

Study on the Role and Contribution of Sustainable Transport

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Abstract: The transportation sector has emerged as a significant contributor to global energy consumption, leading to a disparity between the rates of resource formation and extraction. Consequently, sustainability targets have been established in numerous countries; however, only a limited number of them have made substantial progress toward achieving these objectives. This paper will investigate how sustainable promotion could simultaneously improve social, environmental, and economic sustainability. Socially, it emphasizes that social equity can be advanced by upgrading the accessibility of vulnerable groups of people through service adjustment and subsidy provision of public transport. Environmentally, carbon emission mitigation is considered the primary priority of transportation, so low-carbon infrastructure and electric vehicles are applied in urban. Economically, public transport allows shorter commutation time for workers, and also provides employment opportunities for the unemployed group, shortening the gap of economic inequality. Those sustainable transportation strategies improve sustainability in various fields, efforts from social, environmental and economic measurement also return positive, eco-friendly and equitable impacts toward development, leading to a virtuous circulation in urban areas.

Keywords: Sustainable transportation, Urban sustainability, Low-Carbon Infrastructure

1. Introduction

In recent years, the transport industry has experienced a consistent increase in energy demand. In some European countries, the transport sector has accounted for one-third of total energy consumption over the last decade [1]. Meanwhile, transportation has been identified as one of the most challenging areas in achieving sustainable development [2]. Despite some nations' advancements, energy consumption largely remains reliant on traditional sources, with only a few countries significantly adopting renewables. While some have pivoted towards geothermal and hydroelectric energy, fossil fuels continue to dominate. For instance, data from November 2023 to October 2024 indicates that fossil fuels constituted approximately 62% of China's energy mix [3]. This partial transition indicates that significant progress is still required to meet sustainability objectives. This research aims to discuss methods for promoting sustainable transportation while advancing social, environmental, and economic sustainability simultaneously in urban areas. Furthermore, it provides valuable perspectives for nations shifting from conventional energy consumption frameworks to more sustainable practices.

2. Sustainable Transportation Promotes social Sustainability

2.1. Social Sustainability

Social sustainability is a broad concept which emerged to maintain the balance between ecological and economic sustainability, such as poverty, equity and justice [4, 5]. It aims to provide long-term equality for human activities and interaction. It aligns with the needs of present and future inhabitants, emphasizing the principles of sustainability, strategic and efficient living for all citizens, and underscores the integral connection between human-centered care and infrastructure development [6]. Fundamentally, the strategies aim to ensure equitable change, allowing the public to enjoy public transportation while fostering social sustainability.

2.2. Public Transport Helps Vulnerable Groups

Vulnerable groups include children, the elderly, illnesses and disabilities, and also the transportation disadvantaged population. It not only includes people who suffer from physical pain but also those who highly depend on others to access a normal life, such as unemployed groups who rely on unemployment benefits [7]. It is evident that, despite lower expenditures on travel among the economically disadvantaged, the percentage of their income allocated to transportation exceeds that of their more affluent counterparts [8]. Therefore, some suggestions are provided to lower the total expenditure on transport.

2.2.1. Improving Service Frequency and Quality in High-demand Markets

This public transport frequency adjustment is a strategy aimed at maximizing resource utilization and meeting the demand of all passengers. In the book *Public Transit Planning and Operation: Theory, Modeling, and Practice*, the author outlines a method to quantify the need for public vehicles during different periods [9]. This procedure utilizes dynamic parameters, such as target occupancy and departure frequency. Departure frequency indicates the minimum vehicle departures per hour; for example, a frequency of 4 signifies departures every 15 minutes. Target occupancy is assessed by examining variations between peak and off-peak periods. The procedure forecasts passenger numbers, adjusting departure frequency to match target occupancy—either increasing it to satisfy demand or decreasing it to avoid excess. This adjustment aims to reduce customer wait times, optimize resource allocation by modifying vehicle size and quantity over time, and prevent overcrowding and under-utilization, thereby improving the overall travel experience. Ensuring accessibility for all passengers, especially the elderly, is essential, as they may find it challenging to board buses in crowded conditions due to decreased physical flexibility compared to younger individuals [9]. Ensuring the right to travel for vulnerable populations is essential. Elderly individuals often encounter challenges in securing public transport, leading to reliance on costlier taxi services, which deters travel due to high expenses. Low-income groups similarly face obstacles. Increasing bus service frequency during peak hours can enhance public confidence in mass transit, providing greater access to workplaces, educational institutions, and opportunities. This access is crucial for fostering social equity in developing urban areas, making the implementation of these strategies imperative [8].

2.2.2. Introduced Subsidies for Public Transport

Public transport subsidies can also be considered a powerful policy for achieving social equity, as the target consumers of public transport are low-income groups [10, 11]. This system redistributes subsidies from public transport entities to passengers, enhancing individual benefits through ticket discounts or full reimbursement of season tickets. This shift from institutional to individual support

has been adopted in several cities for improved public welfare. In Brussels, for instance, the government fully reimburses public transport for students, resulting in a 170% increase in weekly travel rates [12]. This subsidy enhances students' access to education, potentially influencing their future prospects. Similarly, in Bogotá, Colombia, this targeted subsidy equates to a 32% reduction in ticket prices, significantly boosting monthly public transport usage [13]. Consequently, issues of inefficiency and corruption within transport firms can be mitigated, ensuring maximization of public rights, as the effectiveness and accuracy of this policy are crucial in tackling social inequality.

3. Sustainable Transportation Upgrade Environment Quality

3.1. Definition of Environmental Sustainability

Environmental sustainability is the maintenance of a balance between the exploitation and regeneration of natural resources, aiming for long-term harmony between humans and nature [14].

3.2. Sustainable Transportation Reduces Carbon Emission

The IPCC report highlighted the significance of the transportation sector in mitigating the worsening environmental conditions [15]. Advanced public transport systems reduce the pressure of carbon dioxide in the air through various means. Since urban transport has shifted to a low-carbon model, the majority of transportation now releases lower carbon emissions than before [16]. The government has heightened awareness of the necessity for low-carbon infrastructure, including bike paths and pedestrian streets. Concurrently, the swift advancement of electric vehicles has underscored the role of private cars, alongside public transport, in promoting sustainable development and resource sustainability.

3.2.1. Low-carbon Transportation Infrastructure.

Several eco-friendly transport infrastructures have been improved in recent years to reduce the average individual carbon footprint of nearly 4 tons [17]. Since walking and cycling are recognized as the modes that contribute the lowest carbon footprint, investments in pedestrian infrastructure and bike-sharing programs can greatly reduce dependence on carbon-intensive transport, promoting healthier and more sustainable mobility [18]. The introduction of green spaces significantly enhances urban environmental quality, playing a vital role in urban development. These areas not only beautify cities but also contribute to reducing greenhouse gas emissions and mitigating air and noise pollution [19]. The design of urban green spaces is significant. Central flowerbeds divide main roads into narrower lanes, with gaps for pedestrian crossings. These lanes, unsuitable for cars, accommodate bicycles and pedestrians. High-carbon-uptake plants are unnecessary; instead, benches should be installed to encourage walking. The objective is to promote walking and cycling as low-carbon transportation options, fostering nearly zero emissions in the area. Furthermore, all road users play a role in reducing carbon pollution, enhancing their engagement in environmental protection.

3.2.2. Electric Vehicles

Private cars have always been considered the major contributors to carbon emissions compared to public transportation. However, the emergence of electric vehicles challenges this stereotype, as the transition from diesel cars to electric vehicles presents a great opportunity to reduce carbon emissions in the transport industry and improve urban air quality [20]. A scientific study evaluated the emissions of gasoline, diesel, and electric vehicles, focusing on SO₂, PM 2.5, NO_x, and NMVOC. While electric vehicles incur significant SO₂ emissions during production, these emissions are negligible during operation. In contrast, electric vehicles consistently demonstrate lower emissions

across the other pollutants, highlighting their environmental advantages. When external costs are assessed, electric vehicles average approximately €7/1000 km, compared to €15/1000 km for diesel and €10/1000 km for gasoline vehicles. This data underscores the leadership of electric vehicles in mitigating environmental impact [21]. The environmental benefits of electric vehicles extend beyond direct impacts, encompassing indirect advantages linked to their market adoption. An increase in electric vehicle market share correlates with a decline in diesel vehicle usage, leading to reduced oil demand, as these are complementary goods. In 2019, electric vehicle adoption contributed to a decrease in oil demand by approximately 0.4 million barrels per day (mb/d), representing 0.4% of global oil consumption. Although conditions were suboptimal, projections indicate that the global electric vehicle count could surge to 320 million by 2030, contingent on sustainable transportation practices. Consequently, oil demand may drop to 6.4 mb/d, mitigating risks of oil spills and habitat destruction while enhancing pollution control from oil extraction and combustion [22].

3.2.3. Challenge

However, electric vehicles have low operating costs, as electricity is generally cheaper than gasoline. Therefore, this reduces the psychological burden on motorists and encourages them to take longer trips, increasing in total energy consumption and offsetting the energy savings, particularly the emission reduction benefits of electric vehicles. The point is that this is contrary to the goal of decarbonization.

4. Sustainable Transportation Promotes Equality in Economic Development

4.1. Definition of Economic Sustainability

Economic sustainability means ensuring a system operates within its maximum capacity to support effective economic production without over-exploiting natural resources. It also aims to achieve equitable resource distribution and opportunities [14].

4.2. Public Transport Increases Working Efficiency

Uneven access to various work locations is a barrier to accessing jobs, becoming a major obstacle to unequal economic growth [23]. Physical obstacles, such as mountains and unpaved roads, often block individuals in rural areas. As a result, they may face two dilemmas: they are either unable to seek better job opportunities or must bear high costs to travel to work, such as transportation expenses. This limitation narrows their potential for development and local economic growth, while also widening the gap between regions. Therefore, research has pointed out that economic development has always been driven by the construction of transportation infrastructure [24]. Kain also noted that if there are only roads but no public transport, people still fail to take full advantage of the opportunities the road offers.

4.2.1. Employment

Investment in public transport is a significant driver of employment growth, every 1 billion dollars invested in public transportation, more than 36,000 jobs are created. Economists have calculated and proved this result [25]. Enhancing transport infrastructure stimulates labor demand across the industrial chain, thereby mitigating cyclical unemployment caused by decreased aggregate demand for goods and services, as the need for road builders significantly rises during construction, operation, and maintenance phases. Jobs involved in these types of industries usually have relatively low literacy requirements for the labour, which means that people who suffer from relative poverty and absolute poverty can apply for these jobs more quickly than for mentally demanding jobs,

contributing to an increase in income for low-income groups, finally narrowing the gap of economic differences between regions.

4.2.2. Shorter Commuting Time

The development of public transport, high-speed rail, and subways has created a robust transportation network, significantly enhancing mobility and reducing travel time for passengers. This reduction in commuting time can be analyzed through three dimensions: access and egress time, waiting time, and in-vehicle travel time [26]. Access and egress times are optimized by the strategic placement of public transportation stations, minimizing long-distance travel for passengers. Bike-sharing and bus stops are conveniently located near subway exits, facilitating swift transfers. Increased departure frequency, as detailed in section 2.2.1, further reduces waiting times. The majority of travel time occurs within vehicles, particularly in metropolitan areas like Paris and Lyon, where the railway system operates efficiently within commuting zones, alleviating traffic congestion and shortening travel durations due to high-speed rail lines [27]. Parking time, often included in trip duration, poses no concern for public transport users, leading to even shorter commuting times when excluded. High parking fees may drive drivers to seek more affordable alternatives, inadvertently extending commuting times [28].

5. Conclusion

Sustainable transportation can promote social, environmental, and economic sustainability through policy implementation, investment, and infrastructure construction. Policies socially enhance the availability of public transport by service frequency alternation and subsidisation. In terms of the environment, sustainability is achieved by mitigation efforts of carbon-natural infrastructures and electric vehicles. Improvement in economic equity could result from a rising employment rate and reduced wasted commuting time. However, case studies for eastern nations still cannot fully support the transformation is applied in reality, since countries with different social structures and economic systems may face barriers when introducing traditional models. Also, there are no measurements that only bring beneficial impacts, and challenges emerge during the execution process, which are still not identified and solutions are still under investigation.

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