

Research on the Pathways of Smart Transportation

Empowering Urban Low-Carbon Transportation Development



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Abstract: As China's dual-carbon strategy moves forward, urban transportation—one of the key sources of carbon emissions—faces growing pressure to reduce emissions. Traditional traffic control is relatively crude, congestion control has limited effects, and long-term low-carbon goals are hard to achieve. Smart transportation, supported by the Internet of Things, big data, artificial intelligence, and other frontier technologies, can reshape how urban transportation operates. This paper examines the core advantages of smart transportation in supporting low-carbon urban development and proposes implementation pathways in five areas: big data supervision platforms, new-energy transport equipment, intelligent road-network scheduling, green travel services, and intelligent governance mechanisms. It also predicts future industry trends. The study aims to enrich the theory of urban low-carbon transportation and provide references for cities pursuing green transportation transitions.

Keywords: smart transportation, low-carbon transportation, urban road network, carbon emission reduction, green travel, intelligent control

Introduction

China's urbanization level continues to rise, and urban motor vehicle ownership has climbed year after year. Urban problems such as traffic congestion and exhaust pollution have become increasingly prominent, and the task of energy saving and emission reduction in transportation remains arduous. Administrative measures such as driving restrictions and vehicle purchase limits can only achieve short-term emission reduction; they cannot deliver sustainable development. New-generation information technology has accelerated the implementation of smart transportation. With its sensing, computing, and dynamic control functions, it opens a new path for upgrading urban transportation systems. By optimizing traffic flow distribution digitally and improving residents' travel structure, it can steadily reduce carbon emissions in transportation. On this basis, the paper focuses on the advantages of smart transportation for empowering

low-carbon transportation, implementation pathways, and future trends, with the hope of supporting green and high-quality urban transportation development.

1. Advantages of Smart Transportation in Empowering Urban Low-Carbon Transportation Development

1.1 Reducing tailpipe carbon emissions

Road congestion causes vehicle idling, low-speed driving, and frequent starts and stops, which are major reasons for rising urban vehicle exhaust emissions. Traditional traffic management relies mainly on manual patrols and fixed control schemes. It lacks road-network traffic forecasting, and control measures are often delayed (Yue et al., 2025). Smart transportation relies on various sensing devices distributed across the urban road network. These devices collect road traffic operation data around the clock. With the help of intelligent algorithms, they predict traffic flow trends and guide

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traffic diversion in advance, thereby easing congestion on main roads during peak periods. By improving vehicle driving conditions, shortening vehicle dwell time on roads, and reducing fuel consumption, smart transportation can reduce tailpipe emissions during operation. At the same time, a smart transportation system can dynamically monitor carbon emissions across the entire road network. It can accurately identify high-emission road sections, peak periods, and traffic bottleneck nodes, and clarify key areas for emission reduction. Based on quantitative monitoring results, management departments can optimize traffic organization plans, fully tap the capacity of the existing road network, and improve traffic efficiency without large-scale road expansion. Continuous improvement in urban road traffic operation, reduced ineffective vehicle travel, and eased urban traffic carbon emission pressure all help ensure the steady achievement of carbon reduction goals in transportation.

1.2 Promoting green travel

The structure of residents' travel has a profound impact on the overall scale of urban transportation carbon emissions. For a long time, public transit and non-motorized travel have suffered from uncertain waiting times, poor transfer connections, and difficulty in obtaining travel information. As a result, the share of private car travel has remained high (Lu et al., 2025). Smart transportation can break down data barriers among buses, subways, shared bikes, and other travel modes. It enables the integration of multimodal travel resources and the development of an integrated travel information service system. It can push real-time travel plans, arrival times, and transfer guidance to the public, making green travel more convenient. With travel big data, operators and managers can grasp the spatiotemporal characteristics of public travel and scientifically optimize bus network layout, stop placement, and departure frequency. This helps make up for shortcomings in public transit services and improves the green travel experience. With better supporting services, residents can gradually change their travel concepts and actively choose low-carbon modes such as public transit, walking, and cycling, reducing the frequency of private fuel vehicle use (Wang, 2025).

Adjusting the travel structure on the demand side can reduce carbon emissions caused by private car travel and lay a solid public foundation for long-term urban transportation development.

2. Pathways for Smart Transportation to Empower Urban Low-Carbon Transportation Development

2.1 Building a smart transportation big data supervision platform

A smart transportation big data supervision platform is a core infrastructure for digitally managing urban transportation across multiple locations. Its importance is self-evident. The platform integrates multiple sensing terminals, including geomagnetic detectors, video capture devices, floating vehicle terminals, and environmental monitoring instruments. It comprehensively collects multi-dimensional traffic data such as road network flow, vehicle operating speed, public transit capacity, and road carbon emissions (Zhong et al., 2025). A unified traffic data resource pool is built to aggregate, clean, classify, and process large volumes of traffic data. This opens data barriers among traffic management, transportation, municipal, and ecological environment departments, breaks the data silos formed by independent operations, and enables joint construction and sharing of data resources among departments. Supported by a built-in carbon emission calculation model, the platform considers road traffic volume, travel speed, and vehicle type composition. It automatically calculates real-time carbon emissions for each road section and time period, generates a carbon emission heat map, and accurately locates long-duration high-emission congestion nodes (Zhang, 2026). Big data is used to analyze and mine periodic congestion patterns and predict traffic operation trends during holidays and morning and evening peaks. Based on quantitative analysis reports produced by the platform, management departments can scientifically plan road networks, reconstruct intersections, optimize traffic signals, and formulate targeted emission reduction plans. The big data platform helps high-level management shift from post-event governance to pre-event warning and enhances the scientific nature

of transportation emission reduction decisions. The platform also builds a dynamic evaluation system for transportation emission reduction results. It continuously tracks congestion relief effects and carbon emission changes after various traffic governance measures are implemented and regularly produces evaluation reports. Managers adjust control strategies dynamically based on evaluation results, forming a closed-loop management model of data collection, analysis, decision-making, and evaluation. This continuously improves the precision of urban traffic governance and provides solid data support for building a low-carbon transportation system.

2.2 Vigorously promoting new-energy intelligent transportation equipment

At present, the promotion of new-energy vehicles still faces practical obstacles such as uneven distribution of charging stations, low scheduling efficiency of charging resources, and fragmented operation and maintenance management. Supported by IoT and cloud control technologies, the smart transportation system can build an integrated operation and maintenance management platform for new-energy vehicles. It coordinates operation data of charging piles, battery-swapping stations, and other energy replenishment infrastructure, and conducts unified scheduling and management of charging facilities. Onboard intelligent monitoring terminals are fully installed on city buses, cruising taxis, ride-hailing vehicles, sanitation vehicles, and other commercial vehicles (Su, 2025). The control platform collects real-time data on vehicle location, remaining battery power, and operating status. Combined with the temporal and spatial distribution of passenger flow, it intelligently plans vehicle routes, departure intervals, and energy replenishment periods. It arranges charging during off-peak electricity periods, reduces pressure on the power grid, and ensures stable 24-hour operation of commercial vehicles. For private new-energy vehicles, a mobile service platform provides real-time information on nearby charging piles, available parking spaces, and charging tariffs. It also offers reservation charging, route navigation, and other supporting services, easing the difficulty of finding charging points. Based on big data, the platform analyzes the spatial

distribution of urban new-energy charging demand and scientifically plans charging infrastructure locations, addressing shortcomings in old urban districts and suburbs. An intelligent operation and maintenance system improves the user experience of new-energy vehicles, strengthens residents' willingness to purchase them, and gradually increases the share of new-energy motor vehicles in cities. This improves the energy structure of urban motor vehicles and fundamentally reduces tailpipe emissions from fuel vehicles.

2.3 Improving the intelligent road network dispatch system

An intelligent road network dispatch system builds on the existing urban road network. It deploys adaptive traffic signals, variable lanes, smart ramp control, tidal lanes, and other intelligent transportation facilities to create a dynamic traffic flow control mechanism across the entire network. The system relies on road sensing devices to collect real-time data on traffic volume and vehicle speed at each road section and intersection. With the support of intelligent algorithms, it dynamically adjusts signal timing. According to traffic flow direction during morning and evening peaks, it changes lane functions to balance road network traffic load. Through intelligent dispatch, it prevents traffic from concentrating too heavily on a few main urban arterial roads, disperses traffic pressure, and reduces the possibility of long-term congestion on local sections (Xue et al., 2025). In the road network dispatch process, the right-of-way of motor vehicles, non-motorized vehicles, and pedestrians is considered comprehensively. The passage sequence of different traffic participants is optimized, reducing conflicts at intersections, improving traffic efficiency along the entire section, and cutting additional carbon emissions caused by rapid acceleration, low-speed driving, and unnecessary idling. On this basis, a regional road network cooperative dispatch mechanism is built. Coordinated signal control among adjacent districts is activated to achieve green-wave travel on arterial roads. At the same time, for special scenarios such as major holidays and large events, pre-set road network diversion plans are used to dynamically guide through traffic and avoid

large-scale congestion. Through continuously iterating road network dispatch strategies, the system maximizes the release of existing road capacity, improves vehicle driving conditions within the region, and coordinates improvements in road network operation efficiency and low-carbon emission reduction benefits.

2.4 Building a smart green travel service system

A smart green travel service system is based on residents' travel needs and supported by mobile internet terminals. It builds an integrated, multimodal travel service platform. The platform integrates all public travel resources, including subways, regular buses, bus rapid transit, shared bikes, shared e-bikes, and water buses, and collects real-time operational data from various transport modes (Lou, 2024). Based on the user's origin and destination, the method automatically generates several complete green travel plans that include walking and transfers. It marks details such as estimated time, transfer stations, and arrival times, making it convenient for residents to compare and choose the best route. With the support of big data, the platform explores residents' travel habits and provides targeted green travel guidance. Through digital point incentives, coupons, and other benefits, it encourages citizens to prioritize public transit. Using long-term travel data accumulated on the platform, operating departments analyze district-level travel volume and peak periods. They then scientifically adjust bus route directions, stop placement, and departure frequency to compensate for areas with weak public transit services. This continuously reduces waiting time, improves transfer convenience, and addresses shortcomings in public transit travel. At the same time, supported by smart management, the level of supporting slow traffic facilities is improved. Big data is used to identify hotspots of non-motorized vehicle travel, optimize non-motorized lane planning, and add safe crossing facilities. Online platforms spread green travel concepts and push tourism-related educational content, gradually changing residents' travel habits. By improving smart green travel services, enhancing the appeal of green travel modes, continuously raising the public transit mode share, and reducing private car travel, the

system promotes a shift in urban transportation on the demand side.

2.5 Strengthening the construction of intelligent governance mechanisms for transportation processes

Improving intelligent governance mechanisms is an institutional guarantee for the stable, long-term development of smart transportation. Under the leadership of government transportation authorities, an overall construction plan for a highly intelligent urban transportation system should be designed. Construction goals, implementation stages, and departmental responsibilities should be defined, and a regular cross-departmental collaborative governance mechanism should be established. Supported by the big data supervision platform, traffic management, transportation, ecological environment, and urban management departments can share information and jointly address traffic congestion, vehicle exhaust, and the construction of green transportation facilities. This breaks the limitations of independent departmental governance. An intelligent transportation carbon emission monitoring and assessment mechanism should be established. With platform support, transportation carbon emission indicators for each district and arterial road should be regularly counted. Congestion control results and emission reduction results should be included in the performance assessment of transportation governance work. Data-based quantitative assessment of governance results forces management units to implement various transportation governance measures. At the same time, online public feedback channels should be built. The public can report road condition problems, suggestions for improving transportation facilities, and other information through smart travel platforms. Managers can optimize transportation governance measures based on public feedback, achieving collaborative governance among government, enterprises, and the public. In addition, technical standards related to smart transportation should be further improved, including standardization of sensing devices, data interfaces, and carbon emission calculation methods, so that various intelligent transportation systems can interconnect and

communicate. A regular system operation, maintenance, and upgrade mechanism should be established, and algorithm models should be updated regularly to improve the accuracy of traffic prediction and carbon emission calculation. With the dual guarantee of institutions and technology, the advanced urban transportation governance model can be continuously optimized, ensuring that smart transportation empowers low-carbon transportation construction and sustainable development.

3. Future Trends of Smart Transportation Empowering Urban Low-Carbon Transportation Development

3.1 Transportation governance achieving comprehensive intelligent upgrade

In the future, urban smart transportation sensing networks will cover the entire city. Roads, tunnels, bridges, parking lots, and other infrastructure will carry large numbers of intelligent sensing devices, forming an integrated space-ground transportation sensing system. The scope of traffic data acquisition will further expand, and acquisition accuracy will improve significantly. Large artificial intelligence models will be used to make long-term predictions about traffic flow in ultra-large-scale road networks. The transportation governance model will shift from post-event emergency response to all-time proactive prevention, allowing possible congestion risks to be resolved in advance. As vehicle-road cooperation technology is widely implemented, autonomous vehicles and smart roadside facilities will exchange information in real time. Vehicle passage will become more orderly, further reducing poor driving behaviors such as lane cutting and abrupt starts and stops, and improving overall traffic efficiency. Supported by an all-domain intelligent system, transportation management departments will make unified arrangements for urban transportation through a single network, coordinating the right-of-way of motor vehicles, public transit, and slow traffic. Transportation governance will place greater emphasis on refinement and human-centered design. On the premise of ensuring traffic safety and efficiency, carbon emissions from the transportation system will be minimized. Comprehensive intelligent

upgrading is expected to reshape urban transportation management and achieve leapfrog improvements in urban low-carbon transportation governance capacity.

3.2 Deep integration of transportation and industry

Smart transportation is one of many interdisciplinary fields. In the future, the trend of cross-industry integration will continue to deepen. Multiple market participants—including new-energy vehicles, intelligent road networks, travel service platforms, and carbon monitoring service providers—will work together, gradually improving upstream and downstream industrial chains. Emerging business forms such as new-energy equipment manufacturing, transportation big data services, carbon accounting services, and smart travel operations will continue to develop and grow, gradually forming a complete low-carbon transportation industry cluster. The deep integration of digital technology and the transportation industry has given rise to new business models such as smart ride-hailing, autonomous shuttle buses, and integrated travel service providers. Market players will use big data to identify business opportunities in transportation and develop diversified green travel products. To ease fiscal pressure on construction, the government will introduce supportive policies and guide social capital into the construction of smart transportation infrastructure. Deep industrial integration can accelerate the iteration of smart urban transportation technology, reduce the construction and operation costs of intelligent facilities, and speed up the implementation of smart urban transportation construction. It will inject sustained industrial momentum into the long-term green development of urban transportation.

Conclusion

With its advantages in improving driving conditions and guiding green travel, smart transportation has become key to achieving a full-scale transition in urban transportation. Cities can systematically promote sustainable urban transportation by building big data supervision platforms, promoting new-energy transport

equipment, optimizing intelligent road network dispatch, building smart travel service systems, and improving intelligent governance mechanisms. In the future, with the implementation of all-domain intelligent governance and the continued integration of related industries, smart transportation will continue to release emission reduction potential. Cities should, based on their own transportation conditions, advance smart transportation projects step by step and continuously optimize traffic control strategies, thereby building a safe, efficient, green, and low-carbon modern urban comprehensive transportation system.

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Conflict of Interest

The author(s) declare that there is no conflicts of interest to this work.

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