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Sustainable Transport and Selected Environmental Assessment Tools

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Małgorzata Mrozik[1], Agnieszka Merkisz-Guranowska[2]

Abstract:

Purpose: *The main purpose of this article is to analyse the role of environmental assessment tools in the context of sustainable transport development. The paper aims to identify the most relevant and widely used tools and methods that support the integration of environmental considerations into transport planning and decision-making processes.*
Design/Methodology/Approach: *The study is based on a critical review of literature and selected case studies illustrating the application of environmental assessment tools in transport. The article presents a structured classification of the most relevant tools and their planning-level applications.*
Findings: *Although numerous tools are available, their application in transport remains fragmented and often limited to procedural compliance. Strengthening their integration can improve the sustainability and transparency of planning processes.*
Practical implications: *The article provides a knowledge base for planners, policymakers, and stakeholders seeking to improve environmental performance in transport systems. It highlights the importance of early-stage environmental assessment in reducing long-term costs and mitigating environmental impacts. The findings can guide the development of better regulatory frameworks and planning practices.*
Originality/value: *This study presents a comprehensive classification and evaluation of environmental assessment tools specifically in the context of transport. It emphasizes the need for systemic integration of assessment methods into planning rather than treating them as formalities. The article also outlines future directions in digitization and data-driven assessments.*

Keywords: *Sustainable transport, environmental assessment, life cycle assessment, LCA, EIA, SEA, planning tools, transport policy.*

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[1]*West Pomeranian University of Technology in Szczecin, Poland, ORCID 0000-0001-8074-1113, e-mail: malgorzata.mrozik@zut.edu.pl;*
[2]*Poznan University of Technology, Poland, ORCID 0000-0003-2039-1806, e-mail: agnieszka.merkisz-guranowska@put.poznan.pl;*

1. Introduction

In the face of escalating environmental challenges and global climate commitments, the transport sector has come under increasing scrutiny for its environmental footprint. Transport is one of the largest contributors to greenhouse gas emissions globally, accounting for nearly one-quarter of direct CO_2 emissions from fuel combustion (UNECE, 2025).

Additionally, it generates a range of negative externalities, including air and noise pollution, land use conflicts, and resource depletion. These impacts highlight the urgent need to transition towards more sustainable transport systems that minimize environmental harm while maintaining accessibility and efficiency.

Sustainable transport, as a concept, encompasses more than just reducing emissions. It involves an integrated approach that considers environmental, social, and economic dimensions, aiming to meet current mobility needs without compromising the ability of future generations to meet theirs. Achieving this balance requires not only technological innovation and infrastructure transformation but also the application of robust evaluation frameworks to guide policy and investment decisions.

Environmental assessment tools play a critical role in this context. They offer structured methods for analyzing, quantifying, and forecasting the environmental impacts of transport systems, plans, and projects. These tools – ranging from strategic assessments and project-based evaluations to life cycle and carbon footprint analyses – provide essential support for evidence-based decision-making and regulatory compliance.

Despite their proven utility, the application of environmental assessment tools in the transport sector remains uneven and, in many cases, underutilized. This is particularly true in the early planning stages, where their integration could maximize environmental benefits and avoid costly revisions at later stages. Furthermore, the increasing complexity of transport systems, especially in urban areas, necessitates more comprehensive, integrated, and dynamic evaluation approaches.

This article aims to examine the relationship between sustainable transport objectives and selected environmental assessment tools. It begins by outlining the theoretical foundations of sustainable transport and environmental evaluation.

Then, it reviews and classifies key tools currently applied in transport planning and operations. Particular attention is given to the role of Life Cycle Assessment (LCA), Environmental Impact Assessment (EIA), and carbon footprint analysis.

2. Theoretical Background

2.1. The Concept of Sustainable Transport

Sustainable transport is an approach that combines environmental responsibility with the goal of providing efficient, safe, and accessible mobility for all users. Its primary aim is to reduce the negative impact of transportation on the environment while maintaining the effectiveness of transport systems. This concept involves integrating various modes of transport – both public and non-motorized – and implementing modern technologies based on clean energy. As a result, it becomes possible to reduce greenhouse gas emissions, limit air pollution, and improve the quality of life in urban areas (Faulin *et al.,* 2019).

One of the key features of sustainable transport is minimizing its environmental footprint. This includes the adoption of cleaner technologies, the promotion of low-emission modes of transport, and the efficient management of natural resources (Faulin *et al.,* 2019). Equally important is the development of intermodal systems that combine different modes of transportation – such as Mass Rapid Transit (MRT), bus services, and non-motorized options like walking and cycling – into a coherent and efficient network (Setiyo, 2023).

However, the implementation of sustainable transport systems faces several challenges. One of the most significant is related to infrastructure needs. Transitioning to greener solutions requires substantial investment in new technologies and in the development of infrastructure that supports low-emission vehicles and renewable energy sources. Public education and increased awareness are also essential, as they play a key role in encouraging the acceptance and widespread use of sustainable transport practices (Setiyo, 2023).

Another important aspect is the need for appropriate political support and the adaptation of economic models. Effective implementation of sustainable transport solutions depends on the development of public policies that account for the external costs of traditional transport modes, such as environmental degradation, noise, and road congestion (David and Fistung, 2020). Without the engagement of governmental and local institutions, and without a systemic approach to funding and regulation, transforming transport systems may prove to be difficult.

Although sustainable transport offers numerous benefits – both environmental and social – its development requires coordinated action and long-term commitment. The creation of comprehensive transport policy frameworks is crucial to support the adoption of innovative solutions and to promote active public participation. Only through such integrated efforts can sustainable practices in the transport sector be successfully implemented and maintained (Ramani and Zietsman, 2016).

2.2 The Role of Environmental Assessment in Transport

Environmental assessment tools used in the transport sector can be categorized into several main groups that differ in scope, purpose, and application stage within the life cycle of a project or policy. The most important include Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA), Life Cycle Assessment (LCA), carbon footprint analysis, and indicator-based systems. Each tool serves a different function and is applied at distinct phases of planning or decision-making.

Strategic Environmental Assessment primarily applies to planning documents and transport development programs, such as mobility strategies or spatial development plans. Its purpose is to identify potential environmental impacts before implementing strategic-level decisions (UNECE, 1991).

In contrast, Environmental Impact Assessment is used at the project level and focuses on analyzing specific environmental consequences, such as noise, air pollution, or habitat fragmentation, related to the construction of roads, railways, or terminals (Maibach *et al.,* 2008).

At the stage of technology selection, Life Cycle Assessment becomes particularly relevant. It allows for a comprehensive evaluation of a product or system's environmental impact from raw material extraction, through production and operation, to end-of-life disposal (Finnveden *et al.,* 2009). LCA is especially valuable when comparing different transport modes or technologies, such as electric versus combustion engine vehicles, by considering both direct and indirect emissions.

A useful complement to LCA is the increasingly popular carbon footprint analysis, valued for its simplicity and focus on greenhouse gas emissions (Instytut Ochrony Środowiska, 2020). This method is particularly useful for urban transport system management and for planning emission reductions in line with climate targets (Banister, 2008).

Another important category includes indicator-based tools, which support the monitoring of sustainable transport policy implementation. These tools typically rely on sets of indicators (e.g., Key Performance Indicators, City Sustainable Transport Index) that measure variables such as emissions per capita, public transport modal share, bicycle lane density, or traffic congestion levels (Kiba-Janiak and Witkowski, 2019). This approach enables benchmarking between cities or regions and helps inform local decision-making.

The tools differ significantly in their technical complexity. Some, like EIA, require spatial analysis and simulations, while others like basic carbon footprint calculations are relatively simple and can be based on publicly available data (Zięba, 2021).

The role of digital tools is growing, particularly those that integrate multiple methods (e.g., GIS models with environmental and energy databases), enhancing usability and accessibility.

The appropriate choice of assessment tool depends on project scale, data availability, assessment objectives, and technical capacity. In practice, hybrid approaches are increasingly common, for example, combining LCA with external cost analysis or quality-of-life indicators (Janic, 2007). Integrating these tools into transport planning processes is essential to achieving sustainable development goals and minimizing the environmental impact of mobility systems.

2.3 International and Regulatory Frameworks

The development and application of environmental assessment tools in the transport sector are strongly rooted in international and regulatory frameworks established at both the European Union and United Nations levels. One of the most important documents in this regard is the Espoo Convention (UNECE, 1991), which mandates environmental impact assessment (EIA) for projects likely to have significant transboundary environmental effects. This convention laid the foundation for subsequent environmental regulations and has been ratified by many countries, including EU Member States.

At the European Union level, two key legal acts are the Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (EIA Directive) and the Directive 2001/42/EC on the assessment of the effects of certain plans and programs on the environment (SEA Directive). These directives have been transposed into national legislation and form the legal basis for environmental assessments at both the project and planning levels (Maibach *et al.,* 2008).

Equally important are regulations related to climate policy, such as the European Green Deal, which sets ambitious targets for greenhouse gas emission reductions by 2050. According to this policy, the transport sector must play a critical role in achieving climate neutrality, requiring the implementation of tools such as carbon footprint analysis and LCA in mobility planning (European Commission, 2019).

At the global level, the United Nations Sustainable Development Goals (SDGs) provide another layer of governance, particularly Goal 11 (“Sustainable Cities and Communities”) and Goal 13 (“Climate Action”), which directly refer to sustainable transport (United Nations, 2025). International organizations such as UNEP and WHO also publish guidelines on the environmental and health impacts of transport, including air quality, noise, and road safety (WHO, 2018).

At the regional and national levels, legal frameworks increasingly mandate the use of environmental indicators and emission analysis. In Poland, for example, SEA and

EIA are required under the Environmental Protection Law and the Act on Sharing Information on the Environment (Zięba, 2021). Additionally, the growing importance of ESG reporting has led many transport operators and infrastructure developers to integrate environmental assessment tools into their management practices.

In recent years, sectoral guidelines and good practice manuals issued by organizations such as IRU, UITP, and the OECD have also become relevant. These documents assist in the practical implementation of environmental assessment in the transport industry (OECD, 2020). Altogether, these international and regulatory frameworks form a multi-level, increasingly integrated system that promotes environmental responsibility in transport planning and operations.

3. Overview and Classification of Environmental Assessment Tools

Environmental assessment is one of the most important components of the decision-making process in planning and implementing transport investments. Its main objective is to identify and analyze potential impacts on the natural, social, and economic environment. The contemporary approach to environmental management in the transport sector requires the use of various tools that enable the assessment of environmental impacts both at strategic and operational levels.

These tools must comply with current legal requirements but should also be effective in modeling, monitoring, and communicating assessment results. An important criterion for their selection is also the ability to integrate them with project management processes, transport policies, and environmental reporting systems.

In practice, the most commonly used tools include: Life Cycle Assessment, Environmental Impact Assessment, Strategic Environmental Assessment, Carbon Footprint analysis, emission monitoring, and sets of environmental indicators. Each of these tools has its specific features, advantages, and limitations, which influence their usefulness in various contexts of transport infrastructure planning and operation.

Life Cycle Assessment enables a comprehensive assessment of environmental impacts over the entire life cycle of a product, system, or process. It is a standardized tool (compliant with ISO 14040 and ISO 14044), which considers phases from raw material extraction, production, operation, to disposal.

This makes it possible to identify the most environmentally burdensome stages. However, its implementation requires access to detailed input data and specialized expertise.

Environmental Impact Assessment is a mandatory tool for many infrastructure projects. Its main purpose is to assess the impact of a specific project on the natural and social environment. EIA has a legal and formal character and is a prerequisite for obtaining an environmental decision. Although it focuses on the design stage, it does not analyze the full life cycle of the investment.

Strategic Environmental Assessment, applies to planning documents and policies, such as transport development strategies or spatial planning documents. It allows for the assessment of environmental effects at the policy-making stage, which increases the likelihood of including environmental aspects in strategic and spatial planning.

The carbon footprint, as a simplified tool, focuses exclusively on greenhouse gas emissions, mainly CO_2. Its popularity is growing due to the simplicity of calculations and the high social relevance of climate emissions. It is increasingly used by public transport operators and in ESG reporting.

Sets of environmental indicators are used to monitor the state of the environment and the effects of implemented transport policies. They allow for trend analysis over time and interregional comparisons. Their advantage is relatively easy implementation, while the main disadvantage may be the limited depth of analysis.

In recent years, hybrid tools have emerged, combining elements of several methods, like LCA and carbon footprint, to obtain a more comprehensive assessment. Environmental assessment tools can be classified according to various criteria: level of application (strategic, tactical, operational), environmental scope (emissions, noise, energy use), complexity, and legal requirements. In practice, the choice of tool depends on the purpose of the assessment, data availability, financial resources, and the competencies of the project team.

Table 1 presents a comparative overview of five commonly used environmental assessment tools in transport.

Table 1. *Overview of selected environmental assessment tools in transport*

Tool	Scope of application	Advantages	Limitations
LCA (Life Cycle Assessment)	Assessment of the full life cycle of transport systems	Comprehensiveness, ISO compliance	High data requirements, computational complexity
EIA (Environmental Impact Assessment)	Assessment of infrastructure investments	Legal obligation, local analysis	Applies only to selected projects
SEA (Strategic Environmental Assessment)	Assessment of planning documents	Strategic approach, policy integration	Lacks technical detail
Carbon Footprint	CO_2 emissions analysis	Simplicity, communicative	Ignores other environmental

			aspects
Environmental Indicators	System monitoring	Ease of implementation, real-time data	Superficiality, data quality dependency

Source: *Authors' analysis.*

4. Integration of Environmental Assessment Tools Into Transport Planning Processes

The integration of environmental assessment tools into transport planning processes is becoming increasingly important in the face of challenges related to climate change, sustainable development, and obligations arising from EU and international policies. Tools such as LCA, EIA, and SEA enable a comprehensive analysis of the environmental consequences of actions undertaken already at the early stages of designing and planning transport investments (Finnveden *et al.,* 2003).

The implementation of these tools not only minimizes the negative impact of investments on the natural environment but also facilitates evidence-based decision-making and supports transparency and public participation. A well-conducted environmental assessment can also reduce the risk of project delays caused by social opposition or legal non-compliance (Glasson *et al.,* 2012).

One of the key aspects of integration is the appropriate timing of using environmental assessment tools. Practice shows that tools like SEA should be applied during the development of transport strategies and planning documents, whereas EIA is more suitable at the project level. LCA, in turn, is mainly used to analyze specific transport technologies and systems, for example, in comparing the environmental footprint of different vehicle types.

The literature emphasizes the need for an integrated approach to environmental assessment, which combines different methods and takes into account the broader socio-economic context (Pope *et al.,* 2004). Such integration allows for a better understanding of the interrelationships between transport policy and climate, health, and urban development goals.

A continuing challenge is the low level of environmental assessment tool usage in some countries and the lack of standardization in their application. In many cases, assessments are carried out in a fragmented way, and their results are not taken into account in subsequent decision-making processes. To improve this situation, it is necessary to provide training for planners, investors, and public administration, and to develop guidelines and digital tools to support the process.

The future of environmental assessment in transport lies in the development of digital platforms, scenario modeling, and integration with big data tools. Solutions are being implemented that allow for continuous environmental impact monitoring using IoT sensors and the integration of data with traffic management and spatial planning systems. This opens up new analytical and predictive possibilities (Zhou and He, 2020).

The effective integration of environmental assessment tools into transport planning requires a systemic approach, cross-sector cooperation, and solid institutional support. It is essential not only to develop methodologies and tools but also to foster a planning culture grounded in the principles of sustainable development and public good.

5. Conclusions

Contemporary transport systems are facing increasing pressure to reduce greenhouse gas emissions, improve air quality, protect natural resources, and minimize negative impacts on human health and ecosystems. The concept of sustainable transport, which integrates social, economic, and environmental needs, has emerged as a response to these challenges.

One of the key tools for implementing this concept is the use of environmental assessment methods, which allow for the systematic identification, analysis, and integration of environmental impacts at various stages of transport planning and project implementation.

This article has presented a variety of tools used to assess the environmental impacts of transport, both quantitative and qualitative in nature. Their characteristics, applications, strengths, and limitations have been discussed. The analysis highlighted the importance of integrating these tools within broader spatial planning strategies and public policy frameworks. Special attention was given to methods such as Life Cycle Assessment, Environmental Impact Assessment, Strategic Environmental Assessment, as well as indicator-based approaches.

The findings indicate that the effective implementation of environmental assessment tools in the transport sector requires several enabling conditions. First and foremost is a systemic approach that brings together multiple disciplines and engages stakeholders at all decision-making levels. Equally important is the standardization of methodologies, transparency of procedures, and broad access to data and decision-support tools. Education and awareness-raising among planners, policymakers, and the general public are also essential.

The integration of environmental assessment tools with transport planning processes not only helps reduce the negative environmental impacts of investments but also supports the development of more resilient, equitable, and future-oriented mobility systems. These tools contribute not only to technical evaluation but also to transparency, public participation, and institutional trust. In the long term, they can significantly enhance the effectiveness of climate policies, improve quality of life in urban and regional areas, and enable more efficient use of resources.

In conclusion, sustainable transport cannot be achieved without adequate analytical, methodological, and institutional support. Environmental assessment tools are an essential component of this support, and when properly applied, they can significantly enhance the effectiveness of actions aimed at sustainable development in the transport sector.

The future of these tools lies in their continued digitalization, integration with other management and planning systems, and adaptability to the rapidly changing social and technological landscape.

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