

Integrating Sustainable Transportation Modes: A Systematic Literature Review of Environmental Impacts

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Integrating Sustainable Transportation Modes: A Systematic Literature Review of Environmental Impacts

Mengintegrasikan Moda Transportasi Berkelanjutan: Tinjauan Literatur Sistematis tentang Dampak Lingkungan

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ABSTRACT

This research aims to investigate the impact of integrating sustainable transportation modes on greenhouse gas emissions, air pollution and environmental degradation in various geographic regions and levels of development. By systematically analyzing relevant literature, this research identifies the factors that influence the effectiveness of sustainable transport mode integration as well as the implications of these findings. Through a systematic literature review method, this research evaluates various studies that have been conducted previously to provide an in-depth understanding of how the integration of sustainable transportation modes can influence these environmental aspects. The analysis results show that the integration of sustainable transportation modes has a significant impact in reducing greenhouse gas emissions and air pollution, especially in urban areas and developed countries. However, significant challenges occur in rural areas and developing countries, where limited transport infrastructure and the habit of using private transport remain major obstacles. The implication of this research is the need for a contextually tailored approach in designing policies and strategies to promote the integration of sustainable transport modes, involving government, transport planning and the private sector.

Keywords: Integration of sustainable transportation modes, greenhouse gas emissions, air pollution, environmental degradation, geographical area, level of development.

ABSTRAK

Penelitian ini bertujuan untuk menyelidiki dampak integrasi moda transportasi berkelanjutan terhadap emisi gas rumah kaca, polusi udara, dan degradasi lingkungan di berbagai wilayah geografis dan tingkat pembangunan. Dengan menganalisis secara sistematis literatur yang relevan, penelitian ini mengidentifikasi faktor-faktor yang mempengaruhi efektivitas integrasi moda transportasi berkelanjutan serta implikasi dari temuan tersebut. Melalui metode tinjauan literatur sistematis, penelitian ini mengevaluasi berbagai studi yang telah dilakukan sebelumnya untuk memberikan pemahaman yang mendalam tentang bagaimana integrasi moda transportasi berkelanjutan dapat mempengaruhi aspek lingkungan tersebut. Hasil analisis menunjukkan bahwa integrasi moda transportasi berkelanjutan memiliki dampak yang signifikan dalam mengurangi emisi gas rumah kaca dan polusi udara, terutama di daerah perkotaan dan negara maju. Namun, tantangan yang signifikan terjadi di daerah pedesaan dan negara berkembang, di mana infrastruktur transportasi yang terbatas dan kebiasaan menggunakan transportasi pribadi masih menjadi hambatan utama. Implikasi dari penelitian ini adalah perlunya pendekatan yang disesuaikan secara kontekstual dalam merancang kebijakan dan strategi untuk mempromosikan integrasi moda transportasi berkelanjutan, dengan melibatkan pemerintah, perencanaan transportasi, dan sektor swasta.

Kata Kunci: Integrasi moda transportasi berkelanjutan, emisi gas rumah kaca, polusi udara, degradasi lingkungan, wilayah geografis, tingkat pembangunan.

1. Introduction

To effectively integrate sustainable transportation modes, it is crucial to consider various factors and strategies highlighted in the literature. Research emphasizes that individual

attitudes towards the environment and sustainable transport modes play a significant role in influencing daily travel behavior towards more sustainable options (Prillwitz & Barr, 2011). Universities can enhance sustainable transportation systems by implementing frameworks that promote the use of sustainable active modes of transportation within their campuses (Dehghanmogabadi & Hoşkara, 2018). Additionally, tools like multiple-criteria decision analysis models can assist freight transporters in selecting sustainable transportation modes for their shipments, contributing to overall sustainability (Fulzele et al., 2019).

In the context of universities, there is a common objective to promote and maximize the use of sustainable transportation modes while minimizing private car usage (Márquez et al., 2019). This aligns with the broader goal of sustainable transportation planning, which involves a shift towards more integrated solutions that encompass improved travel choices, economic incentives, institutional reforms, and technological innovations (Litman & Burwell, 2006). Furthermore, the development of sustainable integrated transit areas, as exemplified in the case of Gorontalo Province in Indonesia, aims to enhance transportation performance by efficiently integrating various modes (Lihawa, 2023).

Efforts to promote sustainable transportation extend beyond universities, with studies underscoring the need for greater integration between semi-public transport and sustainable modes like walking and cycling (Delgado et al., 2022). The implementation of alternative transport networks in university campuses and cities is influenced by various factors such as historical urban characteristics, socio-economic attributes, and sustainable policy frameworks (Pitsiava-Latinopoulou et al., 2013). Moreover, the efficiency of urban transport systems can be improved through the promotion and integration of sustainable transport modes, development of public transport networks, and the adoption of environmentally friendly fuel types (Makarova et al., 2021). In conclusion, integrating sustainable transportation modes necessitates a multifaceted approach that considers individual attitudes, institutional frameworks, urban characteristics, and policy priorities. By promoting the use of sustainable modes, enhancing transportation networks, and implementing comprehensive sustainable transportation plans, communities can progress towards more environmentally friendly and efficient transportation systems.

The introduction to this study highlights the growing climate crisis and the urgent need to adopt sustainable transport as a global response. The existing transportation system has been proven to be a major contributor to greenhouse gas emissions, air pollution, and environmental degradation. However, the emergence of sustainable transportation modes such as public transportation, cycling and electric vehicles provides hope as a potential solution to reduce these impacts. Despite increasing awareness of the importance of sustainable transport, there is still a lack of in-depth understanding of the cumulative impact of integrating sustainable transport modes across different regions and levels of development. This knowledge gap emphasizes the need for systematic research to examine the complex relationship between sustainable transportation integration and its impacts on greenhouse gas emissions, air pollution, and environmental degradation. This research aims to fill this knowledge gap through a systematic literature review that will analyze the cumulative impact of the integration of sustainable transport modes across various geographic contexts and levels of development. A clearly formulated and focused research question will be the basis for this research, with a focus on how the integration of sustainable transportation modes affects cumulative greenhouse gas emissions, air pollution and environmental degradation. It is hoped that the diversity of previous research and the contribution of this research aimed at answering these important questions will provide a better understanding of the importance of sustainable transportation for stakeholders such as governments, transportation planners, and the general public.

2. Research Methods

The research method that we apply in this study is a systematic literature review (SLR) which is designed to answer predetermined research questions. We chose this approach because of its proven ability to provide comprehensive and in-depth insights into a broad and complex topic such as the impact of integrating sustainable transport modes. In this process, we began by formulating clear and focused research questions to provide direction to our literature search. The search keywords we used included terms such as "sustainable transportation integration," "public transit," "cycling," "electric vehicles," and a variety of other related terms. The data collection process was carried out through access to various trusted academic databases such as Scopus, Web of Science, and Google Scholar. We observed strict inclusion criteria to ensure the relevance of the selected articles to our research topic, while also applying appropriate exclusion criteria to filter out articles that were irrelevant or did not fit within the scope of our research. After identifying articles that met the inclusion criteria, we proceeded with a data analysis process that involved extracting relevant information from each selected article. This analysis technique allows us to identify patterns, trends and key findings from the reviewed literature. As for reporting research results, we will adopt a structured report framework, following internationally recognized writing style guidelines for research reports in the social and environmental sciences. With this comprehensive methodological approach, we hope to provide a meaningful contribution to the understanding of the impact of integrating sustainable transportation modes for readers and relevant stakeholders.

3. Results and Discussion

3.1. Cumulative Impact in Various Regions

To address the impact of sustainable transportation on greenhouse gas emissions in urban, rural, and developing areas, it is crucial to consider the complexities and challenges associated with each setting. In urban areas, the integration of sustainable transport, such as efficient public transportation systems and reduced reliance on private cars, has the potential to significantly reduce greenhouse gas emissions (Hassouna, 2023). However, the effectiveness of sustainable transport in urban areas may be debated due to high population and vehicle density, which can offset the benefits of these initiatives (Dablanc & Ross, 2012).

In rural areas, challenges related to transport poverty, limited infrastructure, and connectivity issues further complicate efforts to implement sustainable transportation solutions (Velaga et al., 2012). Studies emphasize the importance of developing sustainable and flexible transport options to address the unique needs of rural communities and improve rural-urban connectivity (Bauchinger et al., 2021). Additionally, the role of employers in promoting sustainable mobility in rural areas has been highlighted as a key factor in reducing dependency on individual car ownership (Soder & Peer, 2017).

In developing areas, the impact of sustainable transportation on greenhouse gas emissions is crucial for mitigating environmental concerns. The need for efficient transportation networks and the prioritization of environmentally friendly transport options have gained significant attention in the scientific community (Mousavimasouleh et al., 2022). Furthermore, the integration of sustainable transport models into urban mobility planning is essential to overcome barriers and promote sustainable development (Okraszewska et al., 2018).

Overall, sustainable transportation plays a vital role in reducing greenhouse gas emissions across different types of areas. While urban areas may face challenges due to high population density, rural areas require tailored solutions to improve connectivity and accessibility. In developing areas, prioritizing sustainable transport options is essential for achieving environmental sustainability and reducing the carbon footprint of transportation systems.

Integrating sustainable transport modes in rural areas can have varying impacts based

on existing transport infrastructure and local travel patterns. While cycling and public transportation can effectively reduce greenhouse gas emissions, challenges like limited accessibility and long travel distances can hinder their adoption (Karjalainen & Juhola, 2019; Aderibigbe, 2022). In developing regions, the integration of sustainable transportation faces complexities due to factors such as inadequate infrastructure, low motorization levels, and financial constraints, which impede the widespread implementation of sustainable solutions (Labib et al., 2018).

Research findings align with these observations, indicating that integrating sustainable transport modes can indeed reduce greenhouse gas emissions in urban areas. However, studies also emphasize the intricate challenges associated with implementing sustainable solutions in rural and developing regions (Karjalainen & Juhola, 2019; Labib et al., 2018). This highlights the need for tailored approaches that consider the unique circumstances of each area to promote sustainable transportation effectively.

The literature underscores the importance of addressing these challenges to enhance the sustainability of transportation systems. By focusing on factors like accessibility, infrastructure development, and community needs, policymakers can work towards overcoming barriers to sustainable transport adoption in diverse settings (Karjalainen & Juhola, 2019; Labib et al., 2018). Moreover, by leveraging insights from previous research, decision-makers can develop strategies that account for the complexities and nuances of different regions, thereby fostering more effective and sustainable transportation solutions globally.

Factors influencing variations in impacts across regions when integrating sustainable transport modes and their effects on greenhouse gas emissions are multifaceted. Developed countries have shown success in reducing emissions through modes like public transport and cycling (Mashayekh et al., 2012). However, challenges like high mobility hinder further progress (Mashayekh et al., 2012). In developing nations, the impact varies based on local contexts; while public transport and cycling can reduce emissions, limited infrastructure and rapid growth pose obstacles (Mashayekh et al., 2012). Economic and financial development positively affect greenhouse gas emissions in developed and converging economies (Zioło et al., 2019). The diversity of emission drivers across European countries emphasizes the need to consider consumption patterns and trade for achieving climate goals (Perrier et al., 2019).

Understanding these dynamics is crucial for designing effective policies. Decision-making in passenger transportation should consider infrastructure and supply chains, not just tailpipe emissions (Chester & Horvath, 2009). Maintaining a balance between economic growth and environmental protection is essential for sustainable energy development (Brożyna et al., 2020). Research and development investments can reduce agricultural sector emissions in developing countries (Spada et al., 2019). Sustainable transportation assessments, like in the Palestinian bus sector, highlight deficiencies that need addressing (Hassouna, 2023). Strategic environmental assessments using data envelopment analysis can evaluate land transportation performance (Wang et al., 2022). In conclusion, integrating sustainable transport modes to reduce greenhouse gas emissions requires tailored approaches considering local characteristics, development levels, and available transport modes. Policy measures should address challenges specific to each region to maximize effectiveness in mitigating environmental impacts.

In developing countries, the integration of sustainable transportation modes faces significant challenges due to limited infrastructure, accessibility, and financial resources (Shafiei & Salim, 2014). Efforts such as implementing affordable public transport and promoting cycling have been made, but their impact remains limited, necessitating further actions. Research has shown a positive correlation between urbanization and CO₂ emissions from transportation in OECD countries (Shafiei & Salim, 2014). The effectiveness of sustainable transportation modes is influenced by factors such as transportation policies, existing infrastructure, and community

behavior, highlighting the importance of tailoring policies to local contexts for successful integration (Shafiei & Salim, 2014).

Studies have demonstrated a link between air pollution and adverse respiratory effects, underscoring the importance of addressing environmental concerns in transportation policies (Kocot, 2020). Furthermore, environmental protection measures like the Environmental Protection Tax Law in China have played a crucial role in mitigating air pollution issues (Hu et al., 2019). Additionally, while the health benefits of cycling and walking are well-known, the risks of air pollution can offset these benefits, necessitating a comprehensive approach to promoting active travel while addressing pollution concerns (Tainio et al., 2016). In conclusion, effectively addressing the challenges associated with sustainable transportation in developing countries requires a nuanced understanding of local contexts and the various factors influencing the success of such initiatives. By taking into account environmental impacts, health risks, and policy interventions, tailored strategies can be developed to promote sustainable transport effectively across different levels of development.

3.3 Comparison and Contrast

In analyzing the cumulative impact of integrating sustainable transport modes across different geographic regions and levels of development, it becomes evident that while the integration of sustainable transportation modes generally leads to a more positive outcome in reducing greenhouse gas emissions, air pollution, and environmental degradation in urban areas and developed countries, significant differences exist across various contexts (Bosworth et al., 2020). In urban areas and developed countries, the positive impact is often attributed to better infrastructure, increased accessibility to alternative transportation modes, and a higher level of environmental awareness (Bosworth et al., 2020). Conversely, in rural areas and developing countries, challenges such as limited infrastructure, financial constraints, traditional travel habits, lower environmental awareness, and higher mobility hinder the adoption of sustainable transport modes (Bosworth et al., 2020).

The implications of these findings underscore the necessity for the development of sustainable transport mode integration strategies that are responsive to the specific needs of each region (Bosworth et al., 2020). Contextual and adaptable policies are crucial to address the unique challenges faced in different areas, emphasizing the importance of a multidisciplinary and evidence-based approach involving stakeholders from government, civil society, and the private sector (Bosworth et al., 2020). Decision-makers can leverage these insights to design and implement effective and sustainable transportation strategies tailored to diverse geographic contexts and levels of development (Bosworth et al., 2020).

By considering the nuances in challenges and opportunities across regions, policymakers can craft strategies that not only promote sustainability but also account for the varying contexts in which these strategies will be implemented. This approach ensures that interventions are not only effective but also sensitive to the specific needs and constraints of different areas, ultimately leading to more successful and sustainable outcomes in the integration of sustainable transport modes.

3.4 Impact Mechanism

The integration of sustainable transportation modes plays a crucial role in mitigating greenhouse gas emissions, reducing air pollution, and minimizing environmental degradation. By promoting the use of public transport, cycling, and electric vehicles, these mechanisms contribute to a more efficient and cleaner energy utilization, ultimately leading to a decrease in emissions (Mashayekh et al., 2012). Electric vehicles, for instance, rely on electricity often generated from renewable sources, while cycling and public transport help in reducing the overall number of motorized vehicles on the roads, thereby lowering emissions (Mashayekh et al., 2012).

Furthermore, the adoption of sustainable transportation modes aids in environmental conservation by curbing air and noise pollution, which in turn enhances air quality and the overall environmental surroundings (Matar, 2023). Additionally, the development of green spaces like bicycle paths and sidewalks as part of sustainable transportation infrastructure not only improves the aesthetics of the environment but also enhances the quality of life for residents (Mashayekh et al., 2012).

Moreover, the shift towards sustainable transportation modes helps in reducing environmental degradation by lessening the demand for environmentally harmful transportation infrastructure such as toll roads and urban sprawls (Chatziioannou et al., 2020). By encouraging the use of public transport and cycling, sustainable infrastructure development can occur, leading to a reduction in negative environmental impacts and a reinforcement of natural ecosystem balance (Chatziioannou et al., 2020). In conclusion, understanding these underlying mechanisms is essential for designing effective policy measures that promote the widespread adoption of sustainable transport modes. By doing so, it is possible to bolster climate change mitigation efforts, reduce greenhouse gas emissions, combat air pollution, and safeguard the environment for future generations.

3.5 Factors Influencing Impact

Integrating sustainable transportation modes involves a complex interplay of various factors that collectively influence their cumulative impact. Transport policies and regulations are pivotal in shaping the direction and scale of sustainable transport integration, with support for public transportation, cycling infrastructure, and incentives for electric vehicles significantly enhancing positive outcomes (Tirachini & Cats, 2020). Moreover, the presence of environmentally friendly transport infrastructure, such as segregated bike lanes and integrated public transit systems, can effectively encourage the shift towards sustainable modes of transport (Levasseur et al., 2015).

Individual behavior and lifestyle choices also play a crucial role in determining the success of sustainable transport integration. Factors like public awareness of environmental issues, travel preferences, and habits directly impact the effectiveness of reducing greenhouse gas emissions and air pollution through sustainable transport modes (Shakibaei et al., 2021). Additionally, economic and social conditions, including financial accessibility, mobility needs, and income levels, influence the adoption and efficacy of sustainable transportation, highlighting the importance of addressing these aspects for successful integration (Zafri et al., 2022).

Furthermore, advancements in sustainable transportation technologies, such as electric vehicles and AI-based systems, contribute to enhancing the efficiency and attractiveness of sustainable transport options (Subhi, 2023). By comprehensively analyzing and understanding these multifaceted factors, policymakers can design effective strategies to promote sustainable transport integration that considers policies, infrastructure, community behavior, economic conditions, and technological advancements (Shen et al., 2023).

3.6 Challenges and Opportunities

To address the challenges in integrating sustainable transportation modes, various opportunities can be leveraged. Government intervention is crucial in formulating policies that support sustainable transport, such as investing in eco-friendly infrastructure, offering incentives for electric vehicle purchases, and implementing regulations to reduce private vehicle usage (Bamwesigye & Hlaváčková, 2019). Additionally, transport planners play a vital role in designing integrated and environmentally friendly transport systems while educating the public on the benefits of sustainable transport (Lee, 2020). The private sector can contribute by providing innovative and cost-effective sustainable transport solutions and supporting the development of technologies that facilitate the adoption of sustainable modes of transport

(AlKhani, 2020).

Furthermore, overcoming resistance to sustainable transportation requires addressing individual preferences and perceptions. This can be achieved through targeted awareness campaigns highlighting the comfort and safety of public transport and cycling, thus encouraging a shift in travel habits (Banister, 2007). Economic and social challenges, such as the high costs associated with electric vehicles and inequalities in access to sustainable transport, can be mitigated through financial mechanisms like subsidies and incentives to promote wider adoption across different social and economic groups (Xue et al., 2017). In conclusion, a multi-faceted approach involving government policies, public awareness campaigns, private sector innovation, and financial incentives is essential to overcome the challenges and promote the effective integration of sustainable transportation modes. By addressing these opportunities, it is possible to create a more sustainable and inclusive transportation system that benefits both the environment and society as a whole.

To address the challenges associated with integrating sustainable transport modes and enhancing the sustainability of transport systems, collaboration among governments, transport planners, and the private sector is crucial. Governments should lead by formulating progressive policies and implementing regulations that promote sustainable transport (Wang et al., 2018). Transport planners play a vital role in designing infrastructure that supports sustainable transport use (Steg & Gifford, 2005). The private sector can contribute by providing innovative technology solutions and transport services to enhance sustainability (Fang et al., 2022).

Research emphasizes the significance of corporate values and culture management capabilities in promoting sustainable development of transport infrastructure enterprises at economic and low-carbon levels (DeAlba-Martinez et al., 2020). Additionally, the loosely coupled nature of transportation systems poses challenges for sustainable freight transportation, creating resistance to change and hindering sustainability efforts (Badassa et al., 2020). Collaboration among stakeholders is essential to create a supportive environment for the broader integration of sustainable transportation modes. By working together, governments, transport planners, and the private sector can drive the adoption of sustainable transport practices, leading to more efficient and environmentally friendly transport systems.

4. Conclusion

In this study, researchers have investigated the impact of integrating sustainable transportation modes on greenhouse gas emissions, air pollution, and environmental degradation in various regions and levels of development. Based on the research results, it can be concluded that the integration of sustainable transportation modes has great potential to reduce greenhouse gas emissions and air pollution, especially in urban areas and developed countries. However, significant challenges occur in rural areas and developing countries, where limited infrastructure, reliance on private transportation, and lack of environmental awareness are major obstacles.

The implication of these findings is the need for a contextually tailored approach in designing policies and strategies to promote the integration of sustainable transport modes. Governments, transport planners and the private sector can play a crucial role in addressing these challenges and seizing opportunities to advance the sustainable transport agenda. However, it is important to remember that each region has its own unique needs and conditions, so successful strategies must be sensitive to the local context.

Limitations of this research include the limitations of the data and methodology used. Additionally, researchers' analyzes may not include all factors influencing the impact of sustainable transportation mode integration. Therefore, future research can further investigate these factors and develop a more holistic approach to overcome the challenges in realizing sustainable transportation. Thus, future research is expected to provide deeper insights and more effective solutions in promoting the integration of sustainable transport modes

worldwide.

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