraints, financing difficulties, and the complexity of integrating new practices. Similarly, the **UNDRR's 2020 report** on critical infrastructure in Europe and Central Asia underscores the need for regional coordination and resilience integration across planning stages but identifies barriers like varying preparedness levels and the complexity of multinational efforts. Meanwhile, **FEMA's 2021 report** advocates for nature-based solutions (NbS) to enhance community resilience, emphasizing their co-benefits but acknowledging challenges in funding, regulatory approvals, and technical expertise. Each document provides valuable insights but also highlights the significant efforts required to overcome these challenges. The E**U Commission's Technical Guidelines for Climate-Proof Infrastructure (2021-2027)** provide detailed methods for integrating climate resilience into EU-funded projects. They offer a robust framework for risk assessment, adaptation planning, and implementation, but face challenges in ensuring compliance across diverse projects and managing potential increased upfront costs that might deter investments. The **UNESCO's 2021 report on Engineering for Sustainable Development** emphasizes a comprehensive approach to embedding sustainability in engineering, highlighting the role of engineers in achieving the UN Sustainable Development Goals (SDGs). While it strongly advocates for interdisciplinary collaboration and incorporating sustainability into education, challenges include bridging theory with practical application and managing costs. The **Regulation (EU) 2022/869** sets guidelines for developing resilient, interconnected energy infrastructure in Europe, focusing on projects of common interest (PCIs) that enhance energy security and support the EU's climate goals. Challenges involve coordinating cross-border projects, navigating different national regulations, and securing both financing and public support for large-scale infrastructure initiatives. In the 4 Section, we discuss about the main critic points of these guidelines and propose some recommendations for policies makers.

4. Discussion and recommendations

This paper builds on early 2000s studies (Howarth & Norgaard, 1992; Articolo & Florio, 2023) to explore how states and public administrations can mitigate climate change risks to protect the environment and infrastructure. The European Commission has yet to make significant progress in addressing climate change, with few studies adapting CBA on current environmental challenges. The paper highlights regulatory limitations in Europe compared to other regions and suggests best practices such as integrating Social Discount Rates (SDRs) into sustainability policies (as in Germany and Sweden), adopting decreasing SDRs for long-term projects (as in the UK), and improving stakeholder engagement. Challenges include economic and political uncertainties, balancing growth with sustainability, and overcoming barriers to large-scale sustainable projects. Key failures in current guidelines include underfunding, project delays, and regulatory hurdles that increase costs. The paper also notes that strategic investments and public-private partnerships, as demonstrated by China, Brazil, and South Africa's REIPPPP, are crucial for advancing renewable energy and sustainable infrastructure.

Challenges for non-European countries include: 1) **Economic Pressures**: High SDRs often reflect immediate economic needs, making long-term environmental projects less appealing. 2) **Political Instability**: Political changes can disrupt sustainable project planning and implementation. 3) **Financial Constraints**: Limited access to financing and high upfront costs hinder large-scale sustainable infrastructure projects. Failures identified include: 1) **Inadequate Valuation of Long-Term Benefits**: High SDRs often undervalue long-term environmental benefits, leading to insufficient investment in crucial climate mitigation projects. 2) **Deforestation and Environmental Degradation**: Brazil and Indonesia continue to face challenges in preventing deforestation, partly due to economic priorities and inadequate long-term planning. 3) **Infrastructure and Policy Inconsistencies**: In countries like South Africa and India, infrastructure issues and inconsistent policies have caused delays and reduced project effectiveness.

Emerging economies must balance rapid growth with sustainability, often focusing on immediate gains due to high Social Discount Rates (SDRs). Strategic investments and public-private partnerships can improve long-term environmental benefits. The "Technical Guidelines for Climate-Proof Infrastructure for 2021-2027" emphasize integrating climate mitigation and adaptation into infrastructure planning, in line with EU climate goals. This includes climate risk assessment, greenhouse gas quantification, and resilience strategy documentation. However, challenges remain in advancing CBA due to methodological gaps and the need for consistent reference scenarios: 1) **Lack of Specific Methodology**: The guidelines do not prescribe a standardized methodology for CBA, which can vary depending on specific loan requirements and sectoral differences. This flexibility, while allowing for adaptability, can lead to inconsistencies in how CBA is applied across different projects, particularly in sectors like energy, where specific methodologies are referenced. This variation complicates the comparability and assessment of investments, potentially undermining the consistency and reliability of CBA outcomes. 2) **Harmonization of Reference Scenarios**: The document highlights the importance of consistency between the scenarios used for calculating the carbon footprint and those used in the CBA. In some cases, discrepancies between these reference scenarios can lead to misaligned assessments, where the CBA may compare 'with project' and 'without project' scenarios without ensuring that the project's reference scenario accurately represents EU climate policy. This misalignment can result in inadequate assessments of a project's climate impact and overall efficacy. To improve CBA for long-term environmental projects, adopting variable and differentiated discount rates is crucial. Variable rates account for changes in the value of time and money, while differentiated rates apply lower rates to environmental benefits. These methods, however, increase complexity and require advanced skills and careful calibration. Effective implementation also needs strong institutional capacity and clear guidelines to ensure CBA accurately reflects the value of long-term environmental impacts.

5. Conclusions

Integrating lower discount rates for valuing climate-neutral and resilient infrastructures demands a broader approach that includes economic, ecological, social, and ethical dimensions. Shifting focus from short-term gains to long-term sustainability and equity requires acknowledging the enduring value of environmental benefits and the responsibility to future generations. Adopting a variable or social discount rate and incorporating non-monetary benefits enables more balanced infrastructure assessments, ensuring long-term societal and environmental benefits are properly valued. While CBA remains valuable for evaluating climate-neutral infrastructures, it needs enhancements to fully capture environmental impacts (Heal & Millner, 2014). This includes adjusting discount rates, incorporating strategic environmental assessments, and recognizing non-monetary benefits for a comprehensive evaluation. Adopting adaptive management strategies and engaging stakeholders in decision-making ensures infrastructure investments remain effective under changing conditions. These steps are essential to align infrastructural investments with sustainable development goals. Further research is necessary in sectors like road and rail to address climate-related stressors and explore cross-sectoral impacts. Overall, improving the economic assessment of climate-neutral infrastructures requires an inclusive, adaptive methodology that considers the complex interplay of economic, environmental, and social factors. This approach is crucial for ensuring that these investments contribute effectively to sustainable development goals.

Endnotes

1 The European Commission recommends a 5% social discount rate for public investments, but this rate may be lower for poorer regions or specific projects like energy efficiency to account for long-term societal and environmental benefits.

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