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Research and Application Demonstration of Key Technologies for Online Car-Hailing Integrated Travel Guidance Services and Low-Carbon Development

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Abstract: To address the dual challenges posed by the growth of urban transportation demand and the carbon neutrality goal, it is crucial to explore in-depth emission reduction paths in the transportation sector. Taking Beijing as an example, this paper focuses on the "key technologies for online car-hailing integrated travel guidance services and low-carbon development", aiming to construct an innovative system that drives the online car-hailing industry towards green and low-carbon transformation. The overall scale, operation characteristics, and new-energy development trends of the online car-hailing market in Beijing are systematically analyzed, and a carbon emission accounting model is constructed. On this basis, this paper focuses on developing a data-driven low-carbon travel guidance service mechanism centered on "carbon inclusion." This mechanism quantifies the baseline emissions and project-scenario emissions. It accurately calculates and rewards the carbon emission reduction of passengers' active choice of new-energy online car-hailing, forming a technical closed-loop of "data monitoring-emission reduction accounting-value incentive-behavior guidance." The research results provide low-carbon development solutions with both technical feasibility and application value for urban transportation managers and travel platforms, and have important demonstration significance for promoting the achievement of the "dual carbon" goal in the transportation sector.

Keywords: Online car-hailing integration; Guidance service; Low-carbon development; Key technologies; Application

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1. Introduction

The deep integration of ride-hailing services with public transportation is giving rise to a new paradigm of green mobility, "Ride-Hailing + Green Transit" Integrated Travel. The core of this model lies in redefining ride-hailing from a stand-alone point-to-point transport mode into a crucial node that seamlessly connects with high-capacity public transport systems, such as metro and bus rapid transit (BRT). By guiding users to shift long-distance trunk journeys to lower-carbon public transportation, while using ride-hailing services only for the "first-and-last mile" connections, the model forms an effective systemic alternative to full-trip private car usage. Compared with traditional travel patterns that rely heavily on private vehicles, integrated travel not only significantly reduces per capita energy consumption and carbon emission intensity per trip but, more importantly, enhances the convenience and attractiveness of green mobility. This, in turn, gradually reshapes residents' travel habits and fundamentally optimizes the overall urban transportation energy consumption structure.

Therefore, this emerging model demonstrates remarkable energy-saving and emission-reduction advantages, as well as substantial application potential, in addressing the dual challenges of urban traffic congestion and environmental pollution, and in advancing the transportation sector toward carbon neutrality [1].

2. Current development status and low-carbon transition trends of Beijing's Ride-Hailing industry

2.1. Overall market landscape

In recent years, ride-hailing has become an indispensable component of China's urban transportation system. Nationwide, as of June 2025, 389 platform companies have obtained operating licenses. In 2024, the total number of ride-hailing orders reached 11.529 billion, with a stable daily average of 31.5 million orders, reflecting strong market vitality and deep social penetration. In Beijing, this trend is even more prominent. By the end of 2024, the city had 12 compliant ride-hailing platforms, with 422,500 active vehicles throughout the year and an average of 151,000 vehicles providing daily services. In terms of operational performance, Beijing's ride-hailing services completed a total of 715 million orders in 2024, translating to a daily average of 1.9524 million orders and an annual passenger volume of approximately 1.0 billion person-times. This scale is equivalent to 42.5% of the annual urban bus ridership and 27.6% of the city's total rail transit ridership, underscoring ride-hailing's role as a key pillar supporting the city's passenger transport system. From a market competition perspective, the industry exhibits a highly concentrated structure. Didi Chuxing dominates with a commanding 73.39% share of total order volume, forming a stable "one dominant, multiple strong" pattern in the competitive landscape.

2.2. Analysis of low-carbon transition characteristics

Although the operational model of ride-hailing resembles that of traditional taxis, the dual drivers of the national "Dual Carbon" goals and technological advancements have made its greening and integration trends increasingly clear. First, in terms of vehicle energy structure, the transition toward new energy is accelerating. Taking Beijing as an example, by the end of 2024, conventional cruising taxis had almost fully electrified, with new energy vehicles accounting for 99% of the fleet. In contrast, the electrification rate of ride-hailing vehicles was only 34% (141,800 vehicles), yet the growth momentum is robust. For example, Didi Chuxing, the market leader, has increased the electrification rate of its annual active fleet from 10% in 2021 to 25% in 2024, demonstrating a clear low-carbon transition pathway. Second, from the perspective of service models, ride-hailing shows substantial potential for integration with public transportation. While direct quantitative data is currently lacking, the relatively short average trip distance of ride-hailing (11.25 km) and its large passenger volume naturally position it as an ideal first-and-last-mile feeder to high-capacity modes such as metro and buses [2]. It thus plays a critical role in building a Mobility-as-a-Service (MaaS) ecosystem and guiding residents toward composite green travel patterns that combine "Ride-Hailing + Public Transit."

3. Calculation of the low-carbon development potential of online car-hailing and analysis of key technologies

3.1. Construction of the carbon emission accounting model

To scientifically evaluate the carbon emission level of the online car-hailing industry and provide a quantitative basis for its low-carbon development path, the primary key technology in this research is to construct a rigorous and suitable carbon emission accounting model. The accounting boundary of this model is precisely defined at the vehicle operation and use stage, aiming to capture the direct environmental impact generated by daily transportation activities. Specifically, the model calculates two types of emissions separately. One is the direct carbon emissions generated by fuel-powered online car-hailing vehicles due to the combustion of fossil fuels during driving. The other is the indirect carbon emissions caused by the electricity consumption of new-energy online car-hailing vehicles (mainly pure-electric vehicles) during driving. The latter depends on the carbon intensity of the power grid they are connected to. This boundary setting clearly separates the operational emissions from those in other stages of the vehicle's life cycle, such as manufacturing and scrapping, focusing on the travel service itself.

The core of the model lies in the scientific determination of the unit-mileage emission factors for vehicles of different power types. For fuel-powered vehicles, the emission factor mainly depends on the fuel efficiency of the vehicle and the carbon content of the fuel used. For new-energy vehicles, the emission factor is jointly determined by the average electricity efficiency of the vehicle and the average carbon emission factor of the regional power grid. Based on this, this research establishes a classified and aggregated accounting framework. By calculating the total operating mileage of the fuel-powered fleet and the new-energy fleet, respectively, and multiplying them by their corresponding unit-mileage emission factors, the annual carbon emissions are obtained. Finally, the total annual carbon emissions of the entire online car-hailing industry can be obtained. This modular model structure can not only accurately inventory the current carbon footprint of the industry, but more importantly, it provides a flexible and reliable analysis tool for subsequent simulation and evaluation of the potential effectiveness of various emission-reduction measures (such as accelerating vehicle electrification and improving operational efficiency).

3.2. Calculation of the total carbon emissions of online car-hailing in Beijing

Based on the carbon emission accounting model constructed above and substituting the actual operating data of the online car-hailing industry in Beijing in 2024, this research accurately calculates that the total carbon emissions of the online car-hailing industry in Beijing in that year were approximately 955,200 tons. A structural analysis of this total clearly reveals the significant differences in the carbon-emission contributions of vehicles of different power types. Specifically, as the main emission source, the 280,700 fuel-powered online car-hailing vehicles had an annual carbon emission of up to 771,600 tons, accounting for 80.8% of the industry's total emissions. In sharp contrast, the 141,800 new-energy online car-hailing vehicles had an annual carbon emission of 183,600 tons, accounting for only 19.2% of the total emissions. This data clearly reveals the core contradiction of carbon emissions in the current online car-hailing industry: the existing fuel-powered vehicles, with about two-thirds (66%) of the vehicle scale, contribute more than four-fifths of the carbon emissions[3].

4. Analysis of key emission-reduction paths and their potential

To systematically evaluate the emission reduction paths of new-energy online car-hailing services, this study conducts a comparative analysis. It mainly compares two travel modes: traditional fuel-powered online car-hailing and new-energy online car-hailing (**Table 1**).

Table 1. Comparative analysis table of emission reduction of travel modes between traditional fuel-powered and new-energy online car-hailing services

Dimension	Traditional fuel-powered online car-hailing	New-energy online car-hailing
Composition of travel mode	Point-to-point direct travel by fuel-powered online car-hailing	Point-to-point direct travel by new-energy online car-hailing
Carbon emission intensity	High	Low
Core emission reduction mechanism	No emission reduction effect	Energy substitution: Replacing high-carbon fossil fuels with low-carbon electricity
Travel efficiency and convenience	High, point-to-point, with strong flexibility	High, similar to traditional fuel-powered online car-hailing, but the charging time needs to be considered
Impact on the transportation system	Aggravate congestion and occupy a large amount of road resources	Also occupies road resources, but without exhaust pollution
Promotion feasibility	Current situation, but contrary to the "dual carbon" goal	Technology is mature, and it is the main current promotion path, but the charging infrastructure needs to be improved

5. Data-driven low-carbon guidance service mechanism for integrated ride-hailing mobility

5.1. Overall framework design of the mechanism

To address the core challenge of insufficient demand-side incentives in the low-carbon transition of ride-hailing services, this study proposes a low-carbon guidance service mechanism. The central concept is to shift the driving force from the supply side to demand-side traction, making passengers the primary incentive recipients. Through precise and real-time positive incentives, the mechanism guides passengers to develop a proactive preference for green travel.

Accordingly, a multi-stakeholder collaborative framework involves government regulatory authorities, ride-hailing platforms, passengers, and third-party certification bodies. Within this framework, government departments are responsible for top-level design, policy support, and supervision, ensuring the mechanism's authority and compliance. As the core hub, the ride-hailing platform undertakes key execution tasks such as technology development, data collection, emission reduction calculation, and reward distribution. Passengers are the direct participants and beneficiaries of the mechanism, with each low-carbon travel choice forming the foundation for the mechanism's operation. The third-party certification bodies independently verify the emission reductions calculated by the platform, thus ensuring data accuracy and the credibility of the emission reduction results.

In this framework, the flows of information and value are clear and well-defined: the information flow originates from the passenger's travel choice, which is recorded, aggregated, and submitted by the platform system for certification, thus forming a trusted data chain. The value flow stems from the verified carbon reductions, which are transformed into tangible rewards (such as coupons or digital badges) that are returned to passengers. This process makes the otherwise intangible environmental contribution explicit and monetizable, completing a closed loop that converts "green behavior" into "economic incentives."

5.2. Precise carbon reduction accounting and dynamic adjustment method

The scientific rigor and effectiveness of the proposed guidance service mechanism are built upon precise carbon reduction accounting and dynamic regulation, both of which are core technical components of this study. The accounting methodology follows the internationally recognized principle of additionality, comparing a baseline scenario with a project scenario. The baseline scenario is defined as the carbon emissions that would result if the passenger took an equivalent-distance trip in a fuel-powered ride-hailing vehicle without being influenced by incentives. The project scenario refers to the actual emissions generated when the passenger deliberately chooses a new energy ride-hailing vehicle for the trip. Based on this, the formula for calculating the per-trip passenger carbon reduction is: Passenger Carbon Reduction = (Baseline Emission Factor – Project Scenario Emission Factor) × Trip Distance

To ensure genuine environmental benefits and avoid overestimating effects by counting the market's natural growth as incentive-driven outcomes, an innovative "additionality verification" and total-emission-reduction control mechanism is introduced on the platform side. The core of this mechanism is the concept of Net Increase in New Energy Vehicle Orders, defined as the portion of the platform's annual new energy orders exceeding the historical natural growth trend. The maximum verified carbon reduction is calculated as: Maximum Verified Carbon Reduction = Net Increase in New Energy Orders × Average Carbon Reduction per Order. This dual-layer accounting and total-control design not only ensures immediate rewards for individual passengers but also guarantees, at a macro level, that the certified carbon reductions genuinely meet the principle of additionality. It forms the technical foundation for the mechanism's credibility [4].

5.3. Application demonstration and benefit evaluation

In the carbon reduction analysis of integrated ride-hailing and green transportation, Didi Chuxing serves as the case study. This demonstration strictly follows the calculation and verification principles of the Ecological Environment Bureau's carbon-inclusive project, using its 2024 published baseline scenario emission factor of 0.1488 and project scenario emission factor of 0.097. For annual average emission reduction forecasts, the methodology is explicit: First, for voluntary passenger choices of new energy vehicles, the emission reduction is calculated as: Emission Reduction = Baseline Emission – Project Scenario Emission. Considering that some new energy vehicles are already in operation, the effective vehicle conversions attributable to the initiative exclude the naturally growing share, capturing only fuel-to-new-energy conversions driven by the activity. The maximum verified carbon reduction is then: Verified Carbon Reduction = Net Increase in New Energy Orders × Average Carbon Reduction per Order. In practice, order volumes are monitored periodically, and when passenger-claimed carbon reductions approach the maximum verified limit, subsequent per-trip reduction results are scaled using an “adjustment coefficient” in line with additionality requirements. Taking Didi as an example, the 2022–2024 average annual increase of 25.288 million new energy orders is set as the natural growth baseline, assuming all new energy orders participate in the program. Three growth scenarios are modelled (30%, 40%, and 50%), corresponding to net increases (beyond natural growth) of approximately 10 million, 20 million, and 30 million orders per year, respectively [5].

At 30% growth: Net increase = 10.53 million orders, max. verified reduction of 6,000 tones CO_2/year.

At 40% growth: Net increase = 22.47 million orders, max. verified reduction of 13,000 tones CO_2/year.

At 50% growth: Net increase = 34.41 million orders, max. verified reduction of 20,000 tones CO_2/year.

Although this analysis is based solely on Didi and may not reflect the full industry outlook, it provides important reference for carbon reduction assessment in integrated ride-hailing plus green mobility systems. Future research can refine and extend the forecasts to encompass the entire industry.

6. Conclusion

Focusing on Beijing’s ride-hailing industry, this study addresses the dual challenges of high carbon emissions and a lack of effective demand-side guidance by innovatively developing a data-driven carbon-inclusive guidance mechanism. The core of this mechanism lies in the creation of a precise carbon reduction accounting method that balances individual-level incentives with macro-level additionality verification, ensuring the authenticity and measurability of emission reduction actions. Application demonstrations and benefit forecasts show that the mechanism can effectively stimulate additional emission reductions beyond natural market growth, yielding significant environmental benefits. The findings provide a quantifiable and operational pathway for advancing the low-carbon transition of the ride-hailing sector and hold substantial practical value for helping urban transportation systems achieve China’s “Dual Carbon” goals.

Disclosure statement

The authors declare no conflict of interest.

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