Research article

Sustainable development of transport infrastructure in the system of national economy

Waqar Bénichou [1]*

[1] University of Transport and Information Technologies, Algeria
* Correspondence: waqarwaqarb@gmail.com

https://doi.org/eiki/xxxxx

Abstract: This research article investigates the sustainable development of transport infrastructure within the national economy, emphasizing the critical intersection of economic growth, environmental responsibility, and social equity. The study explores theoretical frameworks and practical approaches employed in the planning, implementation, and management of sustainable transport systems. The role of integrated transportation planning, multimodal systems, green infrastructure, and smart technologies is analyzed to assess their impact on reducing congestion, minimizing emissions, and enhancing overall accessibility. Examining the effectiveness of public-private partnerships, regulatory measures, and community engagement, the research delves into the challenges and opportunities associated with achieving sustainable transport infrastructure. Additionally, the article explores the significance of smart traffic management systems, fleet modernization, and incentives for environmentally friendly modes of transportation. The regulatory measures and standards implemented to guide sustainable practices are scrutinized, focusing on their role in shaping a transportation landscape that aligns with broader sustainability objectives. The findings aim to provide insights for policymakers, urban planners, and researchers, offering a comprehensive perspective on the complex dynamics involved in fostering a sustainable transport infrastructure system within the national economy.

Keywords: transport infrastructure; sustainable development; effects; benefits; conventional and applicable approaches

1. Introduction

Transport infrastructure plays a crucial role in the development and functioning of a national economy since transport is one of the most important infrastructure branches of material production, which provides production and non-production needs of national economy and population in all types of transportation (Zhang & Cheng, 2023). Transport system is one of the basic branches of the economy, which ensures its stable functioning of necessary conditions for defense capability, national security, state integrity, raising the standard of living of the population (Skorobogatova & Kuzmina-Merlino, 2017). Today, the transport sector is significant and important segment for the country's economy, because the entire transport sector is effective and coordinated system is a driving force for the overall development of the country.

Development and integration processes as well as increased competition in the market of transport services require new approaches to the development of transport relations, the creation of new technologies and improving the quality of services (Komornicki & Goliszek, 2023). Current economies are characterized by increasing the role of transport (Turan et al., 2023), which provides vital activities for population, functioning and development of the state, preservation of its defense capability, the possibility of achieving the country's foreign economic goals. Transport industry is a set of subjects of economic activity regardless their forms of ownership that develop and produce products (perform work and provide services) of certain types that have a homogeneous consumer or functional purpose (Lai, 2020; Skorobogatova & Kuzmina-Merlino, 2017).

Received: December 12, 2023
Accepted: December 29, 2023
Published: January 10, 2024

Transport is the most important and most powerful branch of any industry countries in the world. The structure of the country's transport complex is formed under the influence of many factors. Several factors can significantly influence the transport system in a country, impacting its efficiency, accessibility, and overall performance. These factors are interconnected and can vary based on geographical, economic, social, and political contexts. Key factors include: geography and topography (Felbermayr & Tarasov, 2021); quality and extent of transport infrastructure, including roads, railways, airports, seaports, and public transit (Zhang & Cheng, 2023); economic development (Komornicki & Goliszek, 2023); urbanization (Chanieabate et al., 2023); population density (Jasim et al., 2022); advancements in transportation technology, such as electric vehicles, autonomous vehicles, or intelligent transportation systems (ITS) (Oladimeji et al., 2023); government policies and regulations (Zhang & Cheng, 2023); political stability and effective governance (Marcucci & Stathopoulos, 2012); environmental issues (Alghuson, 2023); cultural preferences and social behaviors (Loyola et al., 2019); international trade and globalization (Rahman et al., 2021); vulnerability to natural disasters, such as earthquakes, floods, or hurricanes (Alghuson, 2023); and fluctuations in energy prices and the availability of energy resources (Voitko et al., 2022). Understanding and addressing these factors is essential for effective transport planning and policy-making. A holistic approach that considers the interplay of these factors can contribute to the development of a resilient, sustainable, and efficient transportation system in a country.

Also, it is necessary to analyze the category of transport itself and outline its features. Thus, transport refers to a set of means intended for the movement of people, goods, signals and information from one place to another (Hashchuk & Tymoshenko, 2020). We found that transport possesses certain features:

transport is the main component connecting production and consumption of products (Felbermayr & Tarasov, 2021);

transport does not produce the latest products, but is a continuation of manufacturing process within the circulation, it only moves products already manufactured by other sectors of the economy (Olabanji & Mpofu, 2022);

transport, through circulation processes, forms additional production of processes and affects the formation of product prices due to its costs of maintenance and operation (Zhang & Cheng, 2023);

transport products do not include raw materials. Unlike industrial sectors of the economy, transport does not use at all raw materials, but, despite this, consumes a huge amount of fuel, electricity, oil and other consumables (Voitko et al., 2022);

transport, the development of which precedes the introduction of production, in turn, affects the location, qualification and cooperation of this production (Komornicki & Goliszek, 2023);

money circulation in the transport sector is different from their circulation in industry and agriculture (Rahman et al., 2021);

transport regulates the production and sale of products and, thereby, takes participation in the labor division in the economy (Rahman et al., 2021; Skorobogatova & Kuzmina-Merlino, 2017);

transport and exchange of goods mutually affect each other in the process of circulation in the economy, having at the same time a close mutual connection (Rahman et al., 2021; Zhang & Cheng, 2023);

transport actively affects various spheres of the state, economy and society, namely: financial sector, national defense, social mutual relations in society, cultural development (Loyola et al., 2019).

In reference literature, the term "infrastructure" is defined as a set of specific forms, methods and processes, as well as structures, buildings, various communications that provide general conditions and normality functioning of economic, social, ecological and other areas vital activities of society, its reproduction and development (Wang et al., 2018). These conditions are created by a complex of industries and spheres of the economy, a system of technical-technological, organizational-economic, social, communication interconnections of all infrastructure elements (Koval et al., 2021). Some researchers consider infrastructure as a combination of activities and relevant subjects engaged in maintenance of social production (Scholten et al., 2023). Infrastructure emerges through the improvement of productive forces of society, deepening of social division of labor (Wang et al., 2018). Also, infrastructure of a high degree of development allows to apply all production potentials (Khadim et al., 2021), minimize production time intervals and accelerate the transition of products to sphere of circulation, deliver material goods to the consumer and satisfy its demand (Koval et al., 2021).

At the same time, transport infrastructure refers to the physical and organizational structures, facilities, and systems that support the movement of people, goods, and services from one location to another (Scholten et al., 2023). It is a critical component of a country's or region's overall infrastructure and plays a fundamental role in enabling economic activities, trade, and social interactions. Transport infrastructure encompasses various modes of transportation, including roadways, railways, airports, seaports, and public transportation systems.

The importance of transport infrastructure for any country is extremely high. It affects economic, defense, socio-political and cultural functions that are important for the state (Ševčenko-Kozlovska & Čižiūnienė, 2022). The economic role of transport lies, first of all, in the fact that it is an organic link of each production, carries out continuous and mass delivery of all types of raw materials, fuel and products from points of production to points of consumption, and also carries out labor division, specialization and cooperation of production. Rational location of production development of new territories and natural resources are impossible without transport.

Findings show that positive impact of transport infrastructure concern various aspects of a country's economy, society, and environment (Komornicki & Goliszek, 2023). The recent research state that positive impacts of well-designed and planned transport infrastructure include economic growth and market access (Donaldson & Hornbeck, 2016); employment opportunities (Laborda & Sotelsek, 2019); trade facilitation both international and regional (Rahman et al., 2021); reduced transportation costs and, as a result, logistics efficiency (Wheat et al., 2019); urban and rural development (Chanieabate et al., 2023); development of tourism industry (Hrushka et al., 2021); improved social interaction (Lee at al., 2020); emergency response (Alghuson, 2023); and improved quality of life by reducing travel times, congestion, and stress associated with transportation challenges (Hybel & Mulalic, 2022).

Sustainable development of transport infrastructure involves the strategic planning, design, and implementation of transportation systems that meet the current needs of society while safeguarding the well-being of future generations and the environment (Abu-Eisheh et al., 2020). This approach encompasses various principles to minimize negative impacts and enhance the overall resilience, efficiency, and inclusivity of transportation networks. One key aspect is the reduction of environmental harm, focusing on mitigating air pollution, greenhouse gas emissions, and noise. Sustainable development seeks to integrate renewable energy sources, promote energy-efficient technologies, and minimize disruption to natural habitats, fostering a transportation system that is environmentally responsible.

In addition, sustainable development of transport infrastructure emphasizes social inclusivity and equity (Pagliara et al., 2020). It prioritizes accessible and affordable transportation services for all members of society, considering diverse needs, abilities, and socioeconomic backgrounds. This includes the promotion of public and active transportation options, such as buses, trains, cycling, and walking, to reduce dependency on individual motorized vehicles. Engaging local communities and stakeholders in the decision-making process ensures that the infrastructure addresses their concerns and needs. Additionally, sustainable transport infrastructure aims to enhance overall resilience to climate change, incorporating climate-adaptive design principles to withstand extreme weather events (Alghuson, 2023). By integrating smart and innovative technologies, fostering multi-modal connectivity, and fostering community engagement, sustainable development of transport infrastructure aims to create a balanced and resilient transportation system that benefits society, the economy, and the environment in the long term (Chakwizira, 2022; Du et al., 2022).

Considering the importance of sustainable development of transport infrastructure in the system of national economy, the research aim is to identify the mechanisms of the impact of transport infrastructure on the economic growth and to describe the role sustainable development of transport infrastructure plain in a country.

To achieve this aim, the following objectives have been defined: (1) to analyze approaches to defining the concept and main characteristics of transport infrastructure; (2) to investigate the relationship between the development of transport infrastructure and economic growth of the country; (3) to characterize the sustainable development of transport infrastructure; (4) to formulate recommendations for improving the policy of development of transport infrastructure in s country.

2. Materials and Methods

We used general scientific and special methods research, in particular methods of theoretical generalization; deductions; logic analysis and synthesis; methods of analogies, system approach; statistical analysis and formalization. Also, the descriptive method was applied to define the main concepts of transport infrastructure; historical and comparative analysis was used for the analysis of national market of transportation system, assessment of the development of cooperation between different countries; correlation analysis was introduced to determine the impact of investments in transport infrastructure for the economic growth. In addition, we used expert assessments and forecasts during the development of scenarios of sustainable development of transport infrastructure.

Various experts from different fields contributed to the research. We involved experts and professionals who specialize in designing and optimizing transport system, in particular civil engineers, transportation engineers, urban planners, environmental scientists, economists, geographers, traffic engineers, professionals in logistics and supply chain management, and legal experts who specialize in transportation law. Such interdisciplinary research teams were essential to address the complex and interconnected challenges associated with transportation planning and development.

3. Results

Transport infrastructure is a subsystem of the market economy, integral component of the entire state or regional infrastructure of economy, without which economic sectors and links cannot function the main production and production area of various types of markets (Felbermayr & Tarasov, 2021). According to Komornicki and Goliszek (2023), transport infrastructure includes means of communication (road, rail, water, air, etc.), a complex of engineering structures, buildings and related devices which ensures the functioning of transport infrastructure elements, and also the necessary means of transportation, management and mutual connection.

Čuš-Babič et al. (2022) believe that the transport infrastructure is a totality of transport communications, passenger service facilities and freight transportation, maintenance and repair facilities, which provide the needs for the provision of transport services, i.e. movement cargo and passengers. Rahman et al. (2021) define transport infrastructure as one of elements of the market infrastructure, the purpose of which is to combine into a single whole production, consumption, processes of distribution of goods and their circulation. At this, the transport infrastructure is considered from the point of view functioning of the regional economy, i.e. it must provide the fastest possible rotation of material, financial and information resources within the framework of the formed spatial (at the level region) of the network structure, taking into account that all elements, including transport infrastructure, in this structure are related to each other as on regionally and at higher levels of functioning. At the same time, Rahman et al. (2021), Skorobogatova and Kuzmina-Merlino (2017) emphasize that the transport infrastructure is designed to ensure constant and high-quality transportation of goods and passengers within the framework of national economy, relying on a certain set of conditions (components), that have developed in a country, to which we refer: normative and legal support, material support, financial and economic development spheres, human resources, organizational conditions.

Other findings show that the transport infrastructure consists of all types of transport, with their parts and links, communication routes, variable composition of motor vehicles, machine maintenance facilities and transport and logistics companies working in the field of transportation people and goods (Ngampravatdee et al., 2023). Transport infrastructure, which is the basis of transport complex of the region, contributes to the formation of the transport network and serves for the transportation of goods and passengers (Hybel & Mulalic, 2022). It participates in formation of the organizational structure of the transport complex, ensuring efficient use of vehicles (Wheat et al., 2019).

On the basis of the analysis of the definitions, we come to the conclusions that transport infrastructure includes a number of components that can be divided into five groups: land transport infrastructure, air transport infrastructure, maritime transport infrastructure, public transport infrastructure, supporting infrastructure. Figure 1 presents the components of transport infrastructure in details. These groups offer a simplified overview of the various components within transport infrastructure, aiding in the understanding of their distinct roles and functions.

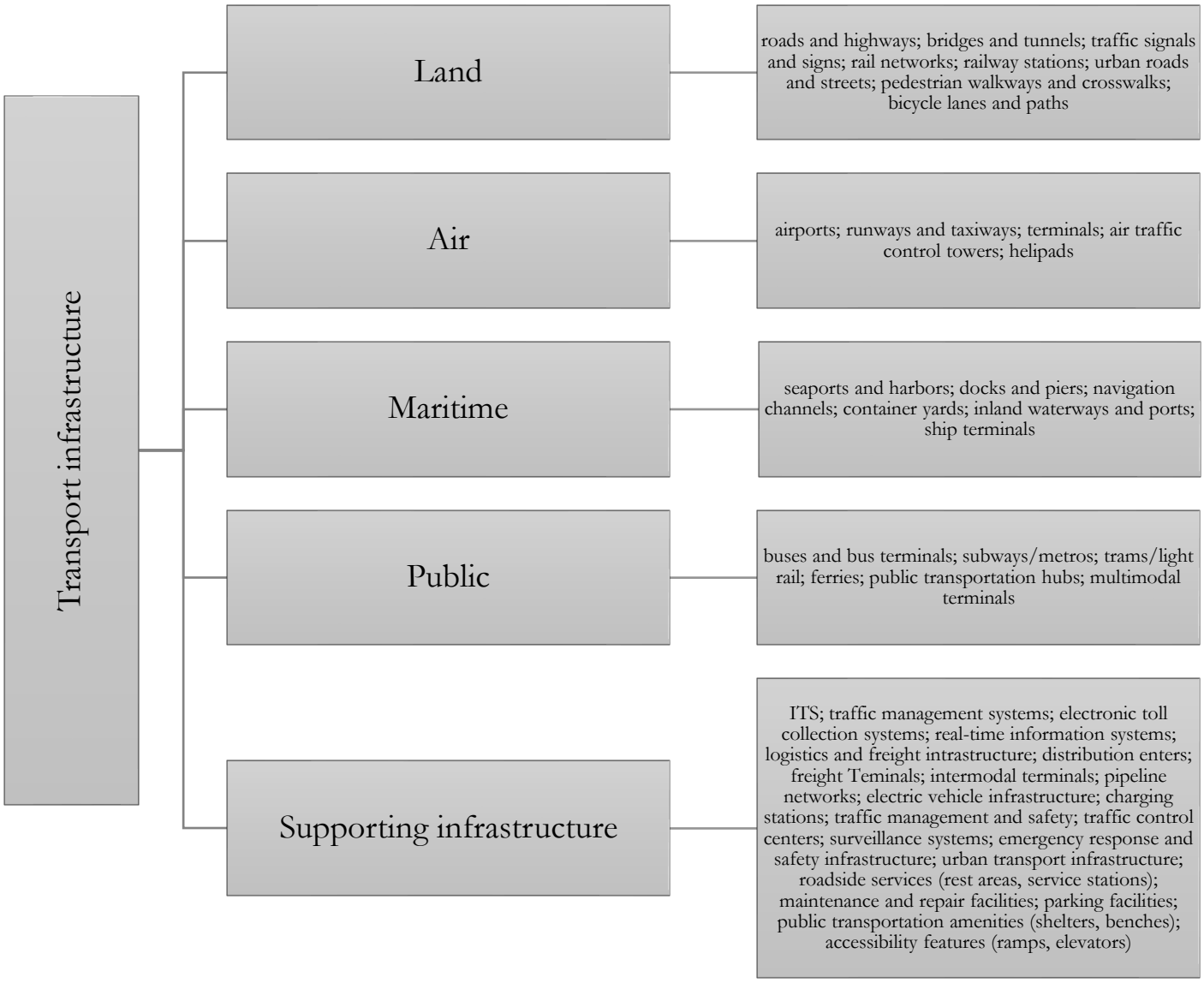

Figure 1. Components of transport infrastructure.

Land transport infrastructure refers to the physical and organizational structures that facilitate the movement of people, goods, and services over land. It encompasses various modes of transportation, primarily focusing on roads and railways, as well as the associated components that support land-based transportation systems (Gonzalez-Navarro et al., 2023). Air transport, often referred to as aviation, is a mode of transportation that involves the movement of passengers and goods through the air using aircraft (Trinh et al., 2022). The air transport system is a complex network of infrastructure, services, and regulations designed to ensure the safe and efficient operation of air travel (Mazzola et al., 2022). Maritime transport infrastructure refers to the facilities, structures, and systems that support the movement of ships and vessels for the transportation of goods, passengers, and commodities by sea. This infrastructure is critical for international trade, connecting ports worldwide and facilitating the efficient and safe flow of maritime traffic (Li et al., 2023). The findings indicate that public transport infrastructure refers to the physical and organizational components that support the movement of passengers using shared or public modes of transportation (Bureau, 2011). This infrastructure is designed to provide accessible, efficient, and sustainable transportation options for the general public. And supporting transport infrastructure refers to various facilities, services, and technologies that play a vital role in ensuring the efficient and safe functioning of transportation systems (Komornicki & Goliszek, 2023). These elements are essential for maintaining and enhancing the overall performance, reliability, and sustainability of the transportation network.

Transport infrastructure exhibits various characteristics that collectively define its functionality, effectiveness, and impact on the overall transportation system. According to recent findings, the key characteristics of transport infrastructure include:

- *Accessibility.* Infrastructure should facilitate seamless connections between different modes of transport, regions, and urban areas, ensuring accessibility for people and goods (Gutiérrez et al., 1998).
- *Efficiency.* Well-designed infrastructure minimizes travel times and costs for both passengers and freight, contributing to economic efficiency (Netirith & Ji, 2022).
- *Safety standards.* Infrastructure must comply with safety regulations and standards to protect users and the environment from accidents and hazards (Batarlienė, 2020).
- *Environmental impact.* Sustainable transport infrastructure minimizes environmental impact, considering factors such as emissions, energy consumption, and land use (Alghuson, 2023).
- *Capacity.* Infrastructure should be designed to accommodate current and future demands, ensuring it can handle increases in traffic and usage (Burinskiene, (2022).
- *Reliability.* Infrastructure should be resilient to natural disasters, accidents, and other unforeseen events, minimizing disruptions to transportation networks (Conceição et al., 2023).
- *Integration.* Effective transport infrastructure integrates different modes of transportation, allowing for smooth transfers and efficient movement of goods and people (Netirith & Ji, 2022).
- *Incorporation of technology.* Modern infrastructure incorporates advanced technologies, such as ITS and automation, to enhance efficiency, safety, and user experience (Oladimeji et al., 2023).
- *Flexibility.* Infrastructure should be adaptable to changing circumstances, such as shifts in transportation patterns, technological advancements, and urban development (Conceição et al., 2023).
- *User-centric design.* Consideration of diverse user needs, including accessibility for individuals with disabilities, to ensure inclusivity and equitable access (Batarlienė, 2020; Conceição et al., 2023).
- *Contribution to economic growth.* Transport infrastructure plays a vital role in supporting economic activities, trade, and investment, contributing to overall economic development (Donaldson & Hornbeck, 2016).

Effective and well-maintained transport infrastructure is fundamental for supporting economic activities, enhancing mobility, and improving the overall quality of life for communities. These characteristics collectively contribute to the success and sustainability of transportation networks.

According to experts, contribution to economic growth (77,5 %), reliability (85,9 %), safety standards (92,5 %), efficiency (89,1 %), and accessibility (76,5 %) have the biggest impact upon transport infrastructure. Figure 2 shows experts' assessment of transport infrastructure impact by categories.

One of the important elements of the transport infrastructure is international transport corridors (Sładkowski & Cieśla, 2018). Their main characteristics include: legislative – normative; clearly the specified territory of transportation routes (car, railway, water), which has the appropriate infrastructure (buildings, structures, equipment, service points, control and management equipment of movement and other components). Some findings indicate that an international transport corridor refers to a designated route or passage that facilitates the seamless movement of goods, services, and people across multiple countries (Alam et al., 2022). The establishment of international transport corridors is often driven by the aim of improving trade and economic cooperation among nations, reducing transportation costs, and promoting efficient logistics and supply chain management (Rahman et al., 2021). These corridors serve as vital channels for the smooth flow of goods between different regions, fostering economic growth, and creating opportunities for international collaboration and development.

Typically, international transport corridors involve the coordination and cooperation of multiple countries, as they traverse national borders. Governments, international organizations, and private stakeholders often collaborate to develop, upgrade, and maintain

the infrastructure along these corridors. Additionally, the establishment of standardized procedures, customs facilitation, and regulatory frameworks are crucial for ensuring the efficient functioning of international transport corridors. These corridors contribute not only to economic development but also to diplomatic and geopolitical cooperation by fostering connections and partnerships among nations along the route.

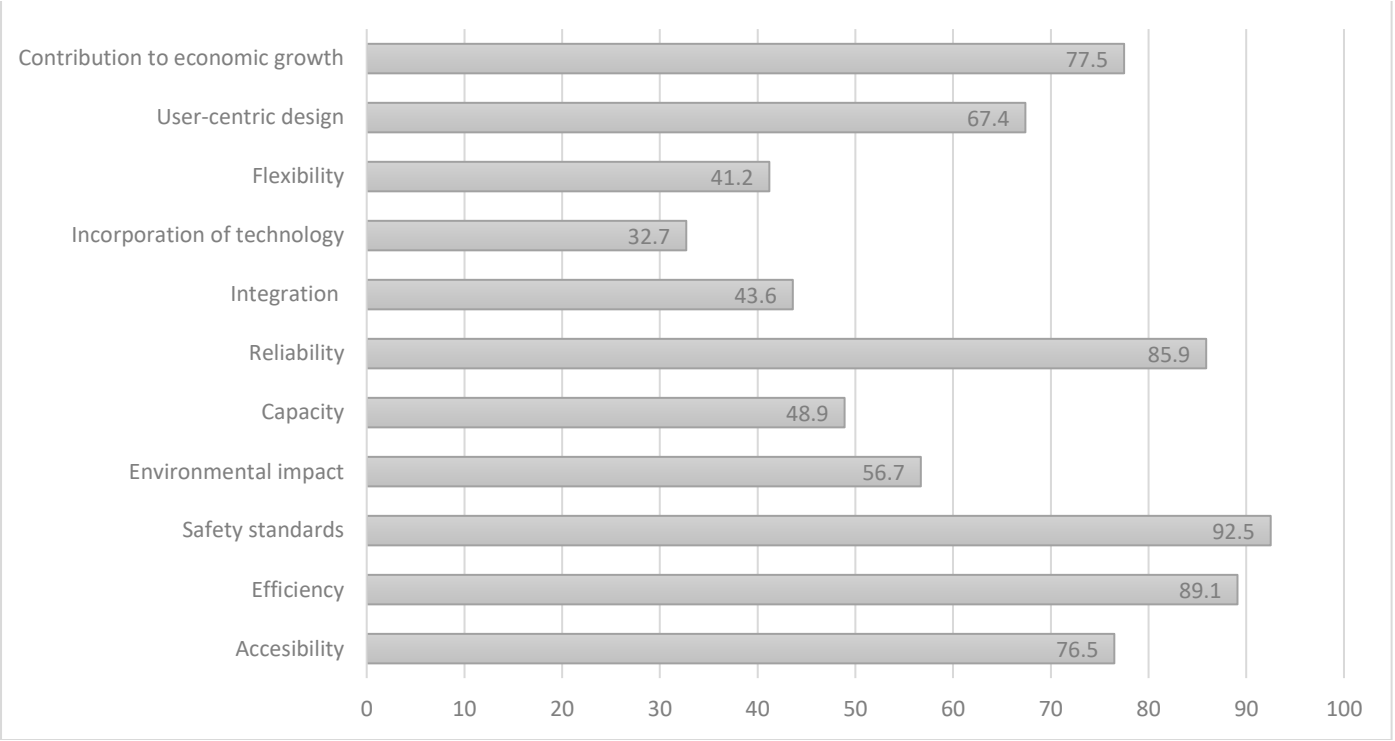

Figure 2. Experts' assessment of transport infrastructure impact by categories.

The accumulation of infrastructure significantly contributes to economic growth of countries. This is evidenced by numerous studies in macroeconomics literature (Vlahinić Lenz et al., 2018). The following directions of influence of infrastructure on development of the national economy: (1) infrastructure acts as one of the factors of production (Zhang & Cheng, 2023); (2) infrastructure provides effective influence of other factors on production; infrastructure that acts in the quality of one of the incentives for the accumulation of the influence of factors on production (Lai, 2020); (3) infrastructure acts as one of the main drivers of demand for national level (Du et al., 2022; Zhang & Cheng, 2023); (4) infrastructure is a component of development policy of national industry (Nenavath, 2023). Table 1 summarizes the effects of transport infrastructure upon economic growth.

Table 1. Effects of transport infrastructure upon economic growth.

Effect of transport infrastructure	Description
Trade facilitation (Rahman et al., 2021)	Efficient transport infrastructure enables the smooth movement of goods, reducing transportation costs and facilitating trade. This, in turn, stimulates economic activity and contributes to increased production and consumption.
Investment attraction (Donaldson & Hornbeck, 2016)	Well-developed transport networks make a country more attractive to investors, as they provide easier access to markets and resources. This can lead to increased foreign direct investment and domestic business expansion.
Job creation (Laborda & Sotelsek, 2019)	The construction, maintenance, and operation of transport infrastructure create job opportunities, both directly and indirectly. This includes jobs in construction, logistics, and related service industries.
Regional development (Hrushka et al., 2021)	Transport infrastructure connects different regions within a country, reducing regional disparities. Improved connectivity can lead to the development of previously isolated areas, promoting balanced economic growth.

Efficient logistics (Wheat et al., 2019)	Well-designed transport systems enhance the efficiency of logistics and supply chains. This results in faster and more reliable movement of goods, reducing delays and increasing overall productivity.
Urbanization and rural development (Chanieabate et al., 2023)	Improved transport infrastructure often leads to urbanization as people migrate to urban centers with better accessibility. This can contribute to the development of cities as economic hubs
Technological advancements (Koval et al., 2021; Oladimeji et al., 2023)	The development of transport infrastructure often involves the adoption of advanced technologies, driving innovation and technological progress within the country
Cultural exchange (Loyola et al., 2019)	Improved transport infrastructure facilitates easier movement of people, fostering cultural exchange and interaction. This can contribute to a more interconnected and culturally diverse society

Therefore, the effects of transport infrastructure on national growth are multifaceted, influencing economic, social, and environmental aspects. Strategic planning and sustainable development practices are essential to harness the positive impacts while mitigating potential drawbacks. We asked experts on the effects of transport infrastructure and the findings show that trade facilitation, job creation, and investments are of the biggest significance. At the same time, experts consider technological advancements and cultural exchange affects economic growth less significantly.

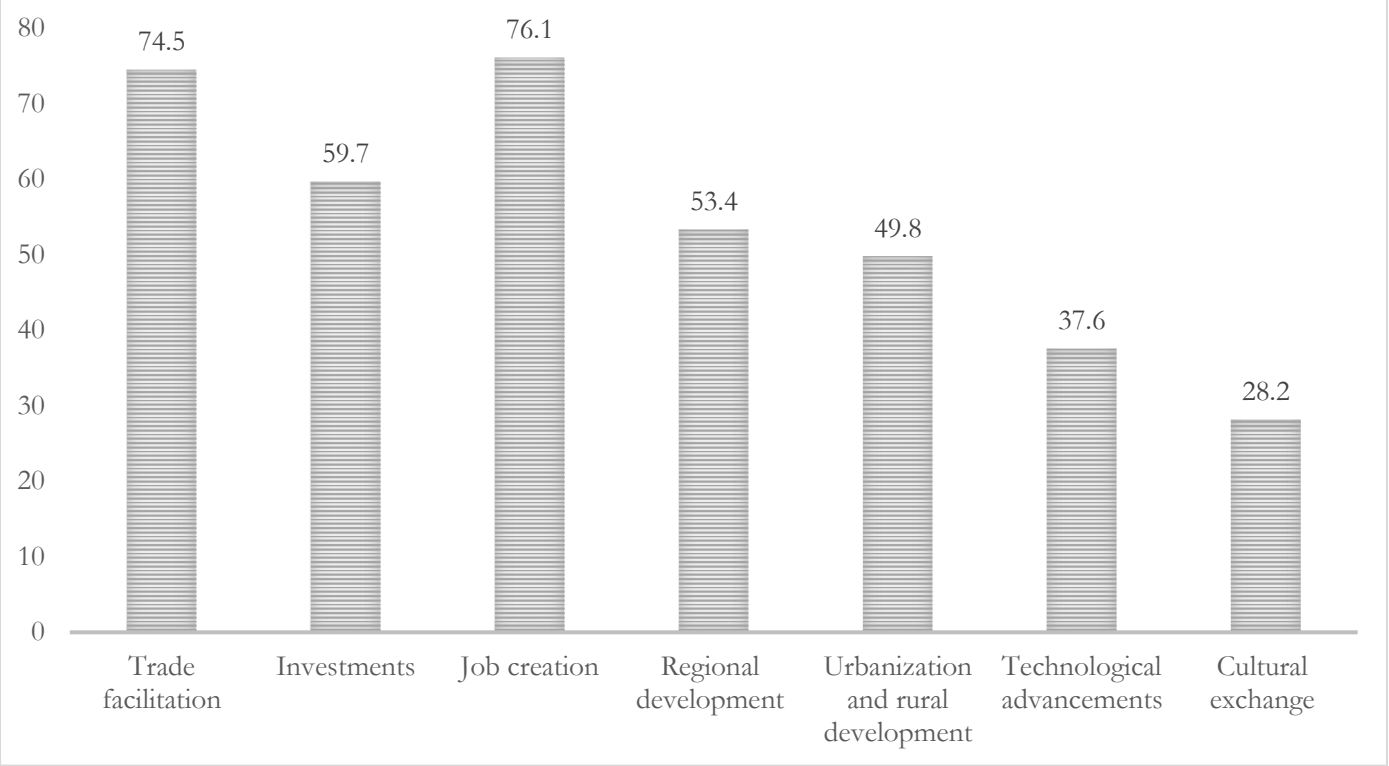

Figure 3. Experts' assessment of effects of transport infrastructure upon economic growth.

At the same time a number of research are devoted to sustainable transport infrastructure. Badassa et al. (2020) state that sustainable transport infrastructure refers to systems and facilities designed, constructed, and operated with a focus on minimizing negative environmental impacts. This includes measures to reduce carbon emissions, energy consumption, and ecological disruption while promoting the use of renewable energy sources and environmentally friendly construction materials (Kapur et al., 2021). Wang et al. (2018) suggest that sustainable transport infrastructure involves economically viable solutions that consider the long-term financial implications and benefits. This definition emphasizes the importance of cost-effectiveness, efficient resource utilization, and the creation of infrastructure that generates economic value over its lifecycle. Also, sustainable transport infrastructure aims to create inclusive and equitable systems that cater to the diverse needs of communities (Pagliara et al., 2020). This includes considerations for accessibility, affordability, and safety, ensuring that infrastructure development does not disproportionately impact vulnerable or marginalized groups. Conceição et al. (2023) define sustainability in transport

infrastructure as a construction that involves building resilient and adaptable systems capable of withstanding the impacts of climate change, natural disasters, and evolving technological trends. It deals with future-proofing infrastructure to ensure its continued functionality and relevance over time. In addition, we found that sustainable transport infrastructure is characterized by integrated and multimodal connectivity, promoting seamless movement of people and goods across various modes of transportation (Mashingaidze & Mutonhodza, 2024). This involves the development of interconnected networks that facilitate a shift towards more sustainable modes of transport, such as public transit, cycling, and walking, while minimizing reliance on single-occupancy vehicles.

These definitions collectively highlight the multifaceted nature of sustainable transport infrastructure, encompassing environmental, economic, social, and adaptive considerations. Achieving sustainability in transport infrastructure requires a holistic approach that addresses the interconnected challenges and opportunities associated with transportation systems (Kramar et al., 2019; Sami & Sara, 2023).

Sustainable transport infrastructure is characterized by several key features that prioritize environmental, economic, and social considerations. Figure 4 shows the essential characteristics of sustainable transport infrastructure.

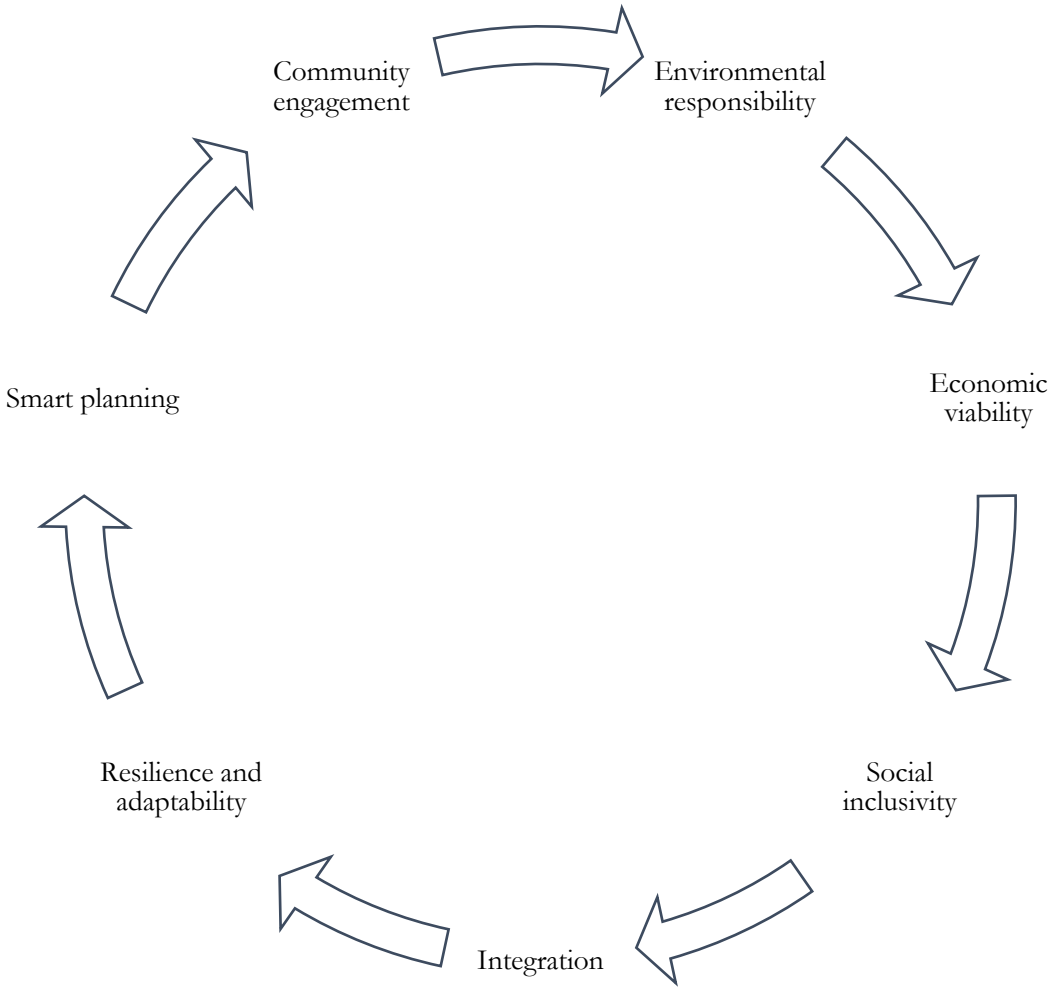

Figure 4. Experts' assessment of effects of transport infrastructure upon economic growth.

Environmental responsibility deals with minimization of negative impacts on the environment, including reduced carbon emissions, minimal habitat disruption, and responsible use of resources (Alghuson, 2023). Also, some researchers demand that the infrastructure incorporates environmentally friendly design principles, such as the use of renewable energy sources, energy-efficient technologies, and eco-friendly construction materials (Abu-Eisheh et al., 2020).

Economic viability means the fact that sustainable transport infrastructure is economically viable, considering both initial construction costs and long-term operational expenses (Komornicki & Goliszek, 2023). It prioritizes efficient resource utilization, life-cycle cost analysis, and the creation of value for the community and economy. The development and maintenance of sustainable transport infrastructure contribute to job creation (Laborda & Sotelsek, 2019), supporting local economies and enhancing social well-being.

Social inclusivity suggests that sustainable transport infrastructure prioritizes accessibility for all, ensuring that it meets the diverse needs of various demographic groups, including people with disabilities and those from marginalized communities (Batarlienė, 2020). It also addresses safety as a paramount consideration, encompassing measures to protect pedestrians, cyclists, and motorists (Conceição et al., 2023).

Integration across different modes of transportation creates connectivity between public transit, cycling, walking, and private vehicles (Netirith & Ji, 2022). Moreover, the infrastructure includes intelligent traffic management systems to optimize traffic flow, reduce congestion, and enhance overall transportation efficiency (Kramar et al., 2019).

Resilience and adaptability are orientation towards counteractions to the impacts of climate change, including extreme weather events and rising sea levels (Conceição et al., 2023). In addition, the infrastructure incorporates adaptable and future-proof technologies, allowing for easy integration of emerging transportation trends and innovations (Badassa et al., 2020).

Smart planning means that sustainable transport infrastructure aligns with smart urban planning principles, promoting compact, mixed-use development that reduces the need for extensive travel and supports local communities (Bamwesigye & Hlavackova, 2019).

Community engagement involves the active participation of the local community in the planning and decision-making processes, ensuring that the infrastructure meets the specific needs and preferences of the people it serves (Koval et al., 2021; Loyola et al., 2019).

These characteristics collectively contribute to the creation of transport infrastructure that balances economic development with environmental stewardship and social inclusivity, fostering a sustainable and resilient future. Figure 5 shows the experts assessments of effects of sustainable transport infrastructure. The findings demonstrate that community engagement and smart planning have the biggest effect. At the same time, environmental responsibility is characterized by less effect according to the respondents.

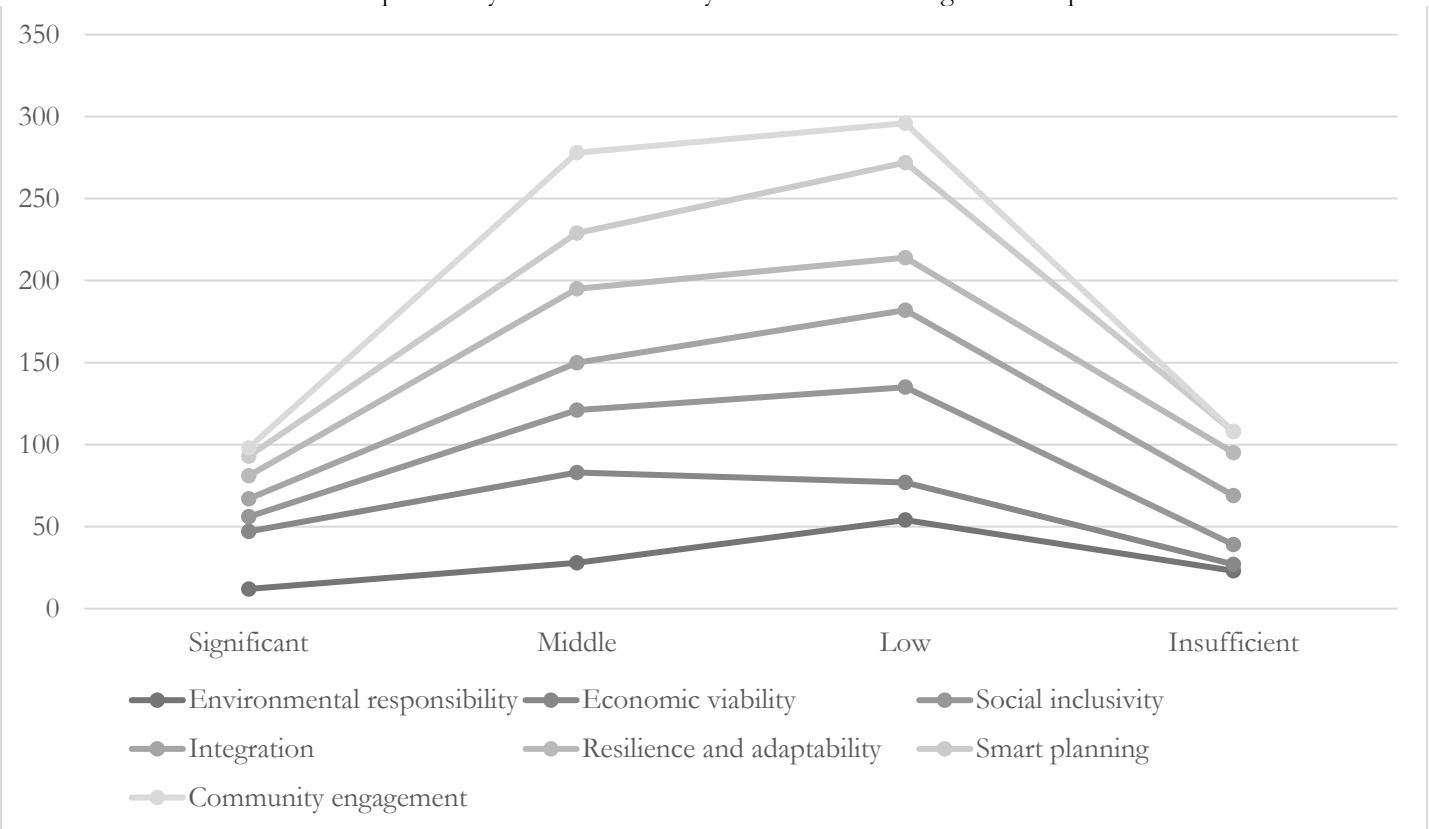

Figure 5. Experts' assessment of effects of sustainable transport infrastructure.

Therefore, implementing sustainable transport infrastructure is imperative for addressing pressing global challenges and fostering long-term societal well-being. By prioritizing environmentally responsible practices, sustainable transport infrastructure helps mitigate climate change by reducing carbon emissions, minimizing habitat disruption, and promoting the use of renewable energy sources (Alghuson, 2023). Economically, it ensures cost-effective solutions that create value, generate employment, and support local economies. Socially, sustainable transport infrastructure enhances accessibility for all, prioritizing safety, inclusivity, and community engagement (Koval et al., 2021). Moreover, it encourages efficient and integrated multimodal connectivity, reducing congestion and enhancing overall transportation efficiency (Conceição et al., 2023). Embracing sustainability in transport infrastructure is not just an ethical imperative; it is a strategic investment in a resilient, adaptable, and equitable future that balances economic growth with environmental stewardship and social progress that successfully addressing these challenges requires a comprehensive and adaptable approach, involving collaboration between employers, employees, governments, and other stakeholders (Badassa et al., 2020). It also involves ongoing efforts to understand and respond to the changing nature of work and the broader societal landscape. At the same time, to implement sustainable transport infrastructure it is necessary to develop specific recommendations that will consider the needs of all the stakeholders of the national economy.

4. Discussion

Implementing sustainable transport infrastructure in a national economy involves considering various conceptual and applicable approaches that focus on environmental, social, and economic aspects. Theoretical approaches to achieve sustainable transport infrastructure include integrated transportation planning (Ghafouri-Azar et al., 2023; Schwedes & Hoor, 2019); multimodal transport systems (Kramarz & Przybylska, 2021); green infrastructure development (Alghuson, 2023); smart technologies (Chakwizira, 2022); public-private partnerships (PPPs) for sustainable infrastructure (Ndlovu & Newman, 2022); behavioral change and demand management (Loyola et al., 2019); life cycle assessment (LCA) and environmental impact assessment (EIA) (Abu-Eisheh et al., 2020); social equity and accessibility (Batarlienė, 2020).

Integrated transportation planning emphasizes comprehensive planning that integrates various modes of transportation, land use, and urban development (Schwedes & Hoor, 2019). The goal is to create a seamless and efficient transportation system that reduces congestion, lowers emissions, and enhances accessibility (Ghafouri-Azar et al., 2023). Governments can adopt integrated planning frameworks that involve collaboration between transportation departments, urban planners, and environmental agencies. This ensures that transportation solutions align with broader sustainability goals.

Multimodal transport systems such as public transit, cycling, walking, and shared mobility, helps reduce reliance on individual car use (Kramarz & Przybylska, 2021). Investments in public transit, cycling infrastructure, and pedestrian-friendly urban spaces are essential (Donaldson & Hornbeck, 2016). Policies that encourage the integration of different modes, like bike-sharing programs or seamless transit connections, support the development of a multimodal transportation system.

Green infrastructure development focuses on creating transportation infrastructure that minimizes environmental impact and promotes ecological sustainability (Alghuson, 2023). Incorporating green design principles in infrastructure projects, such as green roofs, permeable pavements, and wildlife corridors, helps mitigate the environmental impact. Additionally, promoting the use of electric vehicles and renewable energy sources contributes to greener transportation.

Smart technologies can optimize transportation systems, enhance efficiency, and reduce environmental impact. Integrating smart technologies like intelligent traffic management systems, real-time information for commuters, and the use of data analytics for transportation planning can improve overall system efficiency and reduce emissions (Chakwizira, 2022).

PPPs for sustainable infrastructure involves collaboration between public and private sectors to finance, design, and operate sustainable transportation infrastructure projects (Ndlovu & Newman, 2022). Governments can encourage private sector involvement through well-structured PPPs, ensuring that the projects adhere to sustainability criteria. This approach can help overcome funding challenges and bring in innovative solutions.

Behavioral Change and Demand Management encourage changes in travel behavior and demand management strategies to reduce the overall need for transportation and promote sustainable modes (Loyola et al., 2019). Implementing measures like congestion pricing, promoting telecommuting, and providing incentives for using sustainable transportation modes can influence individual behaviors and reduce the demand for private car travel.

LCA and EIA consider the environmental impact of transportation projects throughout their entire life cycle, from construction to operation and decommissioning (Abu-Eisheh et al., 2020). Governments can mandate LCA and EIA as part of the planning and approval process for infrastructure projects. This ensures that the environmental consequences are thoroughly assessed, and sustainability measures are incorporated (Kapur et al., 2021).

Social equity and accessibility emphasize the importance of providing accessible and equitable transportation solutions for all members of society (Batarlienė, 2020). Prioritizing public transit in underserved areas, ensuring affordability, and addressing the needs of vulnerable populations in transportation planning contribute to social equity and accessibility.

Implementing these conceptual approaches requires a coordinated effort from governments, private sector stakeholders, and the community. Successful implementation often involves a combination of policies, regulations, incentives, and public awareness campaigns to drive sustainable change in the transportation sector.

At the same time, sustainable transport infrastructure in a national economy is implemented through a number of applicable approaches that can be translated into actionable initiatives. These practical strategies are the following: investment in public transit (Raza et al., 2023); promotion of non-motorized transportation (Das et al., 2022; Shah et al., 2023); incentives for electric vehicles (EVs) (Alghuson, 2023; Chakwizira, 2022; Du et al., 2022); congestion pricing (Cipriani et al., 2019); urban planning for transit-oriented development (TOD) (Ghafouri-Azar et al., 2023); fleet modernization and efficiency programs (Wheat et al., 2019); smart traffic management systems (Chakwizira, 2022; Raza et al., 2023); community engagement and education (Babaei et al., 2023); regulatory measures and standards (Jelti et al., 2023).

Investment in public transit is oriented towards the increase funding for the development and maintenance of reliable and extensive public transit systems, including buses, subways, light rail, and commuter trains. This investment is typically initiated through a comprehensive planning process that begins with a thorough assessment of transportation needs within a community or region (Koval et al., 2021; Loyola et al., 2019). Governments and transportation authorities identify areas facing congestion, evaluate existing transit infrastructure, and anticipate future demands. Based on these findings, strategic plans are developed to outline the objectives and priorities for improving public transit. Project proposals are then formulated, detailing the scope, costs, and expected outcomes of specific initiatives. Securing funding is a critical aspect of implementation, involving budget allocations from government sources, grants, public-private partnerships, and sometimes dedicated transit-related taxes or fees. Stakeholder engagement is essential during this phase, ensuring that the proposed projects align with community expectations. Regulatory approvals, including environmental impact assessments and necessary permits, are obtained to move forward with the proposed transit infrastructure projects.

Once funding and approvals are secured, the implementation phase kicks off with the design and engineering of transit infrastructure. This involves creating detailed plans for routes, stations, and associated facilities, with a focus on cost estimation and accuracy. Construction follows, with tenders issued and contracts awarded through a competitive bidding process. Rigorous project management and oversight are crucial to ensure that construction adheres to specifications, timelines, and budget constraints. The integration of smart transit systems, such as real-time tracking and electronic ticketing, enhances operational efficiency and user experience (Raza et al., 2023). After construction, thorough testing and commissioning take place, ensuring the safety and reliability of the transit system before gradually introducing services to the public. Ongoing maintenance, routine monitoring, and continuous evaluation of performance complete the implementation cycle, allowing for adjustments and improvements as needed. Throughout this process, collaboration among various stakeholders, including government entities, private sector partners, and the public, remains pivotal for the successful implementation of public transit investments.

Promotion of non-motorized transportation involves a multifaceted approach aimed at creating infrastructure, policies, and incentives that encourage walking, cycling, and other sustainable modes of travel (Shah et al., 2023). The implementation begins with urban planning that prioritizes the development of pedestrian and cycling-friendly infrastructure. This includes

the construction of dedicated bike lanes, pedestrian pathways, and shared spaces designed to enhance safety and accessibility. Many agents are to collaborate to integrate non-motorized infrastructure into existing urban landscapes, creating a comprehensive network that connects residential areas, business districts, and public spaces. Implementing traffic-calming measures, such as reduced speed limits and traffic signal prioritization for pedestrians and cyclists, also contributes to the promotion of non-motorized transportation. In addition, public awareness campaigns are launched to educate residents about the benefits of walking and cycling, fostering a cultural shift toward embracing these modes as viable and healthy alternatives to motorized transport (Alghuson, 2023).

Policy interventions play a crucial role in the promotion of non-motorized transportation. Local governments may enact zoning regulations that encourage mixed-use developments, ensuring that essential services, workplaces, and recreational areas are situated within convenient walking or cycling distances (Das et al., 2022). Incentive programs, such as bike-sharing initiatives and subsidies for purchasing bicycles or related equipment, further encourage the adoption of non-motorized modes. Legislative measures may include the implementation of strict parking policies to discourage car use in city centers and the designation of car-free zones. Collaboration with businesses and employers to provide amenities such as bike storage facilities and showers for cyclists contributes to a supportive environment for non-motorized commuting. Ultimately, successful implementation requires ongoing community engagement, monitoring of infrastructure usage, and a commitment to refining policies and infrastructure based on feedback and evolving transportation needs.

Incentives for EVs are typically implemented through a combination of financial, regulatory, and infrastructure support measures (Chakwizira, 2022). Governments may offer financial incentives such as tax credits, rebates, or grants to reduce the upfront cost of purchasing an electric vehicle. Additionally, subsidies for installing home or workplace charging stations may be provided to enhance charging infrastructure. Regulatory measures may include exemptions or reductions in vehicle registration fees, tolls, or access to congestion zones for electric vehicles. In some cases, preferential treatment, such as priority parking or access to high-occupancy vehicle lanes, is granted to EV owners. Collaboration with the private sector, including partnerships with automakers and utilities, can also play a role in offering discounts or special financing options for electric vehicles. The aim is to create a supportive ecosystem that not only makes electric vehicles more financially attractive but also addresses concerns related to charging infrastructure and operational convenience, thereby encouraging a broader adoption of sustainable transportation alternatives (Du et al., 2022).

Congestion pricing plays a pivotal role in fostering sustainable transport infrastructure by addressing traffic congestion, reducing emissions, and encouraging the adoption of eco-friendly transportation modes (Cipriani et al., 2019). By imposing fees during peak hours or in congested areas, this strategy incentivizes commuters to shift towards public transit, carpooling, cycling, or walking, thereby diminishing the reliance on individual vehicles. The resulting decrease in traffic congestion not only enhances transportation efficiency but also contributes to improved air quality and reduced carbon emissions. Moreover, the revenue generated from congestion pricing can be reinvested into sustainable transportation projects, funding initiatives such as public transit expansion, cycling infrastructure, and pedestrian-friendly urban spaces. Overall, congestion pricing stands as a powerful tool to optimize road capacity, promote environmental sustainability, and shape more resilient and efficient urban transportation systems.

Urban planning for TOD is a key component of sustainable transport infrastructure, designed to create vibrant, efficient, and environmentally friendly urban environments (Bamwesigye & Hlavackova, 2019). TOD focuses on strategically locating and designing development projects, such as housing, commercial spaces, and recreational areas, around public transit hubs. This approach encourages residents to use public transportation options, reducing dependence on private vehicles and mitigating traffic congestion. In a TOD system, transit stations become focal points for mixed-use developments, creating pedestrian-friendly neighborhoods where people can live, work, and access amenities within walking distance of transit nodes (Ghafouri-Azar et al., 2023). The planning process involves collaboration between urban planners, transportation authorities, and local communities. Zoning regulations are often adjusted to allow for higher-density developments near transit stations, fostering a more compact urban form. Pedestrian and cycling infrastructure are prioritized to enhance accessibility to transit nodes and promote sustainable modes of transportation. Additionally, green spaces and public areas are integrated into the urban fabric to create a

sense of community and improve the overall quality of life. By fostering dense, walkable communities centered around transit, TOD not only contributes to reduced car dependency but also promotes social interaction, economic vitality, and a more resilient and sustainable urban environment.

Fleet modernization and efficiency programs play a vital role in the development of sustainable transport infrastructure by addressing the environmental impact of transportation fleets. This strategy focuses on upgrading and optimizing vehicle fleets, both in the public and private sectors, to reduce emissions, enhance fuel efficiency, and embrace cleaner technologies. In the context of public transportation, fleet modernization involves replacing older, less fuel-efficient vehicles with newer models that adhere to higher environmental standards (Wheat et al., 2019). This may include the introduction of electric buses or vehicles powered by alternative fuels, contributing to a reduction in greenhouse gas emissions and air pollutants. Efficiency programs within fleet management encompass initiatives aimed at optimizing the operational performance of vehicles. This can involve implementing maintenance schedules to ensure vehicles operate at peak efficiency, utilizing telematics and data analytics for route optimization, and adopting eco-driving practices. Furthermore, integrating smart technologies into fleet management systems can enhance overall efficiency by providing real-time information on fuel consumption, vehicle performance, and emissions.

Smart traffic management systems are integral components of sustainable transport infrastructure, leveraging advanced technologies to optimize traffic flow, enhance efficiency, and reduce environmental impact (Chakwizira, 2022). These systems incorporate real-time data analytics, sensors, and intelligent algorithms to monitor and manage traffic patterns dynamically. By providing real-time information to commuters, these systems enable better decision-making, reduce congestion, and minimize travel time. Additionally, smart traffic management contributes to lower fuel consumption and emissions by facilitating smoother traffic flow and minimizing idling times (Raza et al., 2023). Through adaptive signal controls, predictive modeling, and integration with other smart city technologies, these systems support a more sustainable urban transportation landscape, aligning with the goals of reducing environmental impact and enhancing the overall efficiency of the transportation network.

Community engagement and education are crucial elements in the development of sustainable transport infrastructure, fostering a sense of inclusivity, awareness, and shared responsibility among residents (Babaei et al., 2023). In the context of sustainable transportation, community engagement involves involving local residents, businesses, and stakeholders in the planning and decision-making processes. Public forums, workshops, and outreach programs are organized to gather input, address concerns, and build a shared vision for transportation initiatives. Education plays a pivotal role in raising awareness about the benefits of sustainable transport modes, such as public transit, cycling, and walking. Campaigns may focus on the environmental, health, and economic advantages of reducing reliance on private vehicles. Furthermore, educational initiatives provide information on alternative transportation options, safety measures, and the broader impact of sustainable transport choices. By actively involving the community and fostering a deeper understanding of sustainable transport practices, infrastructure projects can gain broader support, encouraging behavioral shifts and creating a more resilient and environmentally conscious urban environment.

Regulatory measures and standards are essential components of a sustainable transport infrastructure system, providing a framework to guide and enforce environmentally responsible practices (Jelti et al., 2023). Governments often establish regulations to set emission standards for vehicles, encouraging the adoption of cleaner technologies and reducing the environmental impact of transportation. Additionally, fuel efficiency standards may be implemented to incentivize the use of energy-efficient vehicles. Zoning regulations and land-use policies play a role in promoting sustainable urban development and transit-oriented design, encouraging compact and walkable communities. Some jurisdictions also introduce measures like congestion pricing or road tolls to manage traffic flow and reduce the environmental footprint of individual car travel. By enforcing these regulations, authorities aim to align transportation practices with sustainability goals, promote the use of public transit, and create a more eco-friendly and efficient transport system. Continuous monitoring and updates to these regulatory frameworks are essential to adapt to evolving technologies and ensure sustained progress towards a more sustainable transportation landscape.

Therefore, the implementation of sustainable transport infrastructure is a multifaceted endeavor that requires a comprehensive and collaborative approach. From theoretical frameworks to practical measures, creating a transport system that is environmentally responsible, socially equitable, and economically viable demands strategic planning,

innovative solutions, and ongoing commitment. Integrating concepts such as integrated transportation planning, multimodal systems, green infrastructure, and smart technologies is essential to build a resilient and efficient network. Additionally, public-private partnerships, regulatory measures, and community engagement play vital roles in overcoming challenges and fostering widespread adoption of sustainable transportation practices. As we strive towards a future with reduced emissions, enhanced accessibility, and improved urban livability, it is imperative to continue investing in and refining sustainable transport infrastructure, recognizing its pivotal role in shaping resilient and environmentally conscious societies.

5. Conclusions

Sustainable development of transport infrastructure within the national economy stands as a multifaceted challenge and opportunity, requiring a nuanced understanding of the interconnected realms of economics, environment, and societal well-being. Through an exploration of theoretical frameworks and practical approaches, it becomes evident that fostering sustainable transport infrastructure is not merely a technical endeavor but a transformative process that necessitates a holistic and integrated perspective.

Theoretical approaches, such as integrated transportation planning and multimodal systems, underscore the importance of cohesion in development strategies. The idea of integrating various modes of transportation, land use, and urban planning into a unified framework has shown promise in creating more efficient, accessible, and environmentally responsible transport systems. However, the translation of these theoretical frameworks into actionable policies and projects requires a concerted effort from governments, urban planners, and community stakeholders.

Practical approaches, ranging from investments in public transit to incentives for electric vehicles, form the backbone of actualizing sustainable transport infrastructure. Investment in public transit, as seen in numerous successful case studies, is pivotal for reducing dependency on individual cars and promoting more sustainable commuting habits. The promotion of non-motorized transportation, through the development of cycling infrastructure and pedestrian-friendly urban spaces, not only contributes to environmental sustainability but also fosters healthier and more livable cities. Incentives for electric vehicles, coupled with the expansion of charging infrastructure, accelerate the transition towards cleaner and greener transportation options.

Smart traffic management systems emerge as technological solutions that optimize existing infrastructure and improve overall transport efficiency. These systems, employing real-time data and intelligent algorithms, have the potential to significantly reduce congestion, enhance safety, and contribute to a more fluid and sustainable traffic environment. The incorporation of such smart technologies aligns with the broader goals of creating resilient and adaptable transport systems capable of addressing the evolving needs of growing urban populations. In addition, PPPs have demonstrated their effectiveness in financing, designing, and operating sustainable transport projects. The collaboration between government entities and private sector stakeholders can overcome financial constraints, stimulate innovation, and expedite the implementation of critical infrastructure projects. However, the success of PPPs depends on robust governance structures, clear regulatory frameworks, and a shared commitment to sustainability.

Also, regulatory measures and standards play a pivotal role in shaping the direction of sustainable transport infrastructure. From emission standards to land-use policies, these regulations guide the behavior of stakeholders within the transport sector. They set the bar for vehicle efficiency, influence urban development patterns, and, when well-crafted, contribute to the creation of a transport system aligned with environmental and societal sustainability. We found that community engagement and education are oriented towards sustainable transport initiatives. An informed and engaged community is more likely to embrace and actively participate in the transition towards sustainable transportation practices. Local input is critical in ensuring that projects align with the unique needs and values of the community, and education campaigns foster a deeper understanding of the benefits associated with sustainable transport choices.

In conclusion, the sustainable development of transport infrastructure is a dynamic and ongoing process that requires a delicate balance between various stakeholders, innovative technologies, and evolving societal expectations. The integration of sustainable principles into the transport sector is not just an imperative for environmental conservation; it is an

investment in the resilience, efficiency, and well-being of our communities. As we move forward, it is paramount to build on the insights from theoretical approaches and practical implementations, leveraging the collective wisdom gained to create transport systems that truly serve the needs of the present without compromising the ability of future generations to meet their own.

Further studies could explore several avenues to deepen our understanding and refine sustainable practices within the transportation sector, including long-term impact of sustainable transport infrastructure projects; comparative analyses of sustainable transport practices across different nations or regions; behavioral aspects of sustainable transport adoption; and the role of emerging technologies, such as autonomous vehicles, artificial intelligence, and blockchain, in enhancing sustainable transport infrastructure. Investigating these areas, researchers can contribute to the ongoing refinement of sustainable transport infrastructure, ensuring that future initiatives are informed by a comprehensive understanding of their economic, environmental, and social implications.

References

Abu-Eisheh, S., Kuckshinrichs, W., & Dwaikat, A. (2020). Strategic Planning for Sustainable Transportation in Developing Countries: The Role of Vehicles. *Transportation Research Procedia, 48*, 3019-3036. https://doi.org/10.1016/j.trpro.2020.08.184

Alam, M., Dappe, M. H., Melecky, M., & Goldblatt, R. (2022). Wider economic benefits of transport corridors: Evidence from international development organizations. *Journal of Development Economics, 158*, 102900. https://doi.org/10.1016/j.jdeveco.2022.102900

Alghuson, M. (2023). Exploring the Transport Infrastructure Sustainability Performance: An Investigation of the Transportation Projects in Saudi Arabia. *Sustainability, 15*(19), 14174. https://doi.org/10.3390/su151914174

Babaei, A., Locatelli, G., & Sainati, T. (2023). Local community engagement as a practice: an investigation of local community engagement issues and their impact on transport megaprojects' social value. *International Journal of Managing Projects in Business, 16*(3), 448-474. https://doi.org/10.1108/IJMPB-10-2022-0224

Badassa, B. B., Sun, B., & Qiao, L. (2020). Sustainable Transport Infrastructure and Economic Returns: A Bibliometric and Visualization Analysis. *Sustainability, 12*(5), 2033. https://doi.org/10.3390/su12052033

Bamwesigye, D., & Hlavackova, P. (2019). Analysis of Sustainable Transport for Smart Cities. *Sustainability, 11*(7), 2140. https://doi.org/10.3390/su11072140

Batarlienė, N. (2020). Improving Safety of Transportation of Dangerous Goods by Railway Transport. *Infrastructures, 5*(7), 54. https://doi.org/10.3390/infrastructures5070054

Bureau, D. (2011). Public transport infrastructure, urban sprawl, and post-carbon cities. *Recherches économiques de Louvain, 77*, 125-139. https://doi.org/10.3917/rel.772.0125

Burinskiene, A. (2022). The Concept Towards Transportation Infrastructure and Its Capacity. In: *Development of Smart Context-Aware Services for Cargo Transportation. International Series in Operations Research & Management Science*, vol 330. Springer, Cham. https://doi.org/10.1007/978-3-031-07199-7_12

Chakwizira, J. (2022). Stretching resilience and adaptive transport systems capacity in South Africa: Imperfect or perfect attempts at closing COVID -19 policy and planning emergent gaps. *Transport Policy, 125*, 127-150. https://doi.org/10.1016/j.tranpol.2022.06.003

Chanieabate, M., He, H., Guo, C., Abrahamgeremew, B., & Huang, Y. (2023). Examining the Relationship between Transportation Infrastructure, Urbanization Level and Rural-Urban Income Gap in China. *Sustainability, 15*(10), 8410. https://doi.org/10.3390/su15108410

Cipriani, E., Mannini, L., Montemarani, B., Nigro, M., & Petrelli, M. (2019). Congestion pricing policies: Design and assessment for the city of Rome, Italy. *Transport Policy, 80*, 127-135. https://doi.org/10.1016/j.tranpol.2018.10.004

Conceição, M. A., Monteiro, M. M., Kasraian, D., van den Berg, P., Haustein, S., Alves, I., Azevedo, C. L., & Miranda, B. (2023) The effect of transport infrastructure, congestion and reliability on mental wellbeing: a systematic review of empirical studies. *Transport Reviews, 43*(2), 264-302. https://doi.org/10.1080/01441647.2022.2100943

Čuš-Babič, N., Guerra De Oliveira, S. F., & Tibaut, A. (2022). Interoperability of Infrastructure and Transportation Information Models: A Public Transport Case Study. *Applied Sciences, 12*(12), 6234. https://doi.org/10.3390/app12126234

Das, D., Kalbar, P. P., & Velaga, N. R. (2022). Role of non-motorized transportation and buses in meeting climate targets of urban regions. *Sustainable Cities and Society, 86*, 104116. https://doi.org/10.1016/j.scs.2022.104116

Donaldson, D., & Hornbeck, R. (2016). Railroads and American economic growth: a "market access" approach. *The Quarterly Journal of Economics, 131*(2), 799–858. https://www.jstor.org/stable/26372653

Du, X., Zhang, H., & Han, Y. (2022). How Does New Infrastructure Investment Affect Economic Growth Quality? Empirical Evidence from China. *Sustainability, 14*(6), 3511. https://doi.org/10.3390/su14063511

Felbermayr, G., & Tarasov, A. (2021). Trade and the spatial distribution of transport infrastructure. *Kiel Working Paper, 2181*. Kiel Institute for the World Economy (IfW), Kiel. http://hdl.handle.net/10419/233877

Ghafouri-Azar, M., Diamond, S., Bowes, J., & Gholamalizadeh, E. (2023). The sustainable transport planning index: A tool for the sustainable implementation of public transportation. *Sustainable Development, 31*(4), 2656–2677. https://doi.org/10.1002/sd.2537

Gonzalez-Navarro, M., Zarate, R. D., Jedwab, R., & Tsivanidis N. (2023). Land Transport Infrastructure. *VoxDevLit, 9*(1). https://voxdev.org/sites/default/files/2023-12/Land_Transport_Infrastructure_Issue_1.pdf

Gutiérrez, J., Monzón, A., & Piñero, J. M. (1998). Accessibility, Network Efficiency, and Transport Infrastructure Planning. *Environment and Planning A: Economy and Space, 30*(8), 1337-1350. https://doi.org/10.1068/a301337

Hashchuk, P., & Tymoshenko, Yu. (2020). Definition and Content of the Concept "Transport System". *Bulletin of Lviv State University of Life Safety, 22*, 66-77. doi:10.32447/20784643.22.2020.09
Hrushka, V., Horozhankina, N., Boyko, Z., Korneyev, M., & Nebaba, N. (2021). Transport infrastructure of Spain as a factor in tourism development. *Journal of Geology, Geography and Geoecology, 30*(3), 429-440. https://doi.org/https://doi.org/10.15421/112139
Hybel, J., & Mulalic, I. (2022). Transportation and quality of life: Evidence from Denmark. *Transportation Research Part A: Policy and Practice, 157*, 107-125. https://doi.org/10.1016/j.tra.2021.12.003
Jasim, I. A., Al-Jaberi, A. A., Al-Maliki, L. A., Al-Ansari, N., & Al-Mamoori, S. K. (2022) Do the population density and coverage rate of transit affect the public transport contribution? *Cogent Engineering, 9*(1). https://doi.org/10.1080/23311916.2022.2143059
Jelti, F., Allouhi, A., & Tabet Aoul, K. A. (2023). Transition Paths towards a Sustainable Transportation System: A Literature Review. *Sustainability, 15*(21), 15457. https://doi.org/10.3390/su152115457
Kapur, R., Das, S., Nandineni, R. D. (2021). Sustainable Transportation Infrastructure's Role in Attaining Sustainable Development Goals. In: Leal Filho, W., Azul, A. M., Brandli, L., Lange Salvia, A., Wall, T. (eds) *Industry, Innovation and Infrastructure. Encyclopedia of the UN Sustainable Development Goals.* Springer, Cham. https://doi.org/10.1007/978-3-319-95873-6_52
Khadim, Z., Batool, I., Akbar, A., Poulova, P., & Akbar, M. (2021). Mapping the Moderating Role of Logistics Performance of Logistics Infrastructure on Economic Growth in Developing Countries. *Economies, 9*(4), 177. https://doi.org/10.3390/economies9040177
Komornicki, T., & Goliszek, S. (2023). New Transport Infrastructure and Regional Development of Central and Eastern Europe. Sustainability, 15(6), 5263. https://doi.org/10.3390/su15065263
Koval, V., Neboha, T., & Nesenenko, P. (2021). Institutional Provision of Infocommunication Sphere Development in the Conditions of Digitalization of National Economy. *Economics. Ecology. Socium, 5*, 18-29. https://doi.org/10.31520/2616-7107/2021.5.2-3
Kramar, U., Dragan, D., & Topolšek, D. (2019). The Holistic Approach to Urban Mobility Planning with a Modified Focus Group, SWOT, and Fuzzy Analytical Hierarchical Process. *Sustainability, 11*(23), 6599. https://doi.org/10.3390/su11236599
Kramarz, M., & Przybylska, E. (2021). Multimodal Transport in the Context of Sustainable Development of a City. *Sustainability, 13*(4), 2239. https://doi.org/10.3390/su13042239
Laborda, L., & Sotelsek, D. (2019). Effects of Road Infrastructure on Employment, Productivity and Growth: An Empirical Analysis at Country Level. *Journal of Infrastructure Development, 11*(1-2), 81-120. https://doi.org/10.1177/0974930619879573
Lai, Q. (2020) The Transportation Infrastructure and Regional Economic Growth—Evidence from Dongguan Humen Bridge. Modern Economy, 11, 2055-2080. https://doi.org/10.4236/me.2020.1112137
Lee, J., Arts, J., Vanclay, F., & Ward, J. (2020). Examining the Social Outcomes from Urban Transport Infrastructure: Long-Term Consequences of Spatial Changes and Varied Interests at Multiple Levels. *Sustainability, 12*(15), 5907. https://doi.org/10.3390/su12155907
Li, W., Bai, X., Yang, D., Hou, Y. (2023). Maritime connectivity, transport infrastructure expansion and economic growth: A global perspective. *Transportation Research Part A: Policy and Practice, 170*, 103609. https://doi.org/10.1016/j.tra.2023.103609
Loyola, M., Shiftan, Y., Aviram, H., & Monterde-i-Bort, H. (2019). Impact of Public Transport Context Situation and Culture on Mode Choice. *Social Sciences, 8*(2), 40. https://doi.org/10.3390/socsci8020040
Marcucci, E., & Stathopoulos, A. (2012). Multi-level governance and transport policy: The case of local roads in Italy. *International Journal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti, 39*(1), 15–38. http://www.jstor.org/stable/42748292
Mashingaidze, N., & Mutonhodza, C. (2024). The Search for Sustainable Transport Infrastructure in Harare: Integrating Intelligent Transport Systems. In: Chirisa, I., Matamanda, A. R. (eds) *Urban Infrastructure in Zimbabwe. The Urban Book Series.* Springer, Cham. https://doi.org/10.1007/978-3-031-45568-1_4
Mazzola, F., Cirà, A., Ruggieri, G., & Butler, R. (2022). Air transport and tourism flows to islands: A panel analysis for southern European countries. *International Journal of Tourism Research, 24*(5), 639–652. https://doi.org/10.1002/jtr.2527
Ndlovu, V., & Newman, P. (2022) A Public-Private Partnership Procurement Approach to Sustainable Transport – Zimbabwe Case. *Journal of Transportation Technologies, 12*, 600-618. https://doi.org/10.4236/jtts.2022.124035
Nenavath, S. (2023). Does transportation infrastructure impact economic growth in India? *Journal of Facilities Management, 21*(1), 1-15. https://doi.org/10.1108/JFM-03-2021-0032
Netirith, N., & Ji, M. (2022). Analysis of the Efficiency of Transport Infrastructure Connectivity and Trade. *Sustainability, 14*(15), 9613. https://doi.org/10.3390/su14159613
Ngampravatdee, C., Gharehbaghi, K., Hosseinian-Far, A., Tee, K. F., & McManus, K. (2023). Strategic Initiatives for Large Transport Infrastructure Planning: Reinforcing Sustainability in Urban Transportation through Better Stakeholder Engagement. *Sustainability, 15*(18), 13912. https://doi.org/10.3390/su151813912
Olabanji, O. M, & Mpofu, K. (2022). Assessing the sustainability of manufacturing processes in the manufacture of transport equipment, based on fuzzy grey relational analysis. *South African Journal of Industrial Engineering, 33*(1), 39-50. https://dx.doi.org/10.7166/33-1-2453
Oladimeji, D., Gupta, K., Kose, N. A., Gundogan, K., Ge, L., & Liang, F. (2023). Smart Transportation: An Overview of Technologies and Applications. *Sensors, 23*(8), 3880. https://doi.org/10.3390/s23083880
Pagliara, F., Hayashi, Y., & Ram, K. S. (2022). High-Speed Rail, Equity and Inclusion. *Sustainability, 14*(11), 6710. https://doi.org/10.3390/su14116710
Rahman, I. U., Shafi, M., Junrong, L., Fetuu, E. T. M. K., Fahad, S., & Sharma, B. P. (2021). Infrastructure and Trade: An Empirical Study Based on China and Selected Asian Economies. *SAGE Open, 11*(3). https://doi.org/10.1177/21582440211036082
Raza, A., Zhong, M.,Akuh, R., Safdar, M. (2023). Public transport equity with the concept of time-dependent accessibility using Geostatistics methods, Lorenz curves, and Gini coefficients. *Case Studies on Transport Policy, 11*, 100956. https://doi.org/10.1016/j.cstp.2023.100956
Sami, M., & Sara, K. (2023). Intelligent Transportation Systems for Sustainable Urban Environments. *International Journal of Advanced Natural Sciences and Engineering Researches, 7*(9), 166–177. https://doi.org/10.59287/ijanser.1525
Scholten, K., van Donk, D. P., Power, D., & Braeuer, S. (2023). Contextualizing resilience to critical infrastructure maintenance supply networks. *Supply Chain Management, 28*(7), 1-14. https://doi.org/10.1108/SCM-02-2022-0078

Schwedes, O., & Hoor, M. (2019). Integrated Transport Planning: From Supply- to Demand-Oriented Planning. Considering the Benefits. *Sustainability, 11*(21), 5900. https://doi.org/10.3390/su11215900

Ševčenko-Kozlovska, G., & Čižiūnienė, K. (2022). The Impact of Economic Sustainability in the Transport Sector on GDP of Neighbouring Countries: Following the Example of the Baltic States. *Sustainability, 14(*6), 3326. https://doi.org/10.3390/su14063326

Shah, S., Jaya, V. M., & Piludaria, N. (2023). Key Levers to Reform Non-Motorized Transport: Lessons From the COVID-19 Pandemic. *Transportation Research Record, 2677*(4), 880-891. https://doi.org/10.1177/03611981221117538

Skorobogatova, O., & Kuzmina-Merlino, I. (2017). Transport Infrastructure Development Performance. *Procedia Engineering, 178*, 319-329. https://doi.org/10.1016/j.proeng.2017.01.056

Sładkowski, A., & Cieśla, M. (2018). Analysis and Development Perspective Scenarios of Transport Corridors Supporting Eurasian Trade. In: Sładkowski, A. (eds) *Transport Systems and Delivery of Cargo on East–West Routes. Studies in Systems, Decision and Control*, vol 155. Springer, Cham. https://doi.org/10.1007/978-3-319-78295-9_2

Trinh, T. A., Seo, D., Kim, U., Phan, T. N. Q., Nguyen, T. H. H. (2022). Air Transport Centrality as a Driver of Sustainable Regional Growth: A Case of Vietnam. *Sustainability, 14*(15), 9746. https://doi.org/10.3390/su14159746

Turan, B., Hemmelmayr, V., Larsen, A., & Puchinger, J. (2023). Transition towards sustainable mobility: the role of transport optimization. *Central European Journal of Operations Research, 2023*. https://doi.org/ff10.1007/s10100-023-00888-8

Vlahinić Lenz, N., Skender, H. P., & Mirković, P. A. (2018) The macroeconomic effects of transport infrastructure on economic growth: the case of Central and Eastern E.U. member states. *Economic Research-Ekonomska Istraživanja, 31*(1), 1953-1964. DOI: 10.1080/1331677X.2018.1523740

Voitko, S., Naraievskyi, S., & Trofymenko, O. (2022). Development of Energy Supply Infrastructure Based on Industry 4.0 (on the Example of Ukraine and Turkey). *Ekonomika, 101*(2), 70-91. https://doi.org/10.15388/Ekon.2022.101.2.5

Wang, L., Xue, X., Zhao, Z., & Wang, Z. (2018). The Impacts of Transportation Infrastructure on Sustainable Development: Emerging Trends and Challenges. *International journal of environmental research and public health, 15*(6), 1172. https://doi.org/10.3390/ijerph15061172

Wheat, P., Stead, A. D., Huang, Y., & Smith, A. (2019). Lowering Transport Costs and Prices by Competition: Regulatory and Institutional Reforms in Low Income Countries. *Sustainability, 11*(21), 5940. https://doi.org/10.3390/su11215940

Zhang, Y., & Cheng, L. (2023). The role of transport infrastructure in economic growth: Empirical evidence in the UK. *Transport Policy, 133*, 223-233. https://doi.org/10.1016/j.tranpol.2023.01.017