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Sustainable transportation technologies and vehicles in Vietnam

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Abstract
To address the pressing need for sustainable, low-emission, and energy-efficient transportation solutions, the integration of advanced transportation technologies and sustainable vehicles has emerged as a pivotal approach. In this paper, the evolution of sustainable transportation technologies is critically examined, highlighting key innovations and their impact on the logistics and supply chain sectors in Vietnam. Furthermore, current challenges and potential solutions are explored, offering valuable insights for researchers and practitioners focused on advancing sustainable practices in transportation.

Keywords: Sustainable transportation, green logistics, low-emission vehicles, renewable energy, and eco-friendly transport solutions

1. Introduction
Amid accelerating urbanization and the pressing need for sustainable development, Vietnam stands at a critical juncture in its transportation evolution. As the country continues to experience rapid economic growth, its transportation sector has emerged as a significant contributor to environmental challenges, particularly in urban centers like Hanoi and Ho Chi Minh City. In 2022, the transportation sector accounted for approximately 18% of the nation's total greenhouse gas emissions, with pollution levels in major cities exceeding World Health Organization (WHO) guidelines by more than 200% [1]. This alarming data underscores the urgent need for a paradigm shift towards sustainable transportation technologies.

The adoption of sustainable transportation technologies and vehicles offers a promising pathway to mitigate these environmental impacts while supporting economic growth. For example, electric vehicles (EVs) have the potential to reduce emissions by up to 50% compared to traditional internal combustion engine vehicles [2].This paper focuses on evaluating the current state and potential of sustainable transportation technologies in Vietnam, emphasizing their role in reducing emissions and enhancing energy. efficiency, and improving urban mobility. By analyzing the existing infrastructure, policy frameworks, and technological advancements, this study aims to provide insights into how Vietnam can effectively integrate sustainable transportation solutions to meet its environmental and economic goals.

2. Materials and Methods
This study employs a mixed-method approach, integrating both quantitative and qualitative research methods to provide a comprehensive analysis of sustainable transportation technologies and vehicles in Vietnam. Quantitative data will be gathered from reliable sources, such as government reports, scientific databases, and international organizations, including the Ministry of Natural Resources and Environment (Vietnam), the International Energy Agency (IEA), and the World Bank. This data, which includes greenhouse gas emissions, vehicle usage statistics, and energy efficiency metrics, will be analyzed using statistical techniques to identify trends, patterns, and correlations that underscore the environmental impact of current transportation systems in Vietnam. In addition, qualitative methods will be used to gain deeper insights into the challenges and opportunities associated with adopting sustainable transportation technologies. This involves a review of existing literature, case studies, and expert interviews sourced from platforms like Google Scholar

JSTOR, and ScienceDirect. Furthermore, policy frameworks and infrastructure developments will be analyzed to assess the readiness of Vietnam's transportation sector for integrating sustainable technologies. The combination of these methods allows for a robust evaluation of both measurable impacts and broader contextual factors, ensuring that the research findings are data-driven and contextually grounded, providing actionable insights for policymakers and industry stakeholders.

3. Advancements in Transportation

3.1 Road Transport

Vietnam's road network has expanded significantly in recent years, with an emphasis on improving connections between key economic regions and reducing congestion in major cities. However, the road infrastructure continues to encounter issues, including traffic congestion and high accident rates, particularly in major cities like Hanoi and Ho Chi Minh City [3].

To address these challenges, Vietnam is actively deploying Intelligent Transportation Systems (ITS). ITS leverages sensor technology, surveillance cameras, and intelligent traffic signal systems to monitor and regulate traffic flow, thereby reducing congestion and accidents. A prime example is the ITS implementation in Ho Chi Minh City, where this technology has optimized signal timing and improved overall traffic management [4].

Building Information Modeling (BIM) is additionally becoming more widely used in the design and administration of large-scale road infrastructure. projects. BIM makes it easier to create precise digital models of structures. allowing engineers and project managers to foresee and address technical concerns before construction begins, lowering costs and saving time. This technology also improves asset upkeep and administration after construction [5].

In Vietnam, several investors, contractors, and consulting firms have aggressively used BIM (Building Information Modeling) technology in a variety of projects. Notable projects include Metro Line 2 Ben Thanh-Tham Luong, the National Highway 1 stretch in Quang Tri, the Saigon 2 Bridge project, and the Thu Thiem Tunnel project. The 550 Binh Duong Overpass project employed Revit software to construct a 3D model for the detailed design stage, which included five spans of 40 m length and 16 m width, as well as steel box girders and concrete (Figure 2 and 3) [6].

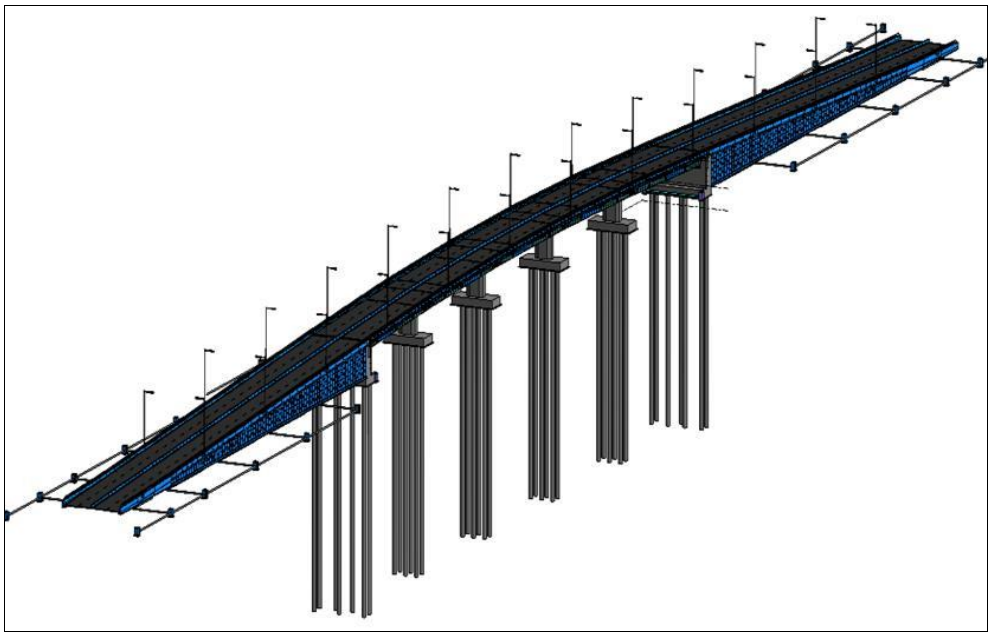

Fig 2: 3D model 550: Binh Duong overpass using Autodesk Revit [7].

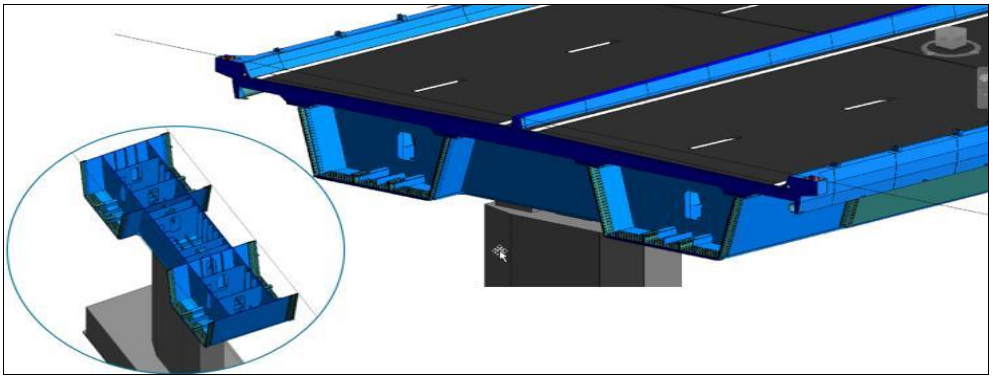

Fig 3: The detailed steel-girder module on top of the pillar [7].

BIM (Building Information Modeling) technology aids in the design, planning, and maintenance of road and bridge projects. For instance, in projects like the Ben Luc and Long Thanh highways, BIM was used to develop a platform for the project lifecycle, helping with planning, detailing, and managing workflow. BIM also automates repetitive tasks involving design rules and codes. Projects such as the Thu Thiem 2 Bridge, the Song Chua Bridge, the Ben Luc-Long

Thanh Highway, and the Vam Cong Bridge have demonstrated that BIM applications help investors shorten schedules and save costs through optimization and addressing challenges at each construction stage. Therefore, accelerating the adoption of BIM in the construction and bridge industries is crucial for contributing to the country's development.

3.2 Railway

Vietnam's existing railway construction is based mostly on a 1,000-mm gauge track with a total length of around 3,143 km, which differs from the worldwide standard gauge of 1,435 mm. This distinction presents substantial obstacles for linking and integrating with regional and worldwide railway networks. The North-South Railway, the nation's backbone, only permits trains to run at speeds of 60–80 km/h, resulting in longer journey times and failing to fulfill current transportation demands. Regional railway lines connecting large cities to vital economic zones suffer severe difficulties owing to obsolete infrastructure that lacks adequate load capacity and speed [8].

The North-South High-Speed Rail Project, with a projected length of 1,545 kilometers, is seen as a significant step forward in upgrading Vietnam's railway transportation infrastructure. This project will employ a conventional 1,435 mm gauge track, which allows trains to travel at speeds of up to 350 km/h, as well as contemporary materials designed to bear heavy loads and retain stability at high speeds. The 25 kV, 50 Hz electrification system, which is similar to high-speed rails in Japan and Europe, will offer reliable and efficient electricity while reducing greenhouse gas emissions. This high-speed train will also have several overpasses and tunnels constructed with innovative technology and high-strength composite materials to improve durability and resistance [9].

To ensure safety and operational efficiency, the project will implement the Automatic Train Control (ATC) system, using sensors and radar systems to monitor the position and speed of trains in real-time. This system minimizes the risk of accidents due to human error and optimizes routing. Additionally, Level 2 European Rail Traffic Management System (ERTMS) technology will be applied to improve train coordination, reduce waiting times at stations, and optimize the line's capacity. IoT sensors and big data algorithms will continuously collect and analyze data on operating conditions and the environment, predicting and preventing incidents, enhancing maintenance efficiency, and reducing operational costs.

For the railway sector, Vietnam's limitations are even more pronounced. The implementation of ATC and similar high-tech solutions is hindered by financial constraints, a shortage of skilled personnel, and insufficient governmental support. Moreover, the existing railway infrastructure is outdated, making the integration of modern technologies even more challenging. Upgrading the current system to accommodate these technologies would require extensive capital investment and time, neither of which are readily available in the current economic climate.

3.3 Electric Vehicle Technology in Road Transportation

Electric Vehicles (EVs) have emerged as a leading solution for reducing greenhouse gas emissions and improving energy efficiency in road transportation. Globally, countries like Norway, the US, and China have made significant strides in promoting EV adoption through robust support policies and the development of charging infrastructure. In Norway, which leads the world in EV market share, the government has implemented various incentives such as import tax exemptions, registration fee waivers, and free parking, which have significantly increased the number of EVs on the road.

In Vietnam, the adoption of EVs is still in its early stages, with a slower growth rate compared to other countries. Major challenges include high investment costs, a lack of charging infrastructure, and limited government incentives. However, the emergence of domestic manufacturers like VinFast offers hope for the EV market in Vietnam. Local production of EVs not only helps reduce costs but also fosters the development of supporting industries, paving the way for the construction of battery manufacturing plants and renewable energy-powered charging stations [10].

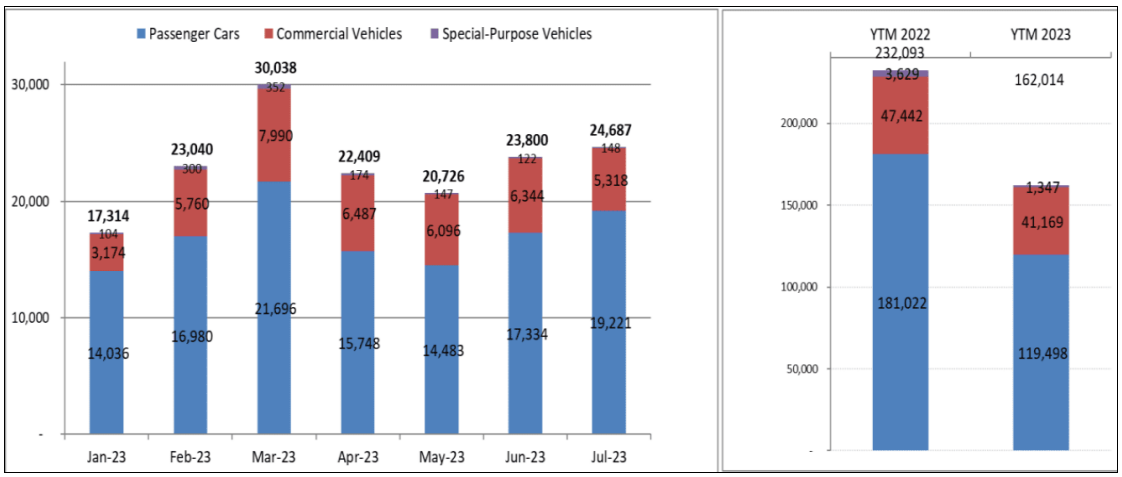

Fig 4: Total market sales by the end of July 2023 decreased by 30% compared to 2022 [10]

For figure 4, domestic car consumption in Vietnam has been experiencing a decline in the first half of 2023, despite deep discounting policies aimed at stimulating demand. According to VIRAC, in the first six months of 2023, Vietnam spent 1.6 billion USD on car imports, with nearly 70,000 units, up 5% compared to the same period in 2022 (63,731 vehicles). Although the number of cars imported to Vietnam in the first half of the year increased by 5% over the previous year, domestic car consumption has decreased sharply compared to 2022 [10].

3.4 Renewable Energy in Railway and Road Systems

Renewable energy integration in railway and road transportation systems is essential for reducing dependence on fossil fuels and mitigating environmental impacts. Globally, countries are adopting solar and wind energy to power transportation infrastructure and vehicles

In Europe, Germany is a leading example of integrating renewable energy into its transportation infrastructure. The country has strategically installed solar-powered charging stations along major highways and railway lines. These stations not only provide clean energy for electric vehicles (EVs) but also support the operation of traffic management systems. By leveraging solar power, Germany reduces reliance on fossil fuels and decreases carbon emissions associated with transportation. The German government has implemented supportive policies and invested heavily in renewable energy infrastructure, including subsidies for solar technology and incentives for electric vehicle adoption. This proactive approach contributes significantly to Germany's status as a leader in sustainable transportation solutions.

Vietnam is at an early stage of adopting renewable energy in its transportation sector. The development of solar-powered charging stations and other renewable energy infrastructure faces several challenges. The primary issue is the lack of existing infrastructure, which requires significant investment and time to develop. Building these facilities involves high costs and logistical considerations, making it a complex process. Furthermore, the integration of renewable energy into the existing transportation network necessitates upgrading current systems and incorporating new technologies, which adds to the complexity and expense [11].

Securing investment capital for renewable energy projects in Vietnam poses a significant challenge. High initial costs and the need for substantial financial resources can hinder the implementation of renewable energy initiatives. Attracting investment requires creating a favorable environment for investors, including clear policies, incentives, and financial support mechanisms. Without these, the development of renewable energy infrastructure in transportation may progress slowly.

Despite these challenges, Vietnam has initiated several pilot projects, such as installing solar-powered charging stations for electric vehicles. These projects demonstrate the potential for integrating renewable energy into the transportation sector and serve as a foundation for future developments. By expanding these initiatives and overcoming existing barriers, Vietnam can enhance the sustainability of its transportation system, reduce carbon emissions, and foster growth in the domestic renewable energy sector.

4. Recommendations

To develop sustainable transportation technologies and vehicles in Vietnam, it is essential to focus investment on several key solutions. First, Vietnam should increase investment in research and development (R&D) to improve efficiency and reduce costs for electric vehicle and renewable energy technologies, while promoting collaboration among research institutes, universities, and businesses in this field. Second, developing supportive infrastructure for sustainable transportation is crucial, including expanding the network of charging stations in both urban and rural areas and adopting public-private partnership (PPP) models to attract private investment.

The government should also implement supportive policies, such as tax incentives and financial packages for businesses transitioning to environmentally friendly vehicle production, along with incubation programs to encourage startups in sustainable transportation. In addition, raising public awareness and encouraging the community to use sustainable transportation options—such as public transport, bicycles, and walking—through education campaigns can help shift behavior and build awareness about the benefits of green transportation.

Furthermore, Vietnam should establish and apply sustainable standards for railway infrastructure, including energy management and environmental protection standards, and construct smart, eco-friendly stations to minimize environmental impact. International cooperation is also essential, enabling Vietnam to access advanced transportation technologies through participation in international agreements on emissions reduction and environmental protection. Lastly, Vietnam should develop an intelligent transportation system (ITS) for road networks, utilizing AI and IoT technologies to manage traffic, reduce congestion, and optimize travel routes, thereby increasing efficiency and sustainability in the transportation system.

These strategies will support Vietnam in building a sustainable transportation system that meets economic and social development needs while reducing environmental impacts in the long term.

5. Conclusion

In conclusion, Vietnam's transportation sector is at a pivotal moment, facing both pressing challenges and significant opportunities as the country moves toward sustainable development. The alarming rise in greenhouse gas emissions and pollution levels in major cities like Hanoi and Ho Chi Minh City highlights the need for immediate action. Transitioning to sustainable transportation technologies, such as electric vehicles, renewable energy-powered infrastructure, and intelligent transportation systems, presents a viable pathway to mitigate environmental impacts, enhance urban mobility, and support economic growth.

However, the journey toward sustainability requires substantial investments in infrastructure, supportive government policies, and public awareness initiatives to drive behavioral change. The adoption of technologies like Building Information Modeling (BIM) and Intelligent Transportation Systems (ITS) in road transport, as well as advancements in railway and renewable energy integration, are promising but need scaling to make a measurable impact.

Vietnam must address barriers such as financial constraints, lack of skilled personnel, and outdated infrastructure to successfully integrate these technologies. The development of pilot projects and partnerships with domestic manufacturers like VinFast are steps in the right direction. By fostering an environment conducive to innovation and international cooperation, Vietnam can transform its transportation landscape, balancing environmental preservation with economic development goals. The findings and recommendations of this report provide actionable insights for policymakers, industry stakeholders, and investors to make informed decisions toward a sustainable transportation future.

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