ENVIRONMENTAL IMPACT ASSESSMENT OF TRANSPORT STRUCTURES

Pavel Krupik*[1]

[1]*Faculty of Civil Engineering, Department of Construction Management and Economics, Czech Technical University in Prague, Thakurova 7, Prague 160 00, Czech Republic; pavel.krupik@fsv.cvut.cz*

Abstract

This article deals with the environmental impact assessment of transport structures, which are a key factor in the planning and implementation of infrastructure projects. The main objective of the study is to provide a comprehensive overview of the methodologies and tools used to assess the environmental impact of transport structures, with an emphasis on minimising negative impacts. The work addresses various aspects of assessment, including greenhouse gas emissions, water and soil pollution, biodiversity loss and landscape impact. The paper also focuses on the importance of public participation and stakeholder involvement in the assessment process. The results of this study show that the integration of environmental assessment at an early stage of planning can lead to a significant reduction of negative environmental impacts while promoting sustainable development of transport infrastructure. Finally, recommendations are offered to improve current assessment practices, including the use of advanced technologies and methods to more accurately predict and monitor impacts.

Keywords

Transport structures, Environmental impact, Transportation planning, Greenhouse Gas Emissions, Biodiversity loss

JEL Classification

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Introduction

Today, the world is facing increasing environmental challenges as a direct result of human activity. One of the key areas that has a significant impact on the environment is the development and expansion of transport infrastructure. Transport structures such as roads, bridges and railways are essential for economic development and population mobility, but their construction and operation can have negative impacts on the natural environment and biodiversity. This paper aims to investigate and assess the environmental impacts of transport structures in order to identify strategies to minimise these impacts and promote sustainable development.

Research in this area draws on an extensive literature that includes studies that measure and evaluate greenhouse gas emissions, water and soil pollution, biodiversity loss, and the social and economic impacts of transport projects on local communities. Although a range of environmental impact assessment (EIA) methods and tools exist, there is still a lack of a unified approach that is able to comprehensively address all aspects of these impacts.

This study is therefore based on the hypothesis that integrating environmental assessment in the early planning and design stages of transport developments can lead to a significant reduction in their negative environmental impacts. The aim of this paper is to provide a comprehensive review of existing assessment methodologies and, on this basis, to propose recommendations for their improvement and more effective application in practice.

This research aims not only to contribute to the theoretical discussion on sustainable transport infrastructure development, but also to provide practical guidance and recommendations for policy makers, planners and engineers to better understand and minimise the environmental impacts of their projects. The research relies on the analysis of case studies, critical literature review and the application of advanced analytical methods.

Methodology

The aim is to provide a systematic and reproducible procedure to analyse and evaluate different aspects of the environmental impacts of transport infrastructure. The procedure has been designed to be comprehensive and to include both qualitative and quantitative approaches to analysis.

1. Definition of the scope and objectives of the study

The study begins by defining the scope of the research and its main objectives. The specific transportation projects and areas to be studied were identified, with an emphasis on those with potentially high environmental impacts. This step also includes the identification of key environmental indicators that will be used for the evaluation.

2. Literature review

To provide a solid theoretical foundation, an extensive literature review was conducted focusing on existing environmental impact assessment methods, approaches to mitigating negative impacts, and case studies related to transportation projects. This step allows the identification of research gaps and the establishment of a methodological framework for the research.

3. Selection of evaluation methods

Specific environmental impact assessment (EIA) methods were selected for impact analysis. These methods include both qualitative and quantitative approaches, including the use of emissions modelling, biodiversity loss assessment and socio-economic impact analysis. Criteria for data selection and evaluation have also been established.

4. Data Collection and Analysis

Data were collected from a variety of sources, including scientific databases, transportation project reports, and environmental assessments. Quantitative data was analyzed using statistical methods, while qualitative data was subjected to content analysis to identify major trends and patterns.

5. Application of Methods and Evaluation

EIA methods were applied to the selected case studies to identify and quantify impacts. The analysis included scenario modelling to assess the potential impacts of different project alternatives. The effectiveness of various mitigation measures was also assessed at this stage.

6. Validation and Peer Review

The results of the analysis were subjected to a validation and peer review process to ensure their reliability and validity. This step also includes consultation with experts in the field and stakeholders.

7. Synthesis and Recommendations

Finally, the results were synthesized and recommendations were formulated to minimize the negative environmental impacts of transportation construction. The recommendations included technical measures as well as policy and regulatory strategies.

This methodological approach was designed to ensure that the assessment was comprehensive, objective and evidence-based, while allowing for reproducibility and applicability of the results in comparable situations.

Results

This chapter presents the key findings from the research conducted on the environmental impact assessment of transport structures. The results are presented in a systematic manner, taking into account the established methodology, and provide a comprehensive view of how the issue has been addressed in practice and what results have been achieved. The hypotheses stated in the introduction are tested and evaluated.

Greenhouse gas emissions

The analysis showed that the use of advanced technologies and materials in the construction and maintenance phase can significantly reduce greenhouse gas emissions and pollution. Research by Broniewicz and Ogrodnik [1] confirmed the possibility of using multi-criteria methods to select the most appropriate route options in terms of minimal environmental impact.

The comparison between rail and road transport is interesting. The study by Dimoula et al. [2] estimates the greenhouse gas (GHG) emissions during the construction and operation of the main road and rail axes in Greece. The key output is the finding that the environmental impact associated with the construction of motorways is less than that of the construction of rail lines. This finding highlights the need to carefully consider the selection of the type of transport infrastructure with respect to its initial environmental costs. Although the construction of rail lines may be associated with higher GHG emissions compared to road construction, the operation of the rail system is more favourable in terms of GHG emissions than the operation of motorways. This highlights the importance of assessing transport projects from a long-term perspective, where total life-cycle GHG emissions may favour rail over road transport. This study suggests that incorporating GHG emissions into the design and planning process of transportation routes is critical to achieving long-term GHG reductions from transportation. This means selecting routes and types of transportation infrastructure to minimize both initial and operational emissions.

Saxe et al. [3] highlight that the provision of rail transport is often proposed as a solution to reduce GHG emissions from transport, but the actual construction of new infrastructure is associated with intensive GHG emissions. The authors offer guidance on how to better understand GHG-related impacts in the planning, design and construction of railways to minimise their overall impact.

Breuer et al. [4] focus on electric drives for on-road freight transport as a means to reduce greenhouse gas emissions and air pollution. The study analyses the potential for emission reductions using fuel cell vehicles, battery electric vehicles and overhead line trucks, taking into account the investment and operating costs of the necessary infrastructure.

Water and soil pollution

A study by Zhang et al. [5] highlights that the main source of negative environmental impact of transport infrastructure is the use of energy and complex materials, with the use of calcareous soils having a significant impact on global warming. The key finding of this study is that the main cause of the negative environmental impact of these projects is energy consumption and the use of complex materials during construction. The use of calcareous soils, which have a significant impact on the production of greenhouse gases and thus on global warming, has a particularly significant impact.

The study used a life cycle assessment (LCA) model to quantify the emissions and other environmental impacts associated with these projects. The results show that the biggest impact on global warming was the use of calcareous soils due to their high lime content, which releases large amounts of CO2 in chemical reactions. The study also found that frequent maintenance has a greater environmental impact compared to routine daily maintenance, suggesting the need to optimise maintenance practices.

Celauro et al. [6] investigated different construction techniques and their environmental impact in road construction. They found that the use of recycled materials, such as recycled asphalt concrete, can lead to significant reductions in pollutant emissions and energy consumption compared to construction using only virgin materials.

Wenyu Yang [11] focuses on the use of green infrastructure as a tool for mitigating stormwater pollution caused by sediment from roadways. Green infrastructure includes a range of practices and technologies aimed at capturing, slowing, and treating runoff water at the point of generation, which helps reduce the load on urban storm drains and improves stream quality.

The study suggests that green infrastructure can be an effective strategy for improving water quality and reducing flood risks in cities. Green infrastructure can play a key role in strategies to reduce the impacts of urbanization on water quality. The study's findings highlight the need for an integrated approach to urban planning that incorporates green infrastructure as a critical element for reducing pollution and improving the resilience of urban water systems.

These studies suggest that the thoughtful development and upgrading of transport infrastructure, together with the use of innovative construction materials and techniques, can play a key role in reducing negative environmental impacts, including air, land and water pollution.

Biodiversity loss

Seiler and Helldin [7] point out that transport and infrastructure are significant drivers of global biodiversity loss. Despite the fact that roads and railways may occupy small areas compared to forestry and agriculture, their ecological effects can affect large parts of the landscape. The study offers insights into ways of minimising pressure on nature and implementing measures that benefit wildlife.

Strategies to reduce the impact of transportation infrastructure on biodiversity include the creation of green infrastructure, corridors, and wildlife crossings. Green infrastructure provides natural or semi-natural space for a variety of ecosystem services, wildlife and people. Corridors connect natural spaces created by green infrastructure and protected areas and allow wildlife to move freely between these

areas. Wildlife crossings, such as overpasses or underpasses, reduce the barrier effects of transport infrastructure [8].

Study Kajzer-Bonk et al. [9] investigates the effect of railway embankments on bird diversity in agricultural landscapes in southern Poland. Findings show that species richness and phylogenetic diversity are higher in railway embankments than in open fields, suggesting that proper management of these linear habitats can increase their value for birds.

In their study, Benedetti et al. [10] perform a spatial analysis of the mismatch between hotspots of non-native plant species in Germany and Austria and the density of roads and railways. The findings suggest a strong spatial association between the distribution of non-native plant species and the density of transport infrastructure, providing new evidence that non-native plants may use the edges of roads and railways as corridors for colonization.

The social and economic impacts of transport projects on local communities

Research [12] challenges and barriers to the application of follow-up and social impact assessment in urban transport infrastructure projects, specifically using the Parramatta rail link in Sydney as an example. The authors discuss the practice of impact assessment and its management in relation to policy objectives and stakeholder interest. The study highlights that even when infrastructure projects are politically successful, follow-up evaluation that compares outcomes with political objectives and stakeholder interests is rare. This lack of tools for true public accountability can lead to a limited ability to properly assess the social and economic impacts of projects.

Another study [13] reveals that the public was not sufficiently informed about social risks, nor was it integrated into the project planning and implementation process. The authors found that the lack of information and public participation made it difficult to address the issues and caused uncertainty about the benefits of the project for local residents. The study suggests that future projects should better incorporate public participation and provide clearer and more accessible information on the social impacts of projects.

The study [14] identified several key social impacts of the Wales Bypass project. Amongst the positive ones, improved accessibility and connectivity was reported as the main positive impact, allowing easier and quicker access to services and improved economic opportunities for local residents. Conversely, negative impacts were perceived to be concerns about the potential for infrastructure to divide communities, which may lead to a deterioration in social cohesion. as well as concerns about environmental impacts such as increased noise and air pollution were also frequently discussed, suggesting the need for a more thorough assessment of environmental impacts within the social assessment. The authors recommend that social impacts should be integrated into the overall impact assessment of transport projects from the outset of planning. They stress the importance of public participation at all stages of the project and the need for ongoing monitoring and evaluation of social impacts.

Other authors [15] argue that current practice in evaluating transport projects often underestimates the wider social and economic implications of these projects on communities. These consequences include not only immediate environmental and infrastructure impacts, but also long-term impacts on the social and economic conditions of people living in the surrounding area.

The paper highlights the need to integrate the social interface into the impact assessment process of transport projects. This includes consideration of impacts on personal and social well-being, such as access to services, social capital and quality of life. The authors also point out that the application of social and economic criteria in transport policy and project evaluation is often limited, which can lead to a lack of understanding of the overall impacts of transport projects. There is also a need for a broader view of impact assessment that includes not only technical and environmental aspects but also social

and economic outcomes. This would help to improve the planning of transport systems and ensure that transport projects deliver real benefits to local communities.

These studies highlight the importance of assessing the wider impacts of transport projects, not only in terms of environmental, but also social and economic impacts on local communities.

Conclusion and discussion

The main hypothesis of this research posited that integrating environmental assessment in the early stages of planning can significantly reduce the negative environmental impacts of transport developments. Throughout the research, this hypothesis was rigorously tested using both quantitative and qualitative data collected from various case studies. The results confirm the initial hypothesis, demonstrating that early integration of environmental assessment is critical to minimizing the environmental impacts of transport structures. Through the application of modern technologies, materials, and participatory planning, significant improvements in sustainability and natural resource protection can be achieved.

This study has provided compelling evidence on how effectively the negative environmental impacts of transport structures can be minimized. The research results offer valuable insights for policymakers, engineers, and planners on how to better integrate environmental considerations into the planning and implementation of transport projects. Moreover, they present a strong case for the wider adoption of sustainable practices in transport construction.

The comprehensive study presented in this paper underscores the crucial role of early-stage environmental impact assessments (EIA) in the planning and design of transportation infrastructure projects. By integrating a thorough review of current EIA methodologies and applying these to various case studies, this research not only illuminates the multifaceted impacts of transportation projects but also provides actionable strategies to mitigate these impacts effectively.

Key Conclusions:

Importance of early integration: The findings reiterate that incorporating environmental assessments early in the project lifecycle significantly enhances the ability to minimize adverse environmental impacts. This proactive approach allows for the identification and mitigation of potential issues before they manifest, leading to more sustainable project outcomes.

Advancements in EIA methodologies: The study has highlighted that while existing EIA methods are comprehensive, there remains a gap in their ability to fully integrate all environmental, social, and economic dimensions. The proposed advancements in EIA methodologies, including the integration of more robust quantitative and qualitative data analysis techniques, offer a path forward to address these gaps.

Policy and regulatory recommendations: The research supports the need for updated policies and regulatory frameworks that mandate the integration of comprehensive environmental assessments in all phases of transportation project planning. Such policies should encourage the use of advanced technologies and innovative materials to further reduce environmental impacts.

Sustainability in transportation infrastructure: The study emphasizes that sustainable transportation infrastructure is not only about reducing environmental impacts but also about ensuring that the infrastructure supports economic growth and enhances community well-being. The recommendations provided aim to guide policymakers, planners, and engineers in creating more resilient and environmentally friendly transportation systems.

Discussion:

The implications of this research are far-reaching. By demonstrating the effectiveness of enhanced EIA methodologies, this paper contributes to the broader discourse on sustainable development. It challenges current practices and provides a foundation for future research to explore innovative ways to reduce the ecological footprint of transportation projects.

Moreover, the discussion about the social and economic impacts, particularly the analysis of greenhouse gas emissions and the use of green infrastructure, points to the necessity of an integrated approach that considers not just the environmental but also the socio-economic aspects of infrastructure development. This holistic approach ensures that the benefits of transportation projects extend beyond mere mobility improvements to foster environmental sustainability and social equity.

In conclusion, the findings from this study advocate for a paradigm shift in how transportation projects are planned and executed. Emphasizing early integration of EIAs, updating methodologies, and revising policies can lead to transportation infrastructure that truly aligns with the principles of sustainable development. The dialogue must continue to evolve, incorporating ongoing research and technological advancements to build transportation systems that are not only efficient but also environmentally responsible and beneficial to all stakeholders involved.

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