STRATEGIC DECISIONS: A SUPPORT MODEL FOR PRIORITIZING PROJECTS IN THE BRAZILIAN TRANSPORT INFRASTRUCTURE

DECISÕES ESTRATÉGICAS: UM MODELO DE APOIO À PRIORIZAÇÃO DE PROJETOS NA INFRAESTRUTURA DE TRANSPORTES BRASILEIRA

DECISIONES ESTRATÉGICAS: UN MODELO DE APOYO A LA PRIORIZACIÓN DE PROYECTOS EN LA INFRAESTRUCTURA DE TRANSPORTE DE BRASIL

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ABSTRACT
Efficient transportation infrastructure is essential for development but faces challenges such as resource demands, environmental impacts, and vulnerability to climate change. This study proposes an innovative action model for Brazil's transportation infrastructure, prioritizing financial viability, socioeconomic benefits, environmental sustainability, and resilience to climate impacts. The model focuses on optimizing resources, fostering adaptability, and promoting equitable development while addressing critical aspects like risk assessment, climate resilience, stakeholder involvement, and transparency. By integrating sustainability and climate adaptation, the study offers a holistic framework to enhance Brazil's transportation sector and ensure long-term resilience.

KEYWORDS
Brazilian transport infrastructure; Environmental sustainability; Climate change adaptation; Risk management; Resilience.

RESUMO
Infraestruturas de transporte eficientes são essenciais para o desenvolvimento, mas enfrentam desafios como alta demanda por recursos, impactos ambientais e vulnerabilidade às mudanças climáticas. Este estudo propõe um modelo de ação inovador para a infraestrutura de transporte no Brasil, priorizando a viabilidade financeira, os benefícios socioeconômicos, a sustentabilidade ambiental e a resiliência aos impactos climáticos. O modelo foca na otimização de recursos, na promoção da adaptabilidade e no incentivo ao desenvolvimento equitativo, abordando aspectos críticos como avaliação de riscos, resiliência climática, envolvimento de stakeholders e transparência. Ao integrar sustentabilidade e adaptação às mudanças climáticas, o estudo oferece uma estrutura holística para aprimorar o setor de transporte no Brasil e garantir sua resiliência a longo prazo.

PALAVRAS-CHAVE
Infraestrutura de transporte brasileira; Sustentabilidade ambiental; Adaptação às mudanças climáticas; Gestão de riscos; Resiliência.

RESUMEN
Las infraestructuras de transporte eficientes son esenciales para el desarrollo, pero enfrentan desafíos como la alta demanda de recursos, los impactos ambientales y la vulnerabilidad al cambio climático. Este estudio propone un modelo

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de acción innovador para la infraestructura de transporte en Brasil, priorizando la viabilidad financiera, los beneficios socioeconómicos, la sostenibilidad ambiental y la resiliencia ante los impactos climáticos. El modelo se centra en la optimización de recursos, la promoción de la adaptabilidad y el impulso del desarrollo equitativo, abordando aspectos críticos como la evaluación de riesgos, la resiliencia climática, la participación de los stakeholders y la transparencia. Al integrar la sostenibilidad y la adaptación al cambio climático, el estudio ofrece un marco holístico para mejorar el sector del transporte en Brasil y garantizar su resiliencia a largo plazo.

PALABRAS CLAVE

Infraestructura de transporte brasileña; Sostenibilidad ambiental; Adaptación a los cambios climáticos; Gestión de riesgos; Resiliencia.

1. INTRODUCTION

An efficient and functional transportation infrastructure is vital for the smooth running of the economy and society (ERDOGAN, 2020; SANTOS *et al*., 2021). However, its operation requires significant financial and spatial resources and is often associated with negative impacts (BRONIEWICZ & OGRODNIK, 2020).

From an environmental point of view, transport infrastructure has a wide-ranging impact on the environment (AMIRIL *et al*., 2014; ASHER, GARG & NOVOSAD, 2020; DA COSTA *et al*., 2022), affecting everything from obvious aspects such as the loss of local ecosystems and changes to the landscape, to emissions of air pollutants and greenhouse gases, noise and disturbances to the quality of ecosystems, as well as interference in hydrological processes (BRONIEWICZ & OGRODNIK, 2020; ASHER, GARG & NOVOSAD, 2020).

Attempts to integrate sustainability into the decision-making process for transportation infrastructure projects continue to gain momentum (BUENO, VASSALLO & CHEUNG, 2015; PAPP *et al*., 2022). Transportation infrastructure projects often suffer from cost overruns and schedule delays, problems that persist despite the extensive research carried out in the field of transportation and planning over the past three decades. Unfortunately, progress in improving the performance of these projects has been limited (LOVE *et al*., 2015).

The development and maintenance of an efficient and resilient transportation infrastructure plays a key role in the economic growth of any nation (DE ABREU *et al*., 2022b; BAYOUMI *et al*., 2022). In Brazil, a country with vast geographical dimensions and diverse transportation needs, making strategic decisions about infrastructure projects becomes crucial (DE ABREU *et al*., 2023b). Transportation infrastructure projects generally involve large amounts of resources, long-term investments (AMIRIL *et al*., 2014).

Therefore, the urgent need to develop an efficient and sustainable transport infrastructure is recognized, with a focus on cities that are more resilient to natural disasters and climate change, in line with the 2030 Agenda. This study proposes a model for action, considering financial viability, socioeconomic and environmental impact. In doing so, it aims not only to optimize the use of limited resources, but also to drive the equitable and sustainable development of the country's transport system, since in 2023 there was a 3.2% increase in emissions from the transport sector, reaching an all-time high of 224 megatons of carbon dioxide equivalent (SEEG, 2024). In this context, this study proposes an innovative approach by presenting a model designed to facilitate decision-making in the prioritization of projects within Brazil's transport infrastructure.

2. METHODOLOGY

The development and implementation of the Brazilian transport infrastructure project prioritization model involved a careful and comprehensive methodological approach. This section describes the main steps and components used in the methodological process.

- Definition of Objectives - Initially, the model's objectives were defined, which include facilitating strategic decision-making in the prioritization of transport infrastructure projects, considering economic, socio-environmental and strategic aspects;
- Literature Review - An extensive literature review was carried out to understand the best practices, approaches and challenges faced when prioritizing transport infrastructure projects. This included academic studies, government reports and analysis by specialized consultancies;
- Stakeholder Identification - The main stakeholders relevant to the process of prioritizing transport infrastructure projects were identified and involved, including government representatives, private sector companies, non-governmental organizations and local communities;
- Definition of Prioritization Criteria - Based on the literature review and discussions with stakeholders, the criteria that would be considered when prioritizing projects were established. This included factors such as economic impact, financial viability, environmental sustainability, regional needs and long-term strategies;
- Model development - The prioritization model was developed using a multidisciplinary approach, integrating concepts from economics, engineering, social and environmental sciences. Quantitative and qualitative tools were used to evaluate and classify the projects according to the established criteria;
- Model validation - The model underwent a validation process, in which experts in the field of transport

infrastructure reviewed and tested its effectiveness. Adjustments and refinements were made based on the feedback received during this phase;

- Pilot Implementation - A pilot implementation of the model was conducted on a representative sample of transportation infrastructure projects in Brazil. This made it possible to assess its practical applicability and identify any challenges or limitations that needed to be addressed;
- Documentation and Dissemination - Finally, the model was comprehensively documented, including all stages of the methodological process, prioritization criteria and results obtained. In addition, efforts were made to disseminate the model among decision-makers, academic institutions and other stakeholders in the field of transportation infrastructure.

This comprehensive and participatory methodology ensured the robustness and relevance of the prioritization model developed, providing an effective tool for guiding strategic decisions in Brazilian transport infrastructure.

3. MODEL

The implementation of a project prioritization model in the Brazilian transport infrastructure is of paramount importance to optimize limited resources and face the growing challenges in this sector (DE ABREU *et al*., 2023b). With Brazil's vast territorial extension and complex transportation needs, it is crucial to identify and select the most critical and strategic projects to promote economic and social development (SANTOS *et al*., 2021). An effective prioritization model can consider various criteria, such as economic impact, current and future demand, environmental sustainability and technical feasibility, ensuring that investments are directed intelligently and in line with the country's long-term objectives (TRAN, YANG & HUANG, 2021). In addition, by providing a transparent and data-based framework for decision-making, this model contributes to increasing investor confidence, streamlining licensing processes and mitigating risks associated with the execution of large-scale projects (TSYGANOV, 2021).

Currently, in Brazil, the National Logistics Plan 2035 (PNL), developed by the Logistics Planning Company (EPL), and the General Guide for Socioeconomic Cost-Benefit Analysis of Infrastructure Investment Projects, published by the Ministry of Economy, can be cited as examples of instruments for planning and evaluating transport infrastructure projects. The former addresses topics such as logistics efficiency and improvements in multimodal connectivity, mentioning aspects like energy efficiency and the reduction of greenhouse gas emissions only as byproducts of improved logistics efficiency. The latter focuses on assessing the economic feasibility of projects, estimating the socioeconomic impacts of infrastructure throughout its lifecycle, among other factors, mentioning emission reductions in the context of impact mitigation but not in terms of resilience.

Adopting a prioritization model can also catalyze the modernization and integration of transport infrastructure, promoting synergies between different modes and regions of the country. By identifying projects that complement and strengthen existing infrastructure, it is possible to create a more efficient and resilient network, capable of supporting economic growth and promoting national and international connectivity (PRUS & SIKORA, 2021). Furthermore, by prioritizing initiatives that encourage innovation and the adoption of disruptive technologies, such as intelligent transport systems and clean energy, the prioritization model can boost countries' competitiveness on the global stage and position the country as a leader in sustainable mobility solutions (DMYTRIIEVA, 2020).

It is essential to emphasize the importance of promoting studies aimed at increasing the resilience of transportation infrastructure to climate change, considering both soft adaptations and hard adaptations (DE ABREU, SANTOS & MONTEIRO, 2022). Soft adaptations encompass political, social, and educational measures that seek to foster adaptation through changes in behavior, public policies, regulations, technical training, and societal awareness. Examples of these actions include awareness campaigns, integrating climate resilience into city master plans, and creating incentives for sustainable practices in the transportation sector (DE ABREU *et al*., 2023a).

On the other hand, hard adaptations refer to structural and technological measures focused on the design, construction, and modernization of physical infrastructure to make it more resistant to climate impacts (DE ABREU *et al*., 2022a). Examples include elevating roads in flood-prone areas, using more durable materials adapted to extreme temperature variations, implementing more efficient drainage systems, and constructing barriers against natural disasters such as storms and landslides (DE ABREU, SANTOS & MONTEIRO, 2022).

By integrating these two approaches in a complementary manner, it is possible to promote a more

comprehensive and effective adaptation, balancing preventive and corrective actions. Investing in the combination of social and structural measures not only strengthens the resilience of transportation infrastructure but also contributes to the development of cities and systems that are more adaptable, safe, and sustainable, aligning with the challenges posed by climate change and the objectives of the 2030 Agenda (DE ABREU *et al.*, 2024b).

A good transport infrastructure model should focus on several key aspects as shown in Figure 1. First, it must prioritize projects efficiently by developing a systematic approach that considers strategic factors, economic impact, and regional needs (TSAMBOULAS, 2007). Additionally, resource allocation optimization is essential, requiring a model that ensures the proper use of financial, technological, and human capital to guarantee successful project execution, as suggested by De Assis *et al.* (2022a; 2022b). Another crucial factor is the identification and mitigation of challenges and risks associated with each project, incorporating strategies for adaptation in the decision-making process (DE ABREU, SANTOS & MONTEIRO, 2022; ROKICKI & OSTASZEWSKI, 2022).

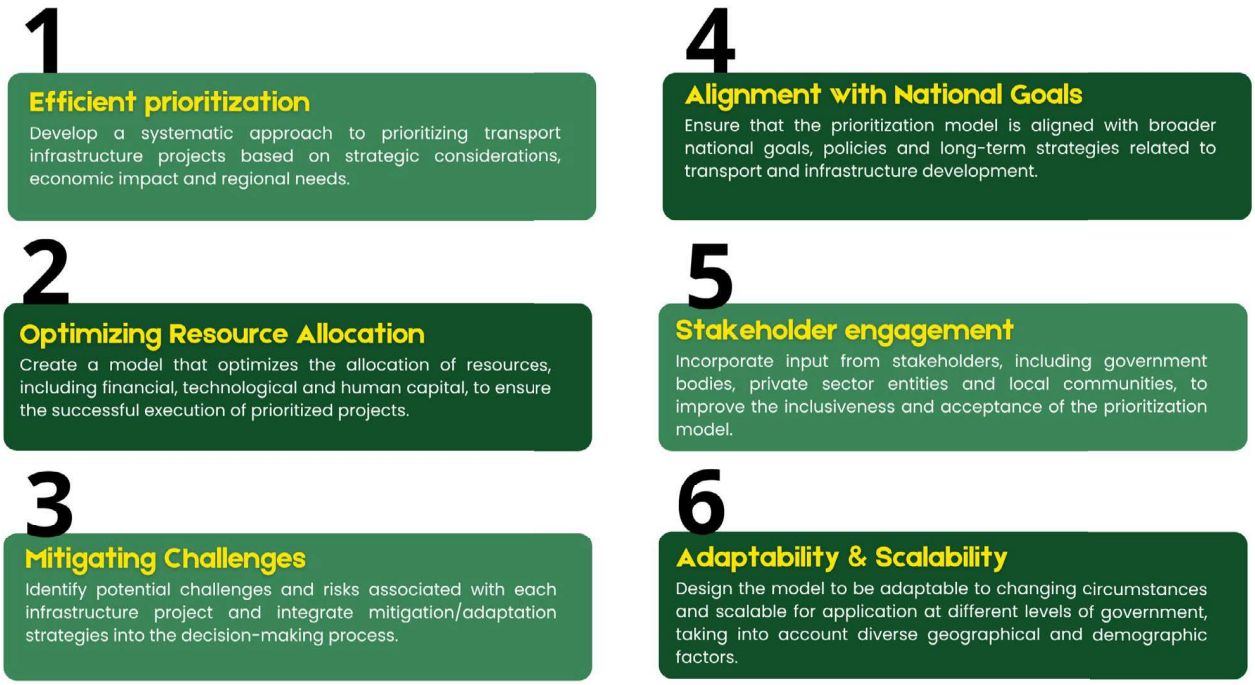

Figure 1: Aspects that should be considered in a transportation infrastructure model with a focus on sustainability.
Source: Made by the authors.

The model must also be aligned with broader national goals, policies, and long-term strategies for transport and infrastructure development, as highlighted by De Assis et al. (2022a; 2022b). Furthermore, it is important to involve stakeholders, including government agencies, private sector entities, and local communities, to enhance the inclusiveness and acceptance of the model (KOPPENJAN, 2005). Finally, adaptability and scalability are vital; the model should be flexible to adjust to changing circumstances and scalable for implementation at different government levels, accounting for geographic and demographic diversity (De Abreu, Santos & Monteiro, 2022).

The support model incorporates a comprehensive, multifaceted methodology that blends quantitative and qualitative factors to enhance the decision-making process for transport infrastructure projects as shown in Figure 2. One of its core components is data analysis. By using in-depth data analysis, the model assesses the feasibility of projects, taking into account their potential impact on regional development and their compliance with environmental sustainability goals. This approach ensures that each project aligns with broader objectives, such as fostering regional growth while adhering to sustainability criteria, as emphasized by De Abreu, Santos & Monteiro (2022).

Another significant component is cost-benefit analysis. This rigorous evaluation method helps determine the economic viability of each project by considering both

short-term and long-term returns on investment. Through this analysis, the model ensures that resources are allocated efficiently, maximizing the economic impact of transport infrastructure projects (De Assis et al., 2022a; 2022b).

Risk assessment also plays a critical role in the support model. By conducting a thorough analysis of potential risks, obstacles, and challenges that may arise during the project's lifecycle, the model provides valuable insights that contribute to more effective risk management. This proactive identification of risks helps to mitigate issues before they become significant problems, improving project outcomes and reducing unforeseen costs (De Abreu, Santos & Monteiro, 2022; Rokicki & Ostaszewski, 2022).

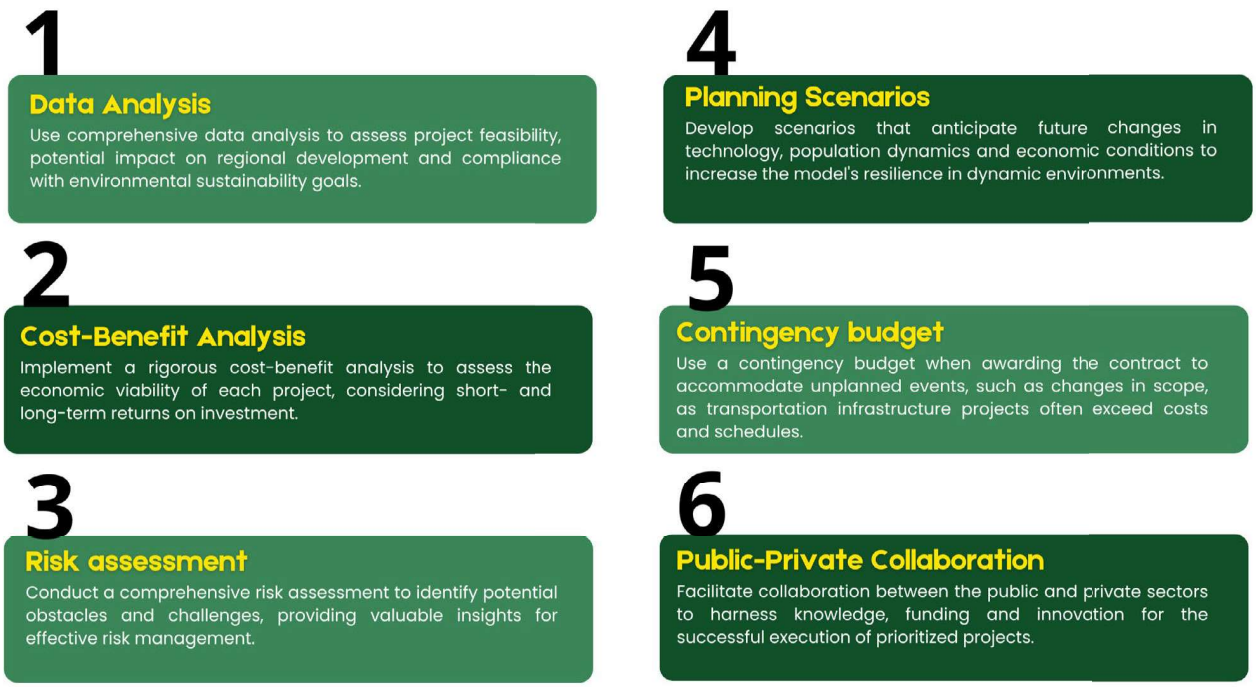

Figure 2: Key components to be considered in a sustainability-focused transport infrastructure model.
Source: Made by the authors.

Scenario planning further enhances the model's robustness by anticipating future changes in technology, population dynamics, and economic conditions (DE ABREU, 2024). By developing flexible scenarios, the model can adapt to shifting conditions in dynamic environments, ensuring that transport infrastructure projects remain resilient and relevant over time. This forward-thinking approach allows decision-makers to adjust plans based on future uncertainties, improving the longevity and sustainability of infrastructure investments.

Another vital element is contingency budgeting, which addresses the common issue of cost and schedule overruns in transport infrastructure projects (DE ABREU *et al.*, 2024a). During the contract award phase, a construction contingency budget is typically established to accommodate unplanned events, such as changes in project scope. This financial cushion allows projects to stay on track despite unexpected developments, as highlighted by Love *et al.* (2014) and Locatelli *et al.* (2017). The inclusion of this budget minimizes disruptions and ensures that project timelines and financial plans are better managed.

Lastly, public-private collaboration is essential for the successful execution of prioritized projects. The model encourages active collaboration between the public and private sectors, drawing on the strengths of both entities. Public-private partnerships allow for the pooling of knowledge, funding, and innovation, leading to more effective and efficient project implementation. By leveraging the expertise and resources of both sectors, infrastructure projects can be completed with greater speed, cost-efficiency, and innovation, ultimately contributing to the broader development of transport infrastructure systems.

The urgency of developing efficient and sustainable transport infrastructure, aligned with urban resilience to

natural disasters and climate change, is evident due to the increasing challenges posed by these phenomena (DE ABREU *et al*., 2022a; DOS SANTOS *et al*., 2024). Although initiatives such as the National Logistics Plan 2035 (PNL), developed by the Logistics Planning Company (EPL), and the General Guide for Socioeconomic Cost-Benefit Analysis of Infrastructure Investment Projects, published by the Ministry of Economy, are valuable instruments, the need to create a robust and integrated action model goes beyond their scope.

The PNL provides strategic guidelines and projections for Brazil's logistical development, while the General Guide establishes technical and methodological criteria for assessing the socioeconomic feasibility of projects. However, these initiatives need to be complemented by an action model that systematically integrates sustainability and urban resilience aspects, ensuring that projects are planned not only to meet current demands but also to mitigate the future impacts of extreme climate events and promote more adaptable cities.

The development of an action model is crucial because it can bring together:

- Multisectoral Integration: Incorporating environmental, social, and economic variables for a holistic approach that the PNL and the Guide, individually, do not fully address.
- Preventive Planning: Focusing on resilience by considering future climate change scenarios, thereby reducing cities' vulnerability to natural disasters.
- Alignment with the 2030 Agenda: Prioritizing the Sustainable Development Goals (SDGs), especially those related to infrastructure, sustainability, and resilience.
- Local Focus: Customizing solutions to address the specific needs of each region or city, recognizing Brazil's significant geographical and socioeconomic diversity.

Thus, an efficient action model will enable existing instruments to be enhanced, transforming current planning and evaluation efforts into more effective public policies aligned with the contemporary demands of sustainable development and resilient urban areas (DE ABREU *et al*., 2024).

4. ATTENTION TO CRITICAL POINTS

A good transport infrastructure model must ensure efficient prioritization of projects, considering both their strategic importance and their economic impact and regional needs (BUENO, VASSALLO & CHEUNG, 2015; ZERJAV, MCARTHUR & EDKINS, 2021). The optimized allocation of resources is key to ensuring the successful execution of these projects, involving the effective management of financial, technological and human capital (PRUS & SIKORA, 2021). Estimating the economic impacts of transportation investment is a fundamental phase for the public policy process at all levels (HOLL, 2006). In addition, it is essential to identify and mitigate potential challenges in each project, integrating adaptation and risk management strategies from the outset of the decision-making process.

A statistical study conducted by Flyvbjer *et al*. (2004), for example, reveals important causes for cost increases in transportation infrastructure projects, based on a sample of 258 projects worth US$90 billion. It found that cost increases are significantly linked to the duration of the implementation phase, suggesting that delays can result in substantial costs. In addition, larger projects, especially bridges and tunnels, tend to face more significant cost increases. Surprisingly, public ownership is not necessarily more problematic compared to private ownership in containing cost increases; instead, the type of responsibility seems to be a more important factor. These findings have significant policy implications, highlighting the need to effectively manage the duration of the implementation phase and consider the type of liability in transportation infrastructure projects.

Aligned with national goals, the model should ensure that projects contribute to the country's broader development objectives, while involving all relevant stakeholders, including government bodies, the private sector and local communities, to ensure inclusiveness and acceptance (PRUS & SIKORA, 2021; DE ASSIS *et al*, 2022a; 2022b). In addition, the model should be designed with adaptability and scalability in mind, allowing for adjustments as circumstances change and for application at different government levels and geographical contexts (SANTOS *et al*., 2021; DE ABREU, SANTOS & MONTEIRO, 2022). It is also vital that the supporting model integrates data analysis, rigorous cost-benefit analysis, comprehensive risk assessments and scenario planning to provide a solid basis for informed decision-making and effective collaboration between the public and private sectors (DE ABREU, RIBEIRO & SANTOS, 2022).

In this regard, Rokicki & Ostaszewski (2022) presented an innovative methodology based on the modified actuarial credibility approach. This approach

makes it possible to adjust initial cost estimates for public infrastructure projects by taking into account the additional risk/uncertainty factor. It therefore offers an interesting alternative to other existing forecasting methods. Through a real case application, the authors demonstrate that, despite its simplicity, the actuarial credibility approach can provide accurate cost estimates compared to more complex methods such as regression analysis (OLS) or machine learning (LASSO). In particular, they show that although forecast accuracy varies between different project categories, actuarial credibility outperforms other forecasting approaches in most cases. As a result, they argue that actuarial credibility should be considered as a relatively simple tool with very modest data requirements that can be easily applied by investors and policymakers to improve project planning and avoid cost overruns.

Policy decisions on investments in transport infrastructure often require an understanding of the welfare effects generated by the use of these infrastructures at a detailed regional level (BRÖCKER, KORZHENEVYCH & SCHÜRMANN, 2010; PRUS & SIKORA, 2021). This is because managing large-scale transportation infrastructure projects is difficult due to frequent misinformation about costs, which results in large cost overruns that often threaten the overall viability of the project (CANTARELLI *et al*., 2013).

In addition to the points mentioned above, it is crucial that a transportation infrastructure model also takes environmental and social sustainability into account (AMIRIL *et al*., 2014). This involves assessing the impact of projects on the environment as well as on local communities, ensuring the mitigation of any adverse effects and promoting practices that contribute to long-term sustainable development (GHAREHBAGHI, MCMANUS & ROBSON, 2019). The planning, construction and operation of transportation infrastructure are associated with a number of adverse effects on the environment. The Strategic Environmental Assessment (SEA) and the Environmental Impact Assessment (EIA) are important legal instruments of global environmental policy that make it possible to identify, predict, prevent and mitigate and/or compensate for these adverse effects (BRONIEWICZ & OGRODNIK, 2020).

Another fundamental aspect is technological innovation (RUDSKOY, ILIN & PROKHOROV, 2021). The model must be prepared to incorporate technological advances that can improve the efficiency, safety and sustainability of transportation systems. This includes not only established technologies such as electric vehicles, but also emerging solutions such as artificial intelligence for traffic management and autonomous transportation systems. In this way, the model becomes adaptable and resilient in the face of technological transformations, ensuring its long-term relevance and effectiveness.

In addition, resilience to extreme events and climate change is a critical factor to consider (WANG *et al*., 2020; DOMANESCHI *et al*., 2024). The model must ensure that infrastructure projects are designed taking into account the possible impacts of natural disasters and climate events, as well as population growth and urbanization patterns that may affect transport demand (DE ABREU *et al*., 2023b; SANTAMARIA-ARIZA *et al*., 2023). Adaptation can be defined as the process of adjusting the system to actual or expected climate change and its effects. These adjustments can be both structural, i.e. rigid adaptations, and political, educational and social, i.e. flexible adaptations (DE ABREU *et al*., 2023b).

In human systems, adaptation seeks to moderate or avoid damage or exploit beneficial opportunities (SUN, BOCCHINI & DAVISON, 2020). Adaptation measures should be linked to current and future risk reduction practices and management initiatives to increase transportation resilience and reduce the impacts of extreme weather events. In addition, these adaptation alternatives and solutions must be compatible with mitigation strategies (i.e. they need to have synergy) to avoid a drastic increase in GHG emissions (DE ABREU, SANTOS & MONTEIRO, 2022).

To further increase transparency and accountability, a series of comprehensive measures need to be implemented. This includes not only ensuring that decision-making processes are transparent and accessible, but also ensuring that relevant information is available in a clear and understandable way to the general public. In addition, it is essential to establish robust monitoring and evaluation mechanisms to track the performance and results of the policies and initiatives implemented.

This will not only allow for more effective accountability, but will also help to identify areas for improvement and take corrective action when necessary. In addition, it is important to promote a culture of responsibility, where decision-makers are held accountable for their actions and decisions, and citizens are encouraged and empowered to actively participate in the decision-making process at all levels. This will not only increase the trust and legitimacy of the model, but will also promote more inclusive and accountable governance, thus contributing to the well-being and progress of society as a whole.

5. FINAL CONSIDERATIONS

The development of an efficient, sustainable and resilient transportation infrastructure is crucial for the economic and social growth of any nation, and Brazil is no exception. This study proposed an innovative action model to prioritize projects within the country's complex transport infrastructure, considering not only financial viability, but also socio-economic and environmental impact. Throughout this research, significant challenges faced by transportation infrastructure projects were identified, including cost overruns, schedule delays and negative impacts on the environment and local communities. The model developed in this study seeks to address these challenges by offering a comprehensive framework that integrates multiple factors and considers sustainability at all stages of the decision-making process.

One of the main contributions of this study is the careful and participatory methodology adopted in developing the prioritization model. Involving key stakeholders from the outset of the process ensured that their concerns and perspectives were adequately considered, increasing the model's acceptance and effectiveness. In addition, the proposed model incorporates a number of key elements, such as comprehensive data analysis, risk assessment, scenario planning and public-private collaboration, which are fundamental to ensuring the effectiveness and long-term sustainability of transport infrastructure projects.

However, it is recognized that there are still challenges to overcome. Integrating technological innovations, adapting to climate change and ensuring transparency and accountability remain important areas of focus for future research and development. Ultimately, this study offers a significant contribution to advancing the field of transport infrastructure in Brazil by providing a holistic and action-oriented approach to prioritizing projects and promoting the sustainable development of the country's transport system. It is hoped that this model can serve as a valuable guide for decision-makers, academic institutions and other stakeholders in the field, helping to shape a more resilient and equitable future for Brazil's transportation infrastructure.

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