

SUSTAINABLE URBAN TRANSPORT IN THE FACE OF RAPID MOTORIZATION: A MULTI-FACETED APPROACH TO REDUCING ENERGY CONSUMPTION AND CO₂ EMISSIONS⁶

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Abstract: *The report provides a comprehensive analysis of the challenges and opportunities to reduce energy consumption and CO₂ emissions in the urban passenger transport sector. A wide range of approaches are covered, such as vehicle efficiency improvements and alternative fuels, creating infrastructure for mass transit and non-motorized transport, implementing policy interventions to manage demand and land-use planning to build compact cities focused on the transit. The analysis uses a range of case studies from both developed and developing cities, highlighting the varying efficacy and viability of different approaches based on the particular urban environment and phase of development. The results highlight the vital need for a comprehensive and diverse planning strategy for sustainable urban transport that includes not only technological measures, but also legislative measures and changes in population behaviour.*

Keywords: *Sustainable Urban Transport, Mass Transit, CO₂ Emissions Mitigation, Energy Efficiency, Policy Interventions, Behavioral Change*

INTRODUCTION

The global transportation sector is in a complex situation, grappling with the dual challenge of meeting the growing demand for mobility while drastically reducing its carbon footprint on the environment. The rise of urbanization and motorization, especially in developing countries, exacerbates this challenge, leading to increased congestion, air pollution, and greenhouse gas emissions (Khan, W., & Karger, N., 2022). As the world strives towards a transition to a sustainable future, the need for innovative and comprehensive strategies to decarbonize the transport sector becomes more urgent than ever.

The Republic of Bulgaria, which is undergoing rapid economic and social transformation, is an example of this global trend. The country's transport sector is experiencing a significant increase in vehicle ownership and use, driven by rising incomes and urbanization. While this trend of motorization signifies economic progress and improved accessibility, it also poses a significant threat to the environment and public health. The Bulgarian government, recognizing the urgency of this challenge, has formulated an Integrated Transport Strategy until 2030, which aims to create a sustainable and efficient transport system that supports economic growth while minimizing environmental impact (Ministry of Transport and Communications of Republic of Bulgaria, 2017).

This article examines the complexity of sustainable urban transport in Bulgaria, drawing on the insights and recommendations of the European Union's White Paper on Transport (European Commission, 2011) and Bulgaria's Integrated Transport Strategy until 2030. It explores the

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multifaceted nature of the challenge, encompassing technological, infrastructural, political, and behavioral dimensions. By analyzing the current state of urban transport in Bulgaria and considering innovative strategies applied in other contexts, this article aims to provide a roadmap for the future of sustainable urban transport in Bulgaria. The focus is on presenting innovative solutions that can effectively address the country's specific challenges and contribute to a cleaner, healthier, and more livable urban environment. In this regard, a study was conducted to select a suitable sustainable mobility scheme for Bulgaria.

EXPOSITION

The Challenge of Rapid Motorization in Bulgaria

Bulgaria, like many developing countries, is experiencing a surge in automobilization, characterized primarily by a rapid increase in private cars. This trend, while indicative of economic progress and improved accessibility, creates significant challenges for the country's urban transport systems and environmental sustainability. Table 1 presents data on registered vehicles in the country for the period 2010-2023 (Ministry of Transport and Communications of Republic of Bulgaria, 2017, Ministry of Internal Affairs - Road Police Unit).

Number and ratio of registered motor vehicles to the population and the length of the republican road network of the Republic of Bulgaria in the period 2010-2023.

Year	Number of vehicles	Ratio to total population (%)	Ratio to working-age population (%)	Length of the republican road network* (km)		
				H	F	S
2010	2 602 463	34.68%	40.62%	437	2970	4030
2015	3 162 037	44.20%	51.92%	734	2954	4025
2020	3 810 000	55.08%	92.05%	806	2883	4019
2023	4 030 487	62.53%	106.93%	840	2879	4019

*(H - Highways, F - First-class road, S - Second-class road)

The data in Table 1 show a sharp increase in car ownership between 2010 and 2023. In just thirteen years, their number in the country has increased from 2.6 million to 4.03 million, which is an increase of 55%. For the same period, the length of the republican road network has changed, with the length of highways increasing by just over 92% to 840 km, while first-class and second-class roads have decreased by just over 3% and over 0.1% respectively, i.e. the level of car ownership interacts with the development of transport infrastructure and urban sprawl (Nakamura, K., & Hayashi, Y., 2013). As a result, the percentage of car owners relative to the population has increased significantly from 34.68% to 62.53%.

This increase in car ownership inevitably leads to a jump in vehicle travel, putting a huge strain on urban road infrastructure, contributing to congestion and air pollution. The accompanying increase in fuel consumption further exacerbates the environmental impact, leading to increased greenhouse gas emissions and dependence on fossil fuels. The shift to the use of private cars, given their low occupancy levels compared to public transport, has a direct impact on energy consumption and CO₂ emissions per capita in urban areas of Bulgaria.

The challenges posed by rapid motorization in Bulgaria necessitate a paradigm shift in urban transport planning and policy. Relying solely on expanding road infrastructure or hoping for technological advances in vehicle efficiency is unlikely to provide a sustainable solution; on the contrary, it can lead to the opposite effect (Rebound Effect), inducing more travel and therefore congestion (Jovanovic, M. M., 2016, Ito, K., Nakamura, K., Kato, H., & Hayashi, Y., 2012, May, Kenworthy, J. R., 2003). A more comprehensive and innovative approach is needed to mitigate the environmental impact of increasing car ownership and use and to promote a more sustainable and livable urban environment for all.

A Multifaceted Approach to Sustainable Urban Transport

Addressing the challenges of rapid motorization and its environmental consequences requires a comprehensive and integrated approach to urban transport planning. This approach must encompass a range of strategies targeting the technological, infrastructural, policy, and behavioral aspects of urban mobility. The European Union's White Paper on Transport and Bulgaria's Integrated Transport Strategy until 2030 provide a framework for such a multifaceted approach, emphasizing the need for a paradigm shift towards sustainable urban transport systems.

Key Components of a Sustainable Urban Transport System

- **Technological Advancement:** Technological innovations play a key role in reducing the environmental impact of urban transport. The gradient development of regulations and technologies in transport since the end of the 20th century has led to improvements in the energy efficiency of vehicles and a reduction in their impact on the environment (Szymalski, W., 2021). The development and adoption of cleaner vehicles, such as electric and hybrid cars, coupled with the use of sustainable fuels, can significantly reduce emissions and energy consumption (Moriarty, P., & Honnery, D., 2002). Bulgaria's Integrated Transport Strategy until 2030 recognizes the importance of technological advancement, particularly in promoting the use of alternative fuels and improving the energy efficiency of the transport sector.

- **Infrastructure Development:** Well-planned and efficient transport infrastructure is crucial for promoting sustainable mobility. Investing in mass transit systems, such as buses, trams, and metro trains, can provide attractive alternatives to private car use. In addition, the development of dedicated cycling and pedestrian infrastructure can encourage active modes of transport, contributing to healthier and more livable cities. Public transport infrastructure must be developed in such a way as to achieve an efficient, safe and comfortable transport system for the user. Good public transport promotes mobility, reduces pollution, reduces congestion and accidents on the road network (Dhar, S., & Marpaung, C. O. P., 2015, Kadam, N. M., Bhakhtyapuri, V. K., & Ghodmare, S. D., 2017 Xu, Y., Gbologah, F., Cernjul, G., Kumble, A., Guensler, R., & Rodgers, M., 2013). The EU White Paper on Transport emphasizes the need for a "core network" of efficient and sustainable transport infrastructure (European Commission, 2011), while Bulgaria's Integrated Transport Strategy focuses on modernizing and expanding the country's transport infrastructure, including the development of intermodal terminals and improved connectivity between different modes of transport (Ministry of Transport and Communications of Republic of Bulgaria, 2017).

- **Demand Management:** Policy interventions aimed at managing travel demand can play a crucial role in reducing reliance on private cars. However, to be adopted and have a real impact, they must serve both private and public interests (Bose, R., & Nesamani, K. S., 2001). Implementing measures such as congestion charges, parking restrictions, and incentives for public transport use can encourage a shift to more sustainable modes of transport, but on the other hand, it can hurt small businesses (Nakamura, K., & Hayashi, Y., 2013). The EU White Paper advocates for the application of the "user pays" and "polluter pays" principles to ensure that transport users bear the full costs of their travel choices, while Bulgaria's Integrated Transport Strategy emphasizes the need for improved transport management through the introduction of innovative systems and market incentives.

- **Land-Use Planning:** Creating compact, mixed-use urban environments with well-connected transport systems can significantly reduce the need for travel and promote sustainable mobility. Transit-oriented development, by integrating land-use and transport planning, enables the creation of vibrant and accessible communities that encourage walking, cycling, and the use of public transport. Both the EU White Paper and Bulgaria's Integrated Transport Strategy recognize the importance of land-use planning in achieving sustainable urban transport, emphasizing the need for integrated urban mobility plans and smart city initiatives.

These four components of a sustainable urban transport system are interconnected and mutually reinforcing. Technological advances in cleaner vehicles and fuels are more effective when supported by adequate infrastructure for their use and complemented by policies that encourage their adoption. Similarly, demand management and land-use planning measures can create an enabling environment for the success of mass transit systems and active modes of transport. By adopting an integrated

approach that leverages the synergy between these different strategies, Bulgaria can effectively address the challenges of rapid motorization and pave the way for the future of sustainable urban transport.

Innovative Strategies for Bulgaria

To achieve a sustainable urban transport system and combat the challenges of rapid motorization, Bulgaria must adopt a set of innovative strategies tailored to its specific context. These strategies should employ a combination of technological advancement, infrastructure development, and policy interventions to promote a shift towards cleaner and more efficient modes of transport. It should be noted that different measures would have different effects depending on the characteristics of individual settlements. Therefore, it is extremely important that the condition of the individual transport networks is thoroughly investigated and analyzed based on volumes of real data (Wacker, M., & Schmid, V., 2002). For the sake of even greater objectivity, it is recommended that surveys of consumer transport habits and needs also be carried out. This type of "bottom-up" approach (Chester, M. V., & Horvath, A., 2010) could further contribute to behavioral change in travelers.

Some of the measures applicable in these strategies are:

➤ *Integrated ticketing and payment systems.*

One of the main obstacles to multi-modal journeys in Bulgaria is the lack of a unified ticketing and payment system across different modes of transport. Implementing an integrated system, as envisaged in the EU White Paper on Transport, will allow seamless travel between buses, trams, metro trains, and other modes of transport using a single ticket or payment method. An additional effect of increasing operational efficiency could be achieved by prepaying the respective transit fee - ticket (Litman, T., 2012). These measures will not only increase passenger convenience but also encourage the use of public transport instead of private cars. Bulgaria's Integrated Transport Strategy until 2030 also recognizes the importance of smart ticketing systems in promoting sustainable urban mobility. The development of a common EU standard for smart intermodal ticketing, while respecting competition rules, is crucial to the success of this strategy. This will facilitate interoperability between different transport operators and ensure a convenient experience for passengers.

➤ *Intelligent transport traffic management systems.*

The use of Intelligent Transport Systems (ITS) can significantly improve the efficiency and sustainability of urban transport networks. By utilizing real-time data and advanced algorithms, ITS can optimize traffic flow, reduce congestion, and improve the reliability of public transport. The EU's Roadmap to a Single European Transport Area emphasizes the importance of implementing ITS and other transport management systems to improve transport efficiency and infrastructure utilization. In the Bulgarian context, the implementation of ITS could include the use of traffic sensors, adaptive traffic signals, and real-time passenger information systems to create a more responsive and efficient urban transport network.

➤ *Promoting cycling and walking.*

Active modes of transport, such as cycling and walking, offer numerous benefits for both people and the environment. They contribute to improved public health, reduced emissions, and enhanced livability of urban areas. To promote cycling and walking in Bulgaria, it is essential to create safe and attractive infrastructure, such as dedicated bike lanes and pedestrian-friendly streets. In addition, public awareness campaigns and educational programs can encourage people to adopt these sustainable modes of transport for their daily commutes and leisure activities.

➤ *Electric mobility initiatives.*

The electrification of urban transport fleets, including buses, taxis, and other shared mobility services, represents a promising avenue for reducing emissions and improving air quality in Bulgarian cities. The EU White Paper on Transport sets ambitious targets for the adoption of clean vehicles, including the phasing out of conventionally-fueled cars in cities by 2050. To achieve this, Bulgaria needs to invest in charging infrastructure and provide motivating incentives for the adoption of electric vehicles. The development of electric mobility initiatives, coupled with supportive policies, can accelerate the transition to a cleaner and more sustainable urban transport system.

Case Studies and Lessons Learned

Examining successfully implemented sustainable urban transport strategies in other cities can provide valuable insights for Bulgaria. These case studies highlight the potential benefits of such strategies and offer lessons for overcoming the challenges and barriers to their implementation.

➤ *Curitiba, Brazil: Pioneering bus rapid transit.*

With a population of 3,852,000 by 2024, Curitiba's BRT (Bus Rapid Transit) system, implemented in 1974 with a population of 859,000, is widely recognized as a pioneering example of sustainable urban transport. The system features dedicated bus lanes, streamlined boarding and payment processes, and high-frequency services, resulting in efficient and attractive public transportation. Curitiba's BRT has successfully reduced dependence on private cars, improved air quality, and stimulated compact, transit-oriented development (Ito, K., Nakamura, K., Kato, H., & Hayashi, Y., 2012).

- **Lessons for Bulgaria:** Curitiba's experience demonstrates the transformative potential of BRT in developing cities. By prioritizing bus infrastructure and implementing efficient operational strategies, Bulgaria can create a cost-effective and attractive public transport system that encourages modal shift away from private cars.

➤ *Bogotá, Colombia: Integrated transport and land-use planning.*

Integrated in 2000, with a population of 6,329,000, Bogotá's TransMilenio BRT system, with a population of 11,658,000 by 2024, combined with integrated urban planning, has achieved significant reductions in carbon emissions and improved urban mobility. The success of the system is due to its extensive network, high quality service and integration with other modes of transport, and land use policies. The city is also introducing car-free days and investing in cycling infrastructure to further encourage sustainable transport. TransMilenio BRT is operated without the help of public subsidies, which speaks volumes about the economic profitability of such a project (W. Hook, C. Kost, U. Navarro, M. Replogle, & B. Baranda., 2010, Nakamura, K., & Hayashi, Y., 2013).

- **Lessons for Bulgaria:** Bogotá's experience emphasizes the importance of integrating transport and land-use planning to create a sustainable urban environment. By prioritizing transit-oriented development and implementing complementary policies, cities in Bulgaria could reduce car dependence and encourage a shift towards more sustainable modes of transport.

➤ *Singapore: Comprehensive demand management and public transport investment.*

Singapore, with a population of 6,052,709 as of 2024, has implemented a comprehensive set of demand management policies and invested heavily in public transport infrastructure, resulting in a highly efficient and sustainable urban transport system. The city's electronic tolling system, combined with high vehicle ownership taxes and a well-developed mass transit network, successfully manages congestion and promotes the use of public transportation (Ito, K., Nakamura, K., Kato, H., & Hayashi, Y., 2012, Kenworthy, J.R., 2003). It should not be overlooked that Singapore is a small parliamentary republic that gained its independence only in 1965, but thanks to its stable governance in the ensuing crisis, it has achieved exceptional economic development with a transparent and prosperous economy.

- **Lessons for Bulgaria:** Singapore's experience highlights the effectiveness of combining demand management policies with public transport investment to achieve sustainable urban transport outcomes. While specific policies may need to be adapted to the Bulgarian context, the underlying principles of managing car use and providing attractive alternatives can be applied to reduce reliance on private vehicles and promote sustainable mobility.

Challenges and Barriers

The case studies also reveal common challenges and barriers to implementing sustainable urban transport strategies, which include:

- **Financial constraints:** The upfront costs of infrastructure development and fleet upgrades can be substantial, particularly for developing countries and countries like Bulgaria. Innovative financing mechanisms, such as public-private partnerships and carbon financing, can help overcome this barrier.

- Institutional coordination: Successful implementation of sustainable urban transport often requires coordination between multiple government agencies and stakeholders. Establishing clear roles and responsibilities and fostering collaboration can help streamline decision-making and implementation processes.

- Public acceptance: Policies that restrict car use or promote alternative modes of transport may encounter public resistance. Effective communication and public engagement are crucial for building support and ensuring the successful implementation of sustainable transport initiatives.

Lessons learned from these case studies show the way to address the associated challenges. They are a good example for any country that seeks to chart a path towards a sustainable urban transport system that benefits both citizens and the environment.

CONCLUSION

The transition to sustainable urban transport in Bulgaria is a complex but necessary endeavor. By adopting a multifaceted approach that incorporates technological innovation, infrastructure development, demand management, and land-use planning, Bulgaria can effectively address the challenges of rapid motorization and create a more sustainable and livable urban environment. Successful implementation of these strategies will require strong political will, effective coordination between stakeholders, and long-term investment in sustainable transport solutions. However, the potential benefits, including reduced emissions, improved air quality, and enhanced quality of life, make this endeavor worthwhile. By embracing innovation and prioritizing sustainable urban transport, Bulgaria can serve as a model for other developing nations grappling with the challenges of rapid motorization and contribute to a greener and more equitable future for all.

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