

Research on Layered Collaborative Cracking Mechanism of Data Barriers in Highway Field

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ABSTRACT

The digital economy is driving government data sharing as a cornerstone of modern governance. Within the transportation sector, the imperative for data interconnection is amplified by the ongoing digitization of highways. The "transportation power" strategy explicitly recognizes data as a critical factor of production, necessitating the dismantling of sectoral silos. Furthermore, a joint notice issued in 2024 by the Ministry of Transport and other departments underscored data sharing as pivotal for implementing highway management innovations, emphasizing the urgency of overcoming cross-sectoral data barriers. In this milieu, addressing the data barrier within Y City's highway department holds significant implications. Primarily, it facilitates "highland linkage" to advance highway digitalization, thereby enhancing traffic governance and the travel experience. Secondly, it contributes to the body of research on cross-sectoral data governance and enriches the collaborative practices of digital governance. This paper commences by characterizing the data barriers observed in a specific locale, proceeds to analyze their root causes, constructs a multi-layered collaborative resolution mechanism, and delineates the application pathways and outcomes. The objective is to furnish a reference for comparable data barrier challenges.

KEYWORDS

Transportation department; Data barriers; Hierarchical collaboration; Digital management of highway

1 Introduction

Addressing the imperatives of digital government evolution and the strategic advancement of the "transportation power" initiative to enhance traffic management efficacy, current highway digital management presents a critical nexus for augmenting future traffic control efficiency. Nevertheless, impediments to cross-departmental data interoperability represent a significant constraint. Focusing on a regional digital highway management initiative, this study scrutinizes the data sharing bottleneck within the G60 Hangzhou Jinqiu Expressway, G1512 Yongjin Expressway, and G527 National Highway in the municipality. It investigates systemic impediments, including the absence of technical interfaces, divergent stakeholder interests, ambiguous delineation of rights and responsibilities, and stalled implementation in practical applications. The research elucidates that these obstacles stem from systemic blockages, a deficit in technical standardization, inadequate institutional frameworks, and lagging conceptual paradigms. Consequently, it proposes a collaborative resolution mechanism structured across the "national-provincial-municipal" tiers, encompassing rule-based collaboration, platform integration, and scenario-driven cooperation. At the national level, rule collaboration will be established in alignment with governmental data sharing regulations. The provincial level will foster platform and interest-based collaboration leveraging the smart highway platform. The municipal level will concentrate on deepening scenario collaboration for specific application contexts. This research not only offers a pathway for addressing local highway data sharing challenges but also furnishes transferable solutions for overcoming cross-departmental data sharing impediments nationwide, thereby advancing the efficacy of inter-agency collaborative governance within the transportation sector.

2 Realistic Representation of Data Barriers Across Subordinate Departments of Highway Digital Management in Y City

In Y City's transportation infrastructure, both the expressway sector ("vertical strip") and the local road network ("local block") face considerable impediments to achieving digitized management. These obstacles manifest distinctly across four critical dimensions: technological, economic, regulatory, and applied, collectively stifling the advancement of integrated highway digital governance.

At the technological frontier, the primary challenges stem from inherent "historical system heterogeneity" and a pervasive "lack of data standardization." The legacy management platforms, independently established across various administrative tiers, exhibit disparate data interfaces, communication protocols, and electromechanical system architectures. This has resulted in a fragmented landscape of incompatible "information silos." Furthermore, a long-standing absence of standardized data formats and definitions—exemplified by variations in the criteria and computation cycles for determining "road network congestion state"—exacerbates the problem. This fundamental architectural

fragmentation renders seamless data integration and on-demand sharing exceedingly difficult, often necessitating reliance on manual processes that are both inefficient and prone to error.

The economic dimension is characterized by a deficit in shared incentives, stemming from divergent organizational objectives. Expressway operators prioritize revenue generation, while local transportation authority's focus on optimizing overall network traffic flow and public safety. This divergence creates inherent conflicts of interest. During periods of network congestion, expressways may resist diverting traffic, fearing toll revenue reduction, and are reluctant to share critical congestion and flow restriction data. Similarly, during maintenance and patrol operations, despite possessing advanced resources like drones, expressways often hesitate to share data due to concerns about increased operational costs and a lack of direct financial benefit. Such data sharing is frequently obstructed under the guise of "data security" and "proprietary trade secrets."

Within the regulatory framework, ambiguity in authority and accountability fosters a culture of "risk aversion in data sharing." The absence of clear protocols defining data-sharing security responsibilities means that responsibility for data breaches, misuse, or erroneous decision-making remains indeterminate. For instance, in the event of an accident, if data containing sensitive information about the involved vehicles and drivers is shared, both the expressway and local traffic police could be held liable for a data breach. Similarly, if, following the sharing of information regarding emergency response resources (such as reflective cones or obstruction removal vehicles), any damage or scheduling errors occur due to local dispatch, accountability becomes unclear. This uncertainty discourages proactive sharing, even when the willingness exists.

From an applied perspective, data is often rendered inert due to a disconnect between its availability and practical utility, manifesting as "data without application." The supply and demand for data remain siloed and disconnected, preventing the formation of a closed-loop interaction with operational scenarios. While information on highway network congestion is released during overload alerts and peak traffic management, it is not synchronized with a real-time push of congestion duration or detailed incident specifics to local authorities. Consequently, local agencies lack the necessary granular information to effectively adjust traffic signal timing, manage variable message signs, or implement other traffic management strategies, thereby limiting the data's potential to inform governance actions. Likewise, during routine maintenance, structured data on road conditions from the network and unstructured information from patrol inspections exist in separate data repositories. This lack of integration means that the underlying causes of observed road defects may remain unknown, hindering effective data-driven intervention and leading to a state of "sharing for the sake of sharing" without tangible value realization.

3 Analysis on the Causes of Data Barriers Across Subordinate Departments in Y City

The fragmentation of data across municipal highway digital management departments in Y City stems from a confluence of systemic, technological, organizational, and cognitive factors, underscoring the inherent complexities of cross-sectoral data governance.

The root cause of systemic challenges lies in organizational structure. The provincial expressway authority operates under direct provincial oversight, dictating personnel, resources, and operations. This differs significantly from local highway departments, which are integrated within the broader administrative system. Consequently, their objectives and performance metrics diverge: the provincial expressway entity prioritizes operational safety, toll revenue, and cost management, while local departments focus on local road network efficiency, public perception, and response times. This divergence makes aligning data-sharing timelines a significant hurdle. Furthermore, administrative silos, created by functional divisions, limit interdepartmental "horizontal" communication. Crucial data exchanges often necessitate a cascading approval process, involving multiple leadership levels, which is both time-consuming and resource-intensive, thereby erecting institutional barriers.

From a technological standpoint, the issues manifest as system incompatibilities and standardization gaps. The informatization initiatives for provincial expressways and local highway systems commenced at different junctures, employing distinct technological generations. Provincial expressway systems, often upgraded from earlier phases, predominantly utilize traditional centralized architectures, whereas newly deployed local systems generally leverage modern paradigms like cloud-native and distributed technologies. This disparity creates poor interoperability for data exchange, necessitating substantial investment in transformation to achieve seamless integration. Moreover, despite governmental directives on data sharing, specific data standards and interface protocols for the highway sector remain undefined. Both provincial expressway and local entities employ unique approaches to data collection, storage, and transmission. For instance, provincial expressways utilize proprietary interface protocols, while local governments adopt generalized industrial protocols. This necessitates the development of middleware solutions, thereby increasing technical costs and transmission latency.

The challenges of "insufficient system supply" and "poor implementation" are multifaceted. Firstly, there's an absence

of a clear benefit-reciprocity framework. The provincial expressway department incurs significant costs for data acquisition and maintenance, potentially increasing operational expenses. However, a compensatory mechanism to balance these costs against benefits is lacking, and perceived authority is insufficient. Secondly, a robust data attribution and authorization framework is absent. Clarity regarding the ownership, usage rights, and management authority of government data is lacking. Provincial expressways exhibit reticence in relinquishing data control, while local authorities fear potential legal ramifications from utilizing unverified data. Thirdly, government data-sharing regulations have not been concretely translated into operational procedures specific to the highway sector, encompassing aspects like approval processes, dispute resolution, and stipulated timelines. The absence of an implementation blueprint for relevant local departments exacerbates data-sharing disorder.

Ideological impediments, characterized by "habitual bias" and "distrust," are also significant. Some officials subscribe to the notion that "possession of data equates to possession of power," positioning data as a critical value asset within their departments. Those holding data are apprehensive of diminished influence post-data sharing. For example, local highway entities are reluctant to share national highway traffic flow statistics with the provincial expressway authority, which, in turn, fears local governments' over-reliance on its proprietary data. Concurrently, interdepartmental distrust prevails. The provincial expressway authority harbors concern regarding the integrity and accuracy of local data, rendering it unusable. Conversely, local entities worry about the inaccuracy and incompleteness of data provided by the provincial authority. These apprehensions result in a reluctance to share data, fostering departmental "information islands" and perpetuating the fragmentation of information.

4 Construction of Hierarchical Collaborative Cracking Mechanism for Data Barriers Across Subordinate Departments

To address data silos within the Y city highway sector, I've developed a tripartite collaborative framework encompassing national, provincial, and municipal levels. This structure is designed to harmonize policy directives with localized operational requirements, thereby dismantling interdepartmental data barriers and fostering robust digital highway management.

At the national echelon, "regulatory coordination" serves as the cornerstone for establishing a robust data-sharing architecture. This involves leveraging the "Regulations on the Sharing of Government Data" to refine the cross-departmental data sharing protocols for highway authorities. Key elements include standardizing highway data classifications (e. g., basic, operational, emergency data), defining metadata specifications (source, format, update frequency), and establishing interface standards (transmission protocols, encryption). This ensures interoperability, allowing for the seamless comparison and integration of data from both highway and local departments. For instance, "road network congestion data" must include standardized elements like road section, timestamp, vehicle speed, and duration, with consistent naming and formatting across datasets. Furthermore, clear responsibilities are delineated: highway departments are tasked with providing data on road network operations, emergency resources, and maintenance, ensuring data quality. Local highway departments are responsible for receiving, utilizing, and storing this data, alongside overseeing network and information security implications and the impact on decision-making. Accountability for data quality rests with the provider, while data usage risks fall upon the user, mitigating departmental reluctance to share. Finally, legal safeguards, including penalties for non-confidential data refusal and integration of data sharing into departmental performance assessments, provide a coercive impetus for compliance.

The provincial tier employs "platform collaboration" and "interest alignment" to surmount technological and proprietary hurdles. Acting as an intermediary, the provincial level utilizes the smart highway platform to engineer a technologically cohesive data-sharing bridge between highway and local entities. This is complemented by an interest-alignment mechanism to balance stakeholder needs. Platform collaboration involves enhancing the provincial intelligent highway data operation platform to create a unified, three-dimensional data-sharing center. This necessitates developing universal data interfaces compatible with both legacy highway systems and modern local platforms, obviating the need for extensive system overhauls. Highway departments can ingest data, such as toll station flow restrictions and traffic volumes, through these interfaces. Local departments, in turn, can access highway-related data via a centralized portal, eliminating point-to-point connections. Data transmission security is paramount, with platform functionalities encompassing encryption, access control, and audit logs to monitor the data lifecycle. Granular access permissions can be implemented, restricting local departments to their specific business data fields. Interest alignment involves establishing diverse incentive structures to encourage highway departments to open their data resources. A financial compensation mechanism, based on data volume, update frequency, and usage, can be funded by provincial budgets to cover data collection and maintenance costs. For example, compensation can be tied to the number of valid data points provided annually and the operational cost savings realized by local entities through reduced redundant data collection.

Additionally, incorporating "data sharing effectiveness" as a key performance indicator for provincial highway operators, covering timeliness, completeness, and accuracy, and linking these metrics to performance bonuses and career progression, further incentivizes data sharing.

At the municipal level, "scenario-based collaboration" guides data sharing initiatives. Municipalities, as primary data application entities, must translate data into tangible governance actions by meticulously identifying specific highway management scenarios. This approach ensures that data sharing directly translates into improved operational outcomes. For road network diversion, highway departments can transmit congestion data, flow restriction times, and impact radii to a central monitoring platform. Local authorities can then leverage this information to adjust traffic light timings, disseminate public advisories on digital signage, and provide feedback to the provincial platform, creating a closed-loop system of data push, action, and feedback. In accident response scenarios, real-time data sharing between highway authorities and local traffic police, transmitted via provincial platforms, enables emergency management departments to rapidly deploy resources. This includes details on accident location, collision type, involved vehicles, and casualties, thereby expediting response times. For maintenance and inspection, municipalities can coordinate highway and local inspection resources through provincial platforms. Unmanned aerial vehicles and inspection vehicles can be deployed to specific road sections and timeframes, with shared inspection videos and reports contributing to a unified road network maintenance file, thereby preventing duplication and enhancing efficiency. A scenario-based evaluation mechanism at the municipal level should quantify the tangible benefits of data sharing, such as reductions in diversion time or improvements in accident response speed. These metrics will inform future data sharing content, ensuring ongoing effectiveness and normalization of scenario-based collaboration.

5 The Application and Effectiveness of the 5-Layer Collaborative Cracking Mechanism in Y City

This initiative outlines a digital management framework for a highway network, termed "highland linkage," within a specific jurisdiction. The core objective is to establish a synchronized management system across provincial, municipal, and county levels, emphasizing phased implementation, pilot optimization, and setting clear performance benchmarks.

The project is structured into three distinct phases: Initial trial period. This period focuses on traffic diversion scenarios within the road network. Key deliverables include: Adapting the smart highway platform to specific interface requirements; establishing data conduits from the highway to the highway monitoring platform for real-time sharing of traffic restrictions and congestion data; processing quarterly compensation funds for the highway operation company based on established standards, with data sharing integrated into their performance assessments; municipal management departments will leverage transformed information boards, traffic light systems, and linkage with highway monitoring to provide real-time updates and guidance at key toll stations. Mechanism improvement period: This period expands the scope beyond city-level traffic diversion to include accident emergency response and maintenance inspections. This involves: Inter-departmental data integration between municipal and highway traffic police for real-time accident data sharing; clarifying emergency resource dispatch protocols and jointly agreeing on inspection plans with highway authorities, including section allocation and data sharing for inspections; provincial optimization of benefit compensation standards based on pilot outcomes, potentially using data usage frequency as a metric. Comprehensive utilization period: This phase aims for full regional integration and operational effectiveness. Key actions include: Implementing a province-wide mechanism for comprehensive highway data sharing among all relevant municipal departments; evaluating operational performance and gathering user feedback; municipal platform adjustments to align with provincial standards, such as optimizing query interfaces and streamlining approval processes; adopting and refining data sharing rules based on best practices from other regions to promote wider replication.

The anticipated outcomes are multifaceted: Enhanced governance efficiency. Real-time data synchronization and streamlined processes are expected to fundamentally improve information exchange and collaborative problem-solving between highway and local road authorities. Near real-time congestion alerts will enable quicker local traffic responses, thereby increasing overall network capacity. Joint accident response and emergency resource deployment will be significantly more agile, reducing the risk of secondary incidents. Operational Cost Savings. A unified platform and collaborative framework will facilitate the optimization of cross-departmental inspection and other resources, leading to considerable operational and maintenance cost reductions. This integrated platform approach will prevent redundancies and inefficiencies inherent in siloed development models. Demonstrated Value and Leadership. The "layered collaboration" methodology, refined through this initiative, offers a replicable framework for similar jurisdictions within the province and valuable insights for national-level improvements in cross-departmental data governance policies, regulations, and standards. This project aims to transition data governance from localized successes to widespread adoption.

6 Conclusion

This paper examines a highway digital management initiative in a specific region, exploring the nature and origins of inter-departmental data silos. It proposes a three-tiered collaborative framework—"national, provincial, and municipal"—to surmount these obstacles. The study identifies data fragmentation in the region's highway and local highway departments, stemming from technological incompatibility, conflicting stakeholder interests, ambiguous roles and responsibilities, and insufficient application synergy. The fundamental drivers of these silos include systemic fragmentation, a deficit in technical standards, inadequate institutional support, and outdated conceptual frameworks. The proposed hierarchical governance model, comprising national-level coordination, provincial platform and interest alignment, and municipal scenario-specific solutions, offers a multidimensional approach to dismantling these barriers and provides a comprehensive strategy for inter-governmental data exchange. As digital technologies mature and national governance structures evolve, the conditions for overcoming cross-departmental data barriers will become more conducive, both practically and institutionally. It is anticipated that this region will further refine its practices, enhance the layered collaborative model, and develop scalable methodologies for national implementation. This will bolster the development of a Digital China, transitioning government service data sharing from intra-departmental cooperation to cross-domain integration, thereby furnishing essential transportation data analytics for the Digital China initiative.

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