# A Framework for Transportation Demand Management in Low-Emission Zones: A Case Study of Jinan, China

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**Abstract: In response to the dual challenges of traffic congestion and environmental pollution prevalent in Chinese megacities, this study aims to construct a modern urban transportation governance system adapted to the needs of green development. Using Jinan as a case study, this research develops a comprehensive framework for transportation demand management within a Low Emission Zone, grounded in the internationally recognized Avoid-Shift-Improve paradigm. The framework systematically proposes specific strategies across four key areas: motor vehicle management, non-motorized transport, parking management, and public transport priority. Concurrently, a multi-dimensional evaluation system covering transport, environmental, social, and economic aspects has been designed to scientifically assess effectiveness. Finally, the study puts forward a phased action plan and institutional support mechanisms, intending to provide systematic references and practical guidance for the sustainable transport development of Jinan and other similar cities.**

**Keywords: Transportation Demand Management; Low Emission Zone; Sustainable Urban Transport; Avoid-Shift-Improve Framework; Urban Governance**

## 1. Introduction

### 1.1 Research Context

China is currently in a critical period of advancing the modernization of its national governance system and capacity. Within this context, urban transportation governance, as a vital component, faces unprecedented challenges. Rapid economic development and accelerating urbanization have led to the proliferation of urban diseases in megacities, including worsening traffic congestion, escalating environmental pollution, and a decline in the quality of life for residents. Consequently, establishing a modern urban transportation governance system that aligns with the requirements of sustainable development, and the Transportation Powerhouse national strategy has become a major issue demanding urgent attention.

This reveals that the core of China's urban transport problem has shifted from a simple deficit in infrastructure supply to a complex governance challenge. The traditional supply-oriented planning approach is increasingly untenable, necessitating a transition toward more sophisticated and systematic demand-side management. This requires a shift in urban governance philosophy from an engineering-centric approach to a comprehensive management and regulatory framework that integrates legal, economic, social, and technological dimensions. This study is situated within this macro-context, exploring effective pathways for the modernization of urban transport governance.

### 1.2 Transportation Demand Management and Low-Emission Zones

Transportation Demand Management (TDM) is a comprehensive suite of policy tools designed to reduce or redistribute the use of single-occupancy vehicles. It encompasses not only technical substances but also public policy attributes and is regarded as a key instrument for governments to address issues like traffic congestion and environmental pollution, thereby achieving sustainable development goals.

A Low-Emission Zone (LEZ) is a specific form of Urban Vehicle Access Regulation that improves air quality and promotes a shift toward sustainable transport modes by restricting access for more polluting vehicles into a designated area [1,2]. An LEZ provides an ideal geographical and policy unit for the concentrated implementation of TDM policies. This study positions the LEZ as the core domain for applying the comprehensive TDM framework, aiming to explore the synergistic effects of their combination.

### 1.3 Research Objectives

This study aims to construct a theoretically robust and practically feasible LEZ-TDM comprehensive framework, applying it to a case study of Jinan. The research objectives include: constructing and evaluating a TDM framework that provides clear strategic guidance for urban transport governance; designing a multi-dimensional evaluation indicator system for the scientific assessment of TDM measures' integrated benefits in optimizing travel structure, alleviating congestion, and reducing emissions; and proposing a phased action plan and support mechanisms tailored to Jinan's context to offer policy references for similar cities.

## 2. The Avoid-Shift-Improve Paradigm

This study adopts the internationally recognized Avoid-Shift-Improve (ASI) framework as the theoretical cornerstone for its TDM strategy. First developed in Germany in the 1990s, this framework provides a clear hierarchy of action for achieving environmental sustainability in the transport sector. It emphasizes that Avoid and Shift strategies should be prioritized, as they fundamentally alter travel demand patterns and often yield greater emission reduction potential and cost-effectiveness than purely technological improvements. This hierarchical approach reflects a sophisticated understanding of sustainable transport policy, moving beyond an over-reliance on technology-centric solutions to emphasize more fundamental changes in urban spatial planning and travel behavior.

### 2.1 Avoid: Reducing Motorized Travel Demand at the Source

The Avoid strategy holds the highest priority in the ASI framework. Its core objective is to reduce the need for motorized travel and shorten trip lengths through optimized land use and urban planning. This directly reduces traffic volume, thereby alleviating congestion, and significantly lowers energy consumption and carbon emissions. Specific measures include promoting compact urban development, fostering mixed-use land patterns, creating 15-minute community life circles, and encouraging telework and online services.

### 2.2 Shift: Transitioning to More Sustainable Transport Modes

The Shift strategy is the second priority, aiming to divert travel demand from high-carbon private motor vehicles to low- or zero-carbon modes such as public transport, walking, and cycling. This strategy is typically implemented through a combination of "push" and "pull" measures. "Push" measures reduce the attractiveness of private cars through policy instruments, while "pull" measures attract users to green modes by enhancing the quality, safety, and convenience of public transport and non-motorized transport systems.

### 2.3 Improve: Enhancing the Efficiency of Transport Systems and Vehicles

The Improve strategy constitutes the third tier of the ASI framework, focusing on enhancing the energy efficiency and environmental performance of existing transport vehicles and the overall system [3]. This includes promoting new energy vehicles, phasing out older, high-emission vehicles, upgrading the technology of public transport fleets, and optimizing traffic flow through Intelligent Transport Systems to reduce excess energy consumption and emissions from idling and frequent acceleration and deceleration.

## 3. Domain-Specific TDM Implementation Strategies

Building on the ASI theoretical foundation, this study operationalizes the general TDM approach into four interconnected policy thrusts. The approach begins with optimizing total travel demand, which directly corresponds to the Avoid principle, aiming to reduce unnecessary trips at a macro level through land-use planning and the promotion of remote work. It then addresses the adjustment of the spatiotemporal distribution of travel, a strategy combining Avoid and Improve that uses measures such as staggered work hours and congestion pricing to disperse concentrated travel demand across time and space. A core component is the restructuring of travel modes, the operationalization of the Shift principle, which aims to significantly reduce the modal share of private cars while increasing that of public transport and non-motorized transport (NMT). Finally, the framework includes the optimization of travel paths, which primarily corresponds to the Improve principle, focusing on enhancing network efficiency through fine-grained traffic management, such as implementing congestion charging or peripheral toll cordons to guide vehicles onto more rational routes.

### 3.1 Motor Vehicle Demand Management

Motor vehicle demand management aims to directly regulate vehicle use through a series of administrative and economic instruments. Administrative restrictions, such as number plate-based driving bans, can rapidly reduce traffic volume in the short term, but their long-term effectiveness is limited, and they may induce circumvention behaviors. Consequently, they are best reserved for temporary control during special events and are rarely used as long-term solutions in international megacities [4].

In contrast, economic instruments are considered more effective and equitable. Congestion charging compels users to internalize the external costs of their travel, and successful implementations in cities like London and Stockholm have demonstrated significant improvements in traffic conditions, reductions in air pollution, and the generation of a sustainable revenue stream for public transport.

Low-Emission Zone charging (pollution fees), a core LEZ policy tool, directly targets vehicle emission levels and is a common practice in cities like London and Berlin to combat traffic-related air pollution and incentivize fleet renewal. However, the implementation of both charging policies in China faces hurdles, including a lack of legal precedent and challenges in gaining public acceptance. Additionally, increasing parking charges in central urban areas, especially for long-duration commuter parking, is an internationally recognized TDM measure that uses a price lever to influence mode choice, though its effectiveness depends on coordinated management across all parking types.

### 3.2 Enhancing Non-Motorized Transport (NMT) Systems

Non-Motorized Transport (NMT) refers to human-powered modes like walking and cycling. Enhancing the NMT system is critical for realizing the Shift strategy and improving urban livability. Its core design principles include safety, continuity, comfort, and multi-functionality [5].

The implementation strategy is a systemic undertaking. It requires ensuring right-of-way and network continuity through standardized road cross-section designs that guarantee adequate width and physical separation for sidewalks and bike lanes, creating a continuous NMT network. There is also a need to improve facility quality and the environment by enhancing pedestrian crossings, universal accessibility design, street furniture, landscaping, and lighting to create an all-age-friendly travel environment. The system should also integrate with urban character, such as leveraging Jinan's unique landscapes to create distinctive NMT corridors that unify transport, recreational, and ecological functions. Institutional and cultural development is equally important, involving the formulation of local NMT design standards, strengthening enforcement against encroachment on NMT space, and cultivating a public culture of NMT through promotion and community events.

### 3.3 Integrated Parking Demand Management

Modern TDM philosophy treats parking management as a primary lever for influencing car use, rather than merely a logistical task of meeting demand. The Supply-Charging-Management integrated policy proposed for Jinan reflects this paradigm shift [6,7].

In parking supply management, the core strategy is to transition from traditional minimum parking requirements to maximum parking limits in central areas and even allow for zero-parking developments, aiming to curb car ownership and use by limiting supply [7]. Concurrently, parking facility layouts should be optimized by gradually reducing on-street parking and vigorously promoting shared parking to activate existing resources and reduce the need for new construction. For parking pricing management, a sophisticated, differentiated pricing system based on location, time of day, and on-street versus off-street status should be established, with substantially increased rates for non-residential parking in the city center and the adoption of progressive charging to manage demand via price signals. Regarding parking management policy, it is necessary to revise local regulations to clarify property rights and management responsibilities, laying the foundation for market-based operations, and to comprehensively promote smart technology applications, utilizing big data and IoT to enhance management efficiency and user experience.

### 3.4 Public Transport Priority: Enhancing Service Competitiveness

Prioritizing public transport is a cornerstone of successful TDM, with the central goal of making it a strong competitor to the private car in terms of travel time, reliability, comfort, and cost. Service improvements should clearly define the role of surface public transport as a foundational and feeder service, complementing the rail network to form an integrated, multi-modal system [8].

Specific improvement actions span multiple levels. Ensuring right-of-way priority is fundamental, achieved by expanding the network of dedicated bus lanes with strict enforcement and implementing Transit Signal Priority at key intersections to reduce delays and improve operational speed and punctuality. Network optimization and coverage enhancement are also critical, requiring the development of a four-tiered bus network and the introduction of flexible services like microbuses to address the last-mile problem. Furthermore, services should be diversified and quality-enhanced, developing differentiated offerings such as express routes and customized buses, and using big data for precise optimization of routes and schedules. Intelligent and information-based systems are equally important, necessitating the construction of a dynamic smart bus cloud and mobile apps to provide real-time information and improve travel experience. Finally, fleet electrification, accelerating the transition to pure electric vehicles, is essential for fulfilling the Improve strategy and reducing the environmental impact of public transport itself. These measures collectively form an interdependent policy ecosystem key to the TDM framework's success.

## 4. Evaluation Framework for TDM Efficacy

**Table 1. Comprehensive Evaluation Indicator System for TDM Measures**

| Dimension | | Evaluation Indicator |
|---|---|---|
| **Transport Benefits** | Travel Structure Optimization | *Modal share of green transport (Public transport & NMT)* |
| | | *Public transport share of motorized trips* |
| | | *Private car modal share* |
| | Congestion Alleviation | *Road saturation level* |
| | | *Average speed of public transport during peak hours* |
| | Safety Improvement | *Frequency of surface motor vehicle traffic accidents* |
| | | *Economic loss from traffic accidents* |
| | Efficiency Enhancement | *Average travel time savings for residents* |
| | | *Public transport accessibility* |
| **Environmental Benefits** | $CO_2$ Emission Reduction | *Total carbon emissions* |
| | | *Timeline for achieving zero carbon in the public transport sector* |
| | | *Carbon peak timing and peak value* |
| | Fuel Consumption Savings | *Petroleum consumption* |
| | Other GHG Reductions | *Methane ($CH_4$) emissions* |
| | | *Nitrous oxide ($N_2O$) emissions* |
| **Social Benefits** | Ensuring Transport Equity | *Accessibility of public services for low- and middle-income groups* |
| | | *Mobility and efficiency for vulnerable groups* |
| | Urban Land Savings | *Reduction in land area for roads and parking* |
| | Urban Vitality Enhancement | *Formation of a compact city structure* |
| | | *Development of 15-minute community life circles* |
| | | *Creation of people-friendly streetscapes* |
| **Economic Benefits** | Travel Cost Reduction | *Total travel costs for residents (including time and monetary costs)* |
| | Urban Operational Costs Reduction | *Reduction in economic losses from traffic accidents* |
| | | *Reduction in transport-related energy consumption* |
| | | *Savings on infrastructure construction and maintenance costs* |
| | Fiscal Revenue for Public Transport | *Fiscal revenue from increased car use costs reinvested in public transport* |

Table 1 shows the comprehensive evaluation indicator system for TDM measures. A scientific evaluation framework is essential for ensuring that TDM policies are evidence-based and continuously optimized [9,10]. The framework constructed in this study, through its clear quantitative indicators, enables a comprehensive measurement of policy effectiveness, rectifying the issue in past analyses of conflating effects with indicators. The design of this system itself is a powerful governance tool. By pre-defining the metrics of success, it shapes implementation priorities and provides the basis for adaptive governance [11].

A notable feature of this evaluation system is its inclusion of a Social Benefits dimension, particularly its focus on transport equity. This directly addresses international concerns about the potential for regressive distributional impacts of TDM policies, reflecting a human-centric approach to policy design. Furthermore, incorporating indicators such as urban land savings and urban vitality enhancement clearly links transport policy to urban spatial quality and long-term development goals.

## 5. Implementation Roadmap and Support Mechanisms

### 5.1 Phased Action Plan

The implementation of TDM policies is a long-term and complex process that requires a phased approach [12]. The proposed action plan reflects a pragmatic strategy for policy sequencing and risk management. By first investing in and improving alternative modes of transport, it builds a foundation for later, more restrictive demand-side measures, thereby enhancing public acceptability and political feasibility.

The near-term (by 2025) focus is on building the foundation by vigorously advancing "pull" measures like public transport priority and NMT system construction to provide high-quality travel alternatives, while beginning to regulate motor vehicle use through moderate economic instruments like parking charge reforms [13]. The mid-term (by 2030) will strengthen regulations by introducing a balanced mix of administrative and economic measures, such as piloting congestion or low-emission zone charging, building on the now more robust public transport and NMT systems. The long-term (2035 and beyond) goal is system maturity, establishing a TDM policy system dominated by market-based economic instruments where green transport modes are highly competitive and demand management relies primarily on price mechanisms to achieve a sustainable equilibrium.

### 5.2 Institutional Support Mechanisms

The successful implementation of TDM depends on a comprehensive and solid institutional support structure [14,15]. A legal and regulatory framework serves as the cornerstone, requiring the amendment of local regulations to provide a clear legal basis for innovative policies like congestion charging and parking standard reforms. Financial sustainability is also crucial; a sustainable funding mechanism is recommended, where revenues from increased car use costs are earmarked through a dedicated fund to be reinvested into the public transport system. Furthermore, technological support is key to enhancing management efficiency, necessitating an integrated urban intelligent transport platform that leverages big data and IoT to support dynamic parking management and demand-responsive transit. Finally, public participation is a prerequisite for long-term sustainability; the government must guide public perception and cultivate a low-carbon travel culture through sustained public awareness campaigns, transparent decision-making, and incentive programs to reduce social resistance [16,17].

## 6. Conclusion and Policy Implications

This study has systematically constructed a comprehensive TDM framework for LEZs, centered on the ASI paradigm. Through a case study of Jinan, it has detailed specific policy instruments across the domains of motor vehicles, non-motorized transport, parking, and public transport, complemented by a corresponding evaluation system and implementation roadmap.

The primary contribution of this research lies in providing a policy blueprint that is both theoretically systematic and practically operational. The value of this framework resides not only in the comprehensiveness of its specific measures but also in its internal logical consistency and systemic synergy. It underscores a clear hierarchy of priorities—managing demand at the source (Avoid), optimizing travel structure (Shift), and enhancing system efficiency (Improve)—reflecting a profound understanding of sustainable transport development.

For Jinan and other Chinese megacities facing similar challenges, the framework presented here offers significant policy implications. It signals a critical transformation in the philosophy of urban transport governance—from passively accommodating traffic growth to proactively managing and shaping travel demand, and from relying on singular engineering solutions to employing an integrated toolkit of legal, economic, technological, and social instruments. Ultimately, the successful implementation of this framework will depend not just on precise technical design, but on sustained political will, robust institutional support, and genuine public engagement. This is not only the path to achieving sustainable transportation but also a core requirement for advancing the modernization of urban governance capacity.

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