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Sustainable Transportation Management and Cyclist Safety Protection within the Normative Framework of Green Transportation Policy

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Abstract. Green transportation policy has increasingly been regarded as a cornerstone of urban mobility reform worldwide, yet its explicit orientation toward cyclist safety remains insufficiently developed. This paper examines how sustainable transportation management policies can be normatively designed to advance cyclist safety as a primary policy objective, not a secondary concern. Drawing on a qualitative literature review, the study explores the structural relationship between green transportation frameworks and the protection of cyclists within urban road systems. The discussion covers key policy dimensions including physical infrastructure standards, speed regulation, legal frameworks, public education, technological support systems, and inter-agency coordination. The study argues that a coherent policy architecture is essential for ensuring that the promotion of cycling as a low-emission mode is accompanied by robust safety provisions. Without this coherence, green transportation policy risks generating a structural contradiction between its environmental aspirations and its duty of care toward vulnerable road users. The findings affirm that cyclist safety and environmental sustainability are mutually reinforcing values that must be embedded together within any credible urban transportation governance framework.

Keywords: Cyclist Safety; Green Transportation Policy; Non-Motorized Transportation; Road Safety Governance; Sustainable Urban Mobility.

1. INTRODUCTION

A paradigm shift in the global urban transportation system has been taking place gradually but consistently over the past few decades. Various cities around the world are beginning to realize that excessive dependence on private motorized vehicles produces a number of detrimental consequences, both from environmental, economic, and quality of life aspects of their citizens (Gössling, 2020). Exhaust emissions produced by motorized vehicles have become one of the largest contributors to the degradation of air quality in urban areas. This condition prompts city planners, policymakers, and academics to seriously consider alternative modes of transportation that are more environmentally friendly and efficient (Şahin, 2023). Within this framework of thought, sustainable transportation then emerged as an approach that is considered capable of answering various systemic problems faced by modern cities in a more comprehensive and structured manner (Artemchuk, 2025).

Sustainable transportation is essentially an approach that places harmony between human mobility, environmental sustainability, and social justice as the main principles that cannot be separated from one another. This approach requires a fundamental reconfiguration of the way humans move within urban spaces, including the redistribution of street space that has been dominated by motorized vehicles. Green transportation policies arising from this approach include the development of renewable energy-based public transport, the construction of

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adequate pedestrian infrastructure, and the provision of cycling lanes that are safe and systematically connected (Papadakis et al., 2024). Each element in the sustainable transportation system is designed to reinforce one another, so that changes to one component will provide benefits felt broadly by all road users, including the most vulnerable groups.

Among the various modes of transportation developed within the framework of sustainable transportation, the bicycle occupies a strategic and significant position (Çiçek, 2025). The bicycle is a means of mobility that produces zero emissions, is efficient in space utilization, economically affordable, and provides direct health benefits for its users. Various progressive cities in the world have seriously developed cycling infrastructure as an integral part of their urban transportation systems. The development of bicycle lanes integrated with other modes of public transportation is considered one of the indicators of success for a sustainability-oriented transportation policy (Fomenko, 2024). The popularity of the bicycle as a daily mode of transportation continues to increase, along with the growing public awareness of the importance of an active and low-emission lifestyle in increasingly dense urban living (Wang, 2024).

The increase in bicycle use as a daily mode of transportation brings its own consequences that need to be examined critically and scientifically. When the volume of bicycle users increases on urban streets that are not yet fully prepared to accommodate their presence safely, the potential for accidents and injuries also increases (Naim & Felix, 2022). Cyclist safety becomes an issue that cannot be resolved partially, because it is closely related to the physical design of infrastructure, the behavior of other road users, the prevailing regulatory framework, and the quality of law enforcement in the field. This condition confirms that an increase in the number of bicycle users without being accompanied by the preparation of an adequate protection system can actually worsen safety risks (Naim & Felix, 2022). The growth of the cycling ecosystem must always go hand in hand with the strengthening of planned safety governance.

Green transportation policies developed by various countries and cities have quite significant diversity in terms of approaches, instruments, and the scope of their protection for cyclists (Dias et al., 2021). Some policies focus on the construction of physical infrastructure such as dedicated bicycle lanes, traffic signs that are responsive to the needs of cyclists, and secure bicycle parking areas. Others emphasize regulatory aspects and economic incentives, such as low-speed zone regulations, tax policies that favor bicycle users, and bicycle procurement subsidy programs (Caliari et al., 2018). However, not all of these policies explicitly place cyclist safety as a top priority. The gap between policy orientation toward

environmental sustainability on one hand, and safety protection for bicycle users on the other hand, is an issue that needs to be examined academically and systematically.

The fundamental problem surrounding cyclist safety within the framework of green transportation policy is closely related to the absence of an integrated safety perspective since the policy planning stage. Green transportation policies are often formulated with the primary goal of reducing carbon emissions and encouraging modal shifts from motorized vehicles to more environmentally friendly modes. However, during this formulation process, the safety dimension of the users who are precisely the targets of this modal shift is frequently neglected. Consequently, the infrastructure built does not always comply with adequate safety standards, the regulations established are not strong enough to protect cyclists from the risk of accidents, and public education programs on cycling safety have not developed as they should. This condition creates a serious gap between policy ambitions and the reality of protection received by cyclists in the field.

The safety of cyclists becomes increasingly complex when viewed from a broader transportation management perspective. Cross-sector coordination between spatial planning agencies, transportation departments, traffic police, and public health institutions still does not operate effectively in many urban systems. The absence of solid coordination causes cyclist safety policies to often be sectoral and fail to address the root of the problem. Technical standards for bicycle lane construction that vary from one region to another further worsen the consistency of protection received by cyclists (Martínez-Díaz & Arroyo, 2023). Moreover, the lack of a systematic monitoring and evaluation framework for cyclist safety policies makes it difficult to implement evidence-based improvements. This overall condition demonstrates that the issue of cyclist safety is not merely a technical problem, but rather a policy governance challenge that requires serious attention.

The importance of scientifically examining the relationship between green transportation policies and cyclist safety feels increasingly urgent today, especially given the ongoing acceleration of urbanization in various parts of the world. Rapid urban development exerts great pressure on urban transportation systems, where the presence of cyclists increasingly competes with motorized vehicles for limited space. Under such conditions, weak or misdirected policies will result in disproportionate risks for bicycle users. A normative study of green transportation policies and their implications for cyclist safety provides the necessary foundation to build a strong scientific argument to drive policy improvements. Without a solid research foundation, policy improvement efforts will only be reactive and non-systemic.

This study aims to outline normatively and conceptually how sustainable transportation management policies based on green transportation principles can be formulated in such a way that they substantially improve cyclist safety within the urban transportation ecosystem. This objective is achieved through a critical review of various policy frameworks, transportation management principles, and the normative implications arising from the relationship between sustainability orientation and the safety protection of bicycle users. Theoretically, this study contributes to the development of a conceptual framework that places cyclist safety as an integral element of green transportation policy, rather than as a supplementary addition. Practically, the results of this study are expected to serve as a reference for transportation policy planners in drafting regulations that are more responsive to the needs and vulnerabilities of cyclists in a systematic and sustainable manner.

2. RESEARCH METHOD

This study was conducted using a qualitative literature review approach, which is a research method that relies on written documents, scientific manuscripts, and various products of academic thought as its primary sources. This method was selected because the nature of the issue being examined is normative and conceptual, thereby requiring an analysis of various arguments, policy frameworks, and theoretical perspectives developing within scientific literature. Mohajan (2018) asserts that qualitative research provides ample space for researchers to understand the substance of an issue interpretively, paying attention to nuances of meaning that cannot be captured through a quantitative approach. In this study, this approach is applied to critically examine how green transportation policy frameworks position cyclist safety within their normative designs. All research materials were obtained from accountable scientific sources, including reputable journals, policy reports, and academic textbooks relevant to the topic being studied.

The process of collecting and processing the research materials was carried out systematically, taking into account the relevance, credibility, and novelty of the sources used (Prokopenko et al., 2025). As outlined by De Vaus and De Vaus (2013), document review-based research requires precision in determining source inclusion and exclusion criteria to ensure that the arguments built rest on a solid and academically accountable foundation. Each source used in this study was selected based on its suitability for the topics of sustainable transportation management and cyclist safety. These materials were then organized into major themes that reflect the argumentative flow of the study, ranging from green transportation policy frameworks and road safety management principles to the normative implications

resulting from the intersection of these two domains. In this manner, the study is able to present a structured and argumentative understanding of the problems defined in the problem formulation.

3. RESULTS AND DISCUSSION

Green transportation policies are essentially born from the need to restructure urban mobility systems that have long been dominated by the logic of motorized vehicles. These policies encompass various instruments designed to reduce the intensity of fossil fuel use within the transportation system, while simultaneously encouraging the public to shift to more energy-efficient and low-emission modes (Pojani & Stead, 2018). Within the normative framework underlying green transportation policies, the bicycle is positioned as one of the most environmentally friendly and affordable core components. However, what needs to be critically examined is that green transportation policies have not consistently integrated the dimension of cyclist safety into their policy designs (Biju, 2018). Safety is still frequently treated as a technical issue separate from the sustainability policy framework, even though both are an inseparable unit if the ultimate goal is to create a mobility system that is fair and safe for all road users (Yuan & Carey, 2020).

Sustainable transportation management has a much broader scope than just regulating traffic flow. It includes land-use planning that supports non-motorized accessibility, the establishment of infrastructure standards that protect vulnerable users, the development of inclusive mobility information systems, and the construction of regulatory frameworks that provide legal certainty for all road users (Uribe-Chavert et al., 2025). In a planned and systematic management approach, cyclist safety is not an additional output, but rather a success indicator that must be measured periodically. A transportation system that successfully encourages a modal shift from motorized vehicles to bicycles but fails to protect cyclists from the risk of accidents has not truly achieved the real objective of sustainability. A mature sustainable transportation management framework must position cyclist safety as an explicit goal that is planned, budgeted, and evaluated systematically.

Physical infrastructure is the first and most visible component in green transportation policies oriented toward cyclist safety. Bicycle lanes designed with strict safety standards, which include clear physical separation from the flow of motorized vehicles, constitute the most fundamental infrastructural element that must be available. This separation is not sufficient if it is merely a marking line on the asphalt, as normative evidence from various international policies demonstrates that structural separation—such as guardrails, surface

elevation differences, or the use of different materials—provides much more tangible protection (Normukhammadov, 2025). The geometric design of intersections is also a critical point in cyclist safety engineering, considering that most accidents involving cyclists occur at conflict points between bicycle flows and motorized vehicle flows. Designing intersections that accommodate the sightlines and reaction times of cyclists is part of the normative obligation of any transportation policy that claims to be environmentally friendly and pro-safety (Cantisani et al., 2019).

Motorized vehicle speed regulation is a policy instrument that has a strong normative correlation with the safety level of cyclists. Within the framework of green transportation policy, reducing maximum speeds in urban areas is not merely an environmental policy, but simultaneously a measurable road safety policy. Low-speed zones consistently produce safer interaction quality between motorized vehicles and soft-mode users such as cyclists and pedestrians (Jafari et al., 2025). Various jurisdictions in Europe, for instance, have established low-speed zones in residential areas and city centers as a common policy standard, rather than an exception. This normative approach indicates that speed regulation is not a standalone policy, but must be understood as part of a larger and integrated road user protection system (Karndacharuk & McTiernan, 2019).

Cycling safety education and awareness is a policy dimension that is frequently overlooked in discussions about sustainable transportation. Green transportation policies that prioritize the construction of physical infrastructure without being accompanied by adequate safety education programs tend to create hidden vulnerabilities for new cyclists who are not yet trained to face the dynamics of urban traffic. Cycling safety literacy programs include understanding safe riding etiquette on roads, the correct use of safety equipment, and recognition of the rights and responsibilities of cyclists as road users. Ideally, this education is designed gradually according to the age groups and experience levels of the users. A sustainability-oriented transportation policy has a normative responsibility to ensure that every user encouraged to shift to bicycles receives sufficient safety knowledge before they interact with complex traffic systems (Wachnicka et al., 2023).

The use of technology in sustainable transportation management systems opens up significant opportunities for improving cyclist safety. Intelligent traffic management systems capable of detecting the presence of cyclists and adaptively adjusting traffic signal durations are among the innovations implemented in various cities with advanced cycling policies (Che & Tian, 2024). Street lighting that is responsive to the presence of cyclists at night, navigation applications that provide safe routes for bicycle users, and early warning systems at dangerous

intersections are concrete examples of technological application within a policy-based safety framework. Normatively, this technology must be developed as a complement to, rather than a substitute for, adequate physical infrastructure. Excessive reliance on technological solutions without improving physical infrastructure will only produce illusory and uneven protection for all levels of bicycle users (Li et al., 2024).

The legal framework and regulatory enforcement are the foundations that determine the normative effectiveness of the entire cyclist safety policy. Without consistent law enforcement, no matter how good the infrastructure design is and no matter how sophisticated the applied technology is, non-compliant road user behavior will continue to create high risks for cyclists (Putra & Fakrulloh, 2025). Within the framework of green transportation policy, strengthening legal aspects includes the imposition of proportional sanctions for violations that endanger cyclists, the regulation of right-of-way priority for soft-mode users, as well as clear legal recognition of the existence of cyclists as equal road users. Effective law enforcement also requires adequate institutional capacity from the responsible authorities, including a good understanding of the interaction dynamics between motorized vehicles and bicycles in diverse urban environments (Putra & Fakrulloh, 2025).

The integration between green transportation policies and urban spatial planning is a normative prerequisite that often escapes attention. A city that designs a good cycling system but allows spatial development to be sprawling and unfriendly to pedestrians is essentially building an internal contradiction within its urban mobility policy (Colombo & Dijk, 2023). The integration of spatial planning and transportation requires that the development of residential, commercial, and public facility areas be carried out with due regard to safe and comfortable bicycle access. Standards for providing bicycle lanes must become part of development licensing requirements, rather than a voluntary addition. Zoning policies that support moderate density with layouts that support short trips by bicycle represent one of the most effective spatial planning instruments in supporting a safe cycling ecosystem (Schlossberg, 2022).

The social justice perspective in green transportation policy has direct implications for the safety of cyclists across various user groups (Pugliese et al., 2025). In many cases, bicycle users from low-income groups, women, the elderly, and people with disabilities face greater safety risks because they often use road corridors that lack supporting infrastructure. A socially just green transportation policy must ensure that the distribution of cycling safety infrastructure reaches all layers of urban areas, including peripheral areas and communities that historically have received less attention in transportation planning. Equalizing access to safe bicycle lanes

is not merely a matter of infrastructure equality, but is also a normative statement about the value of justice embraced by a public policy system (Cunha & Silva, 2022).

Coordination among stakeholders is a managerial element that strongly determines the implementation quality of cyclist safety policies within the framework of sustainable transportation. A well-designed policy that is managed without clear coordination between planning agencies, implementing bodies, and supervisory institutions will experience a significant degradation of quality in practice. This coordination includes the alignment of technical infrastructure standards, the unification of cross-institutional cyclist accident databases, and the development of feedback mechanisms that allow periodic policy evaluations based on normative facts (Mikušová et al., 2024). The success of cities recognized as pioneers in cyclist safety is generally underpinned by a strong institutional coordination structure, where there are no gaps in responsibility that allow safety issues to fall through without clear and structured management (Martínez-Díaz & Arroyo, 2023).

The dimension of culture and social behavior also helps determine the extent to which green transportation policies can provide tangible protection for cyclists. The prevailing social norms within a society regarding how to share road space, respect for other modes of transportation, and perceptions of cycling safety all interact with formal policies in shaping the reality of road safety. Policies that fail to take this cultural dimension into account tend to face resistance at the implementation level, as societies that do not yet possess a mature road-sharing culture will find it difficult to adapt their behavior based on regulation alone (Puhalsky, 2022). A careful policy approach must be able to combine regulative instruments with effective public communication programs, as well as actively involve cycling communities in the formulation and monitoring process of applicable safety policies.

Evaluation is a stage that is frequently overlooked in the sustainable transportation management cycle, even though it represents the most critical mechanism to ensure that cyclist safety goals are genuinely achieved. A good evaluation requires a clear indicator framework, encompassing output indicators such as the length of constructed bicycle lanes, outcome indicators such as changes in the volume of bicycle users, and impact indicators such as changes in the level of accident risks faced by cyclists (Mehdi, 2016). Without a structured evaluation system, cyclist safety policies will only become formal documents incapable of stimulating real improvements. An outcome-based evaluation approach adapted from modern public management provides a strong framework to assess whether the implemented green transportation policies have truly delivered measurable safety benefits for bicycle users.

International standards in road safety, as formulated in various global normative frameworks on road safety, provide a valuable reference for the development of cyclist safety policies at the local level (Kristianssen, 2022). The Vision Zero approach, which originated in Sweden and was subsequently adopted by various cities around the world, is the most influential example of the application of road safety standards that place the value of human life above all other considerations. Within this framework, any traffic accident resulting in death or serious injury is considered a system failure, rather than merely unavoidable bad luck. This normative approach holds highly significant relevance for cyclist safety policies, as it shifts the paradigm from risk management to risk elimination as the primary objective.

Designing cyclist safety policies that are responsive to user needs requires a careful understanding of cyclist travel characteristics across various types of urban environments (Reggiani et al., 2021). Bicycle trips in high-traffic density city centers require a different kind of protection compared to bicycle trips in quiet residential areas. Policies that utilize a one-size-fits-all approach tend to be suboptimal in providing adequate protection. Policy differentiation based on corridor characteristics, user types, and travel patterns is a planning principle that is more responsive and grounded in a realistic understanding of diverse cyclist needs. By taking this diversity into account, safety policies can be designed with greater precision and deliver more equitable benefits.

Comparative public policy perspectives offer highly useful insights for the development of cyclist safety frameworks within sustainable transportation. By examining how various policy systems in different countries respond to cyclist safety challenges, universal policy principles as well as contextual factors influencing successful implementation can be identified. A normative comparison between the Dutch approach, which places cyclists as a top priority in the road user hierarchy, and the approaches in countries that have only begun to develop their cycling systems, yields valuable lessons regarding policy sequencing and prioritization (McLeod et al., 2020). The purpose of such comparative studies is not to suggest blind imitation, but rather to identify underlying principles that can be contextually adapted according to local conditions.

Cyclist safety within the framework of green transportation policy is a multidimensional issue that requires an integrated policy approach (Schepers et al., 2014). A green transportation policy that is truly oriented toward cyclist safety must integrate elements of safe physical infrastructure, strict speed regulations, consistent law enforcement, programmed safety education, appropriate technological utilization, and structured evaluation frameworks into a coherent policy system. Cohesion among all these elements is not something that occurs

automatically, but is rather the result of a strong institutional commitment, visionary policy leadership, and effective coordination mechanisms among various stakeholders. By establishing this kind of cohesion, sustainable transportation policies will be capable of realizing a cycling ecosystem that is truly safe, equitable, and sustainable for all users.

4. CONCLUSION

The relationship between sustainable transportation management policies based on green transportation and cyclist safety is simultaneously normative, structural, and strategic. A green transportation policy designed without placing cyclist safety as an objective equal to environmental sustainability targets will result in a normatively flawed mobility system, because it encourages a modal shift to bicycles without providing adequate protection for its users. Conversely, when cyclist safety is treated as a core pillar within the architecture of green transportation policy, the resulting system will be capable of delivering urban mobility that is simultaneously environmentally friendly, socially efficient, and protective of the most vulnerable users. Achieving this condition requires integration between physical infrastructure, strong regulations, public education, supporting technology, as well as consistent policy evaluation based on road safety principles that are measurable and accountable.

Normatively, this study implies that transportation policy designers at various levels of government need to reformulate the priority frameworks within sustainable transportation policy documents, so that cyclist safety receives explicit recognition equal to emission reduction targets and the promotion of environmentally friendly modes. This reformulation is not sufficient if it is merely declarative; rather, it must be followed by the allocation of adequate budgets, binding technical standards, and clear accountability mechanisms for each agency responsible within the transportation management system. Academically, this study encourages future research to develop a more detailed conceptual framework regarding the normative integration between road safety policies and green transportation policies, including the development of policy assessment models capable of measuring the extent to which a sustainable transportation policy provides tangible and measurable protection for cyclists as a road user group in most need of systemic protection.

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