

A Study on Fare Strategy for Shenzhen Metropolitan Area Intercity Railway under Four-Network Integration

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Abstract

Shenzhen Metropolitan Area Intercity Railway is characterized by “entering urban centers, integrating into urban rail networks, and serving commuting needs”, with functional positioning and technical features that distinguish it from both traditional Pearl River Delta intercity railways and urban rail transit systems. Existing fare systems fail to meet the operational requirements of metropolitan area intercity railways. Based on a systematic analysis of the operational characteristics of the Shenzhen Metropolitan Area Intercity Railway, this paper thoroughly examines the adaptability of existing urban rail and intercity railway fare structures. It proposes four pricing principles: “balancing cost orientation with affordability, unifying the user-pay principle with social equity, coordinating hierarchical differentiation with network integration, and reconciling flexibility with stability expectations.” Furthermore, it establishes a four-in-one fare strategy framework comprising “parallel implementation of regional integration and cross-metropolitan coordination, a distance-based tiered fare system with rate-based pricing, a two-way synergy between high-frequency commuter discounts and specific surcharges, and periodic fare evaluation and adjustment”. This study provides theoretical foundations and practical references for the scientific pricing of metropolitan area intercity railways.

Keywords

Metropolitan Rail Transit, Public-Transit-Oriented Operation, Network Integration, Fare Strategy

1. Introduction

As the development of the Guangdong-Hong Kong-Macao Greater Bay Area

(GBA) is elevated to a national strategy, the process of regional integration has accelerated, with increasingly frequent flows of factors of production among cities. This has created an urgent need for an efficient, convenient, and integrated rail transit network. In 2019, the National Development and Reform Commission (NDRC) first formally introduced the concept of “four-network integration” at the national level in its Guidelines on Cultivating and Developing Modern Metropolitan Areas, clarifying the development direction of “promoting the integration of trunk railways, inter-city railways, suburban (metropolitan) railways, and urban rail transit”. In July 2020, NDRC approved the “Construction Plan for Intercity Railways in the Guangdong-Hong Kong-Macao Greater Bay Area (2020-2030)”, explicitly calling for the development of a multi-level rail transit system. As a core component of this plan, the Shenzhen metropolitan area intercity railway network is tasked with connecting Shenzhen, Dongguan, and Huizhou, and promoting the same-city development of the metropolitan area. The Guangdong Provincial Government has made a policy decision to transfer the responsibility for the construction of GBA intercity railways from the original Guangdong Provincial Iron Investment Group to Guangzhou Metro and Shenzhen Metro, with projects to be advanced separately under the Guangzhou metropolitan area and the Shenzhen metropolitan area. This adjustment marks a new phase in the construction and operation of intercity railways, shifting from the traditional national railway-led model to a locally led, metro-style operation model. Fares, as a core economic lever for regulating passenger flow distribution, balancing operating costs, and reflecting social equity, play a critical role in determining the operational efficiency and sustainable development of the rail transit network. Given the significant differences in functional positioning and technical characteristics between the Shenzhen metropolitan area intercity railways and existing GBA intercity and urban rail systems (Table 1), the existing rail transit fare system is no longer suitable for the development needs of metropolitan area intercity railways.

Regarding the issue of fare setting for metropolitan area intercity railways, Wang *et al.* [1] addressed the practical need for integration between suburban railways and urban rail transit, proposing a zone-based distance-proportional fare

Table 1. Comparative analysis of the Shenzhen metropolitan area intercity railway and other systems.

| | Functional Positioning | Design Speed (km/h) | Headway (min) | Transfer with Urban Rail |
|--|--|---------------------|------------------------------------|--|
| Existing Pearl River Delta Intercity Railway | Serving business, tourism, and leisure travel within urban agglomerations or metropolitan areas | 140~200 | Peak: 30 - 60 Off-peak: 60 - 90 | Off-station transfer |
| Shenzhen Urban Rail Transit | Commuter rapid transit within the municipal area | 80 | Peak: 2 - 5 Off-peak: 6 - 10 | Seamless transfer within paid area |
| Shenzhen Metropolitan Area Intercity Railway | Serving intercity business and travel needs while accommodating municipal and cross-city commuting | 160 | Peak: 6 - 8 Off-peak: 10 - 15 | Seamless transfer with unified QR code |

model for suburban railways. Their model divides the network into two fare zones: within the urban area, suburban railways and urban rail transit share a unified fare system, while in the peripheral areas, a distance-proportional fare scheme based on a fixed rate per kilometer is applied. Zhang [2] studied multi-path, cross-system seamless fare schemes for metropolitan area rail transit and proposed two fare calculation models based on utility-weighted paths and average-weighted paths. Li *et al.* [3] explored transfer modes and fare systems between intercity railways and subways in the context of integrated development trends, and analyzed the adaptability of different strategies under distance-proportional fare systems, including separate pricing for intercity railways and subways, cross-system pricing, and cross-section pricing. Wen [4] investigated fare schemes for the Pearl River Delta intercity railway, conducting a technical and economic comparison between a zone-based fare system and a single-fare system. She proposed adopting a zone-based system with differentiated fares for express trains (stopping only at major stations) and local trains (stopping at all stations). Li *et al.* [5] studied the impact of periodic tickets on commuter passengers using intercity railways and found that periodic tickets can effectively reduce travel costs for high-frequency commuters. Wang *et al.* [6], taking the Shenzhen metropolitan area intercity railway as the research background, analyzed the differences between intercity railways and urban rail transit in terms of ticket management models, fare systems, and fare clearing and settlement, and proposed design ideas for intercity railway ticketing solutions.

In summary, existing research has largely focused on fare models and ticket management for suburban railways and traditional intercity railways, while relatively few studies have addressed fare setting for metropolitan area intercity railways as an emerging mode. Moreover, existing studies have not fully accounted for the hybrid function of “intercity + suburban express” and the high-frequency commuting passenger characteristics of this mode. This paper takes the Shenzhen metropolitan area intercity railway as the research object. Based on an analysis of its route overview, passenger flow, and operational characteristics, it examines the adaptability of existing fare schemes, clarifies pricing objectives and principles, and then constructs a fare-setting strategy tailored to its development characteristics. The aim is to resolve the core contradictions in fare pricing for metropolitan area intercity railways and promote the coordinated achievement of financial, functional, and social value.

The paper adopts a four-step progressive analytical framework of “policy review, network comparison, passenger flow forecast, strategy synthesis”, as detailed below:

1) Policy review: Systematically review the strategic plans and operational management requirements for “four-network integration” of rail transit issued by the central government and Guangdong Province, and clarify the functional positioning of the Shenzhen metropolitan intercity railways and the policy boundaries for fare setting.

2) Network comparison: Compare and analyze the technical characteristics and operational differences among the existing Pearl River Delta intercity railways, Shenzhen's urban rail transit, and the Shenzhen metropolitan intercity railways from the perspectives of functional positioning, design speed, station spacing, headway, and transfer modes, thereby revealing the applicability deficiencies of the existing two fare systems.

3) Passenger flow forecast: Provide quantitative basis for setting step-wise fare parameters based on key indicators such as the predicted travel structure distribution, trip purpose composition, and the proportion of transfer passenger flows for each line.

4) Strategy synthesis: Based on the above analyses, define the pricing objectives and four principles, and construct an integrated four-dimensional fare-setting strategy framework, covering regional fare mechanisms, fare system design, differentiated product development, and dynamic adjustment mechanisms.

2. Overview of the Shenzhen Metropolitan Area Intercity Railway

Route Overview

The Shenzhen metropolitan area intercity railway network includes the Shenzhen-Huizhou intercity railway (briefly called SH intercity railway), Shenzhen-Dapeng intercity railway (briefly called SD intercity railway), Dapeng branch line, and the southern extension of the Guangzhou-Dongguan-Shenzhen (briefly called GDS intercity railway) intercity railway, with a total length of approximately 304.5 km and a design speed of 160 km/h (observed). The total length under near-term construction is approximately 202.4 km. The SH intercity railway (Qianbao to Pingdi) is 58.2 km long with 11 stations; the SD intercity railway (Airport T4 to Julong) is 69.2 km long with 11 stations; the Dapeng branch line is 39.4 km long with 6 stations; and the southern extension of the GDS intercity railway is 35.6 km long with 6 stations. The SD, SH, and Dapeng branch lines achieve cross-track operation at stations such as Wuhe and Pingshan. The southern extension of the GDS intercity railway is interconnected with the existing GDS intercity railway, forming a networked layout and enabling rapid connectivity within the core area of the Shenzhen metropolitan area (**Figure 1**).

1) Deep integration with the urban rail transit network

During the planning and construction of the Shenzhen metropolitan area intercity railway, deep integration with the urban rail transit network has been achieved. Over 80% (observed) of the stations are transfer stations, and transfer passengers account for nearly 60% (observed) of total passenger flow, reflecting the high level of integration between the intercity network and the urban metro system. Transfer stations are primarily designed with "T"-shaped or "L"-shaped station hall transfers, effectively shortening transfer distances and improving efficiency. At the operational management level, mutual recognition of security checks and interoperability of fare collection systems have been realized between

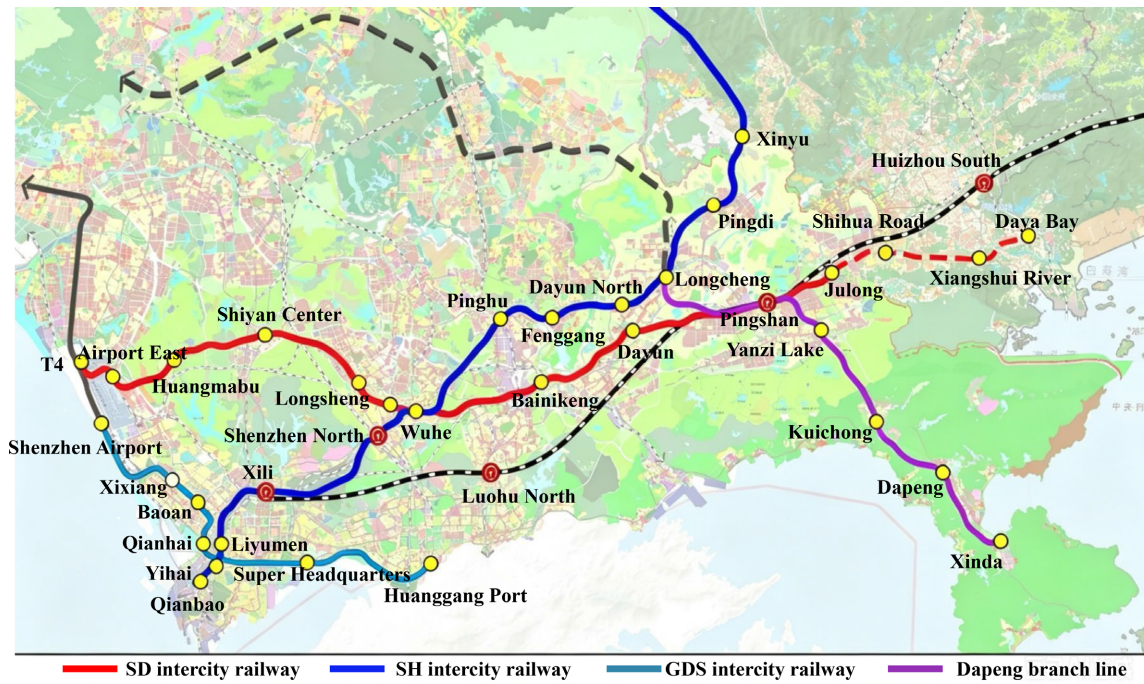


Figure 1. Layout of intercity railways under near-term construction in the Shenzhen metropolitan area.

the intercity railway and the metro. Passengers are not required to exit the station and tap their cards again; a single tap during transfer completes the fare payment, significantly enhancing travel continuity. Some sections adopt a shared corridor model, such as the SH intercity railway sharing a corridor with the planned Metro Line 21. Taking the passenger flow organization from Longcheng to Wuhe as an example (Figure 2), passengers have three differentiated route options: direct travel via the SH intercity railway, transferring from Metro Line 3 to the SD intercity railway, or transferring to Metro Line 5 at Buji Station. This fully demonstrates the service characteristics of multi-path selection under network-based operation conditions.

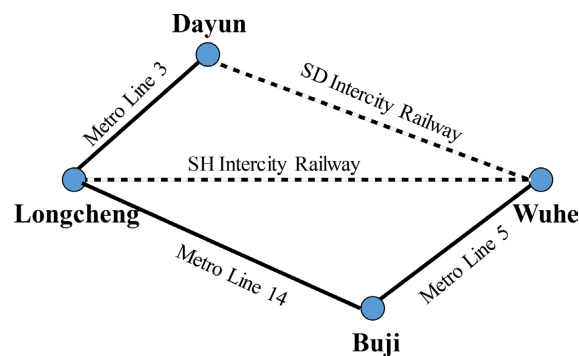


Figure 2. Multi-path travel distribution from Longcheng to Wuhe.

2) Metro-style operation and cross-line operation organization

In March 2022, the Department of Transportation of Guangdong Province issued the *Measures of the Department of Transportation of Guangdong Province*

for the Administration of Intercity Railway Operation, which stipulates that intercity railway operation and management shall adopt metro-style, network-based operations. The Shenzhen metropolitan area intercity railway is designed according to a metro-style operating model. According to the intercity railway design documents, the SH intercity railway will have a headway of 6 minutes during peak hours in the initial operation phase, and can reach 3.5 minutes in the long term, significantly reducing passenger waiting times. Passengers can travel by scanning a QR code or tapping a transit card, allowing them to board anytime without waiting. This operating model creates a continuous travel experience between intercity railways and urban metros in terms of service perception, eliminating the operational disconnect that traditionally existed between intercity railways and urban public transport. Meanwhile, the southern extension of the GDS intercity railway is interconnected with the existing operational GDS intercity railway, and the SD, SH, and Dapeng branch lines can achieve cross-line operation.

3) Diverse travel demands

Compared with the traditional Pearl River Delta intercity railways, which are located on the peripheries of cities and serve a single function of cross-city business and tourism travel, the Shenzhen metropolitan area intercity railway exhibits a composite functional characteristic of “intercity + suburban express”. Among passengers on the existing Guangzhou-Shenzhen railway, Guangzhou-Shenzhen-Hong Kong high-speed railway, and Xiamen-Shenzhen railway, commuters between Guangzhou and Shenzhen and between Pingshan and central Shenzhen already account for 35% (observed) of passengers. According to passenger flow forecast data [7], commuters will account for 64% of passengers on the SH intercity railway, while business travelers will account for 32%; on the SD intercity railway, commuters and business travelers will account for 62% and 28%, respectively, with the railway also serving some airport access and egress functions. The Dapeng branch line exhibits a pronounced tourism-oriented passenger flow characteristic, with tourists accounting for 30% of passengers on weekdays during peak seasons and rising to 50% on weekends (Figure 3). These data indicate that

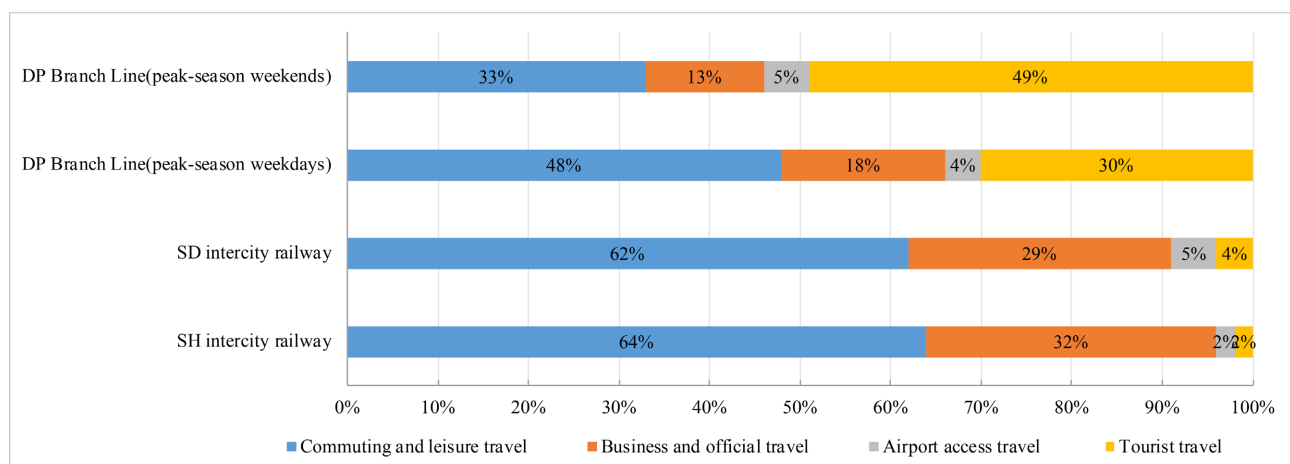


Figure 3. Passenger flow distribution structure of the Shenzhen metropolitan area intercity railway.

the Shenzhen metropolitan area intercity railway must simultaneously meet diverse travel demands, including commuting, business, and tourism, placing higher demands on transport organization and ticketing services.

3. Adaptability Analysis of Existing Rail Transit Fare Systems and Schemes

There are two fare systems for rail transit in the Greater Bay Area. One is the distance-based integer-stepped fare scheme represented by urban rail transit. The other is the single-rate fare scheme represented by the Pearl River Delta intercity railway. The characteristics of these two fare systems and their adaptability to the fare setting of the Shenzhen metropolitan area intercity railway are analyzed as follows:

3.1. Adaptability Analysis of the Urban Rail Transit Fare Scheme

Since 2010, Shenzhen urban rail transit system has adopted a distance-based integer-stepped fare scheme. The base fare is 2¥ (observed) for the first 4 km (observed). For distances between 4 and 12 km, each additional 1¥ allows 4 km; between 12 and 24 km, each additional 1¥ allows 6 km; and beyond 24 km, each additional 1¥ allows 8 km. The average fare per passenger-kilometer is 0.3¥. This scheme, centered on public welfare, is adapted to short-distance distribution needs within the city. However, directly applying it to the Shenzhen metropolitan area intercity railway presents three core problems:

1) Contradiction between rigid fares and elastic costs, leading to a cost-revenue mismatch

The current fare system of the Shenzhen urban rail transit has been in place for sixteen years since its implementation in 2010. This rigidity in fares sharply contradicts the elastic growth of operating costs. During this period, costs for labor, consumables, price indices, and equipment maintenance and renewal have all shown significant upward trends, while fare revenue has struggled to grow due to the long-term lock-in of fares. This has led to a serious mismatch between revenue and costs, creating an unsustainable development model of “the more passengers carried, the greater the loss”. Compared with urban rail transit, intercity railways have technical and economic characteristics that include larger investment scales, longer station spacing, and higher operation and maintenance standards. Directly applying the current low fare level would directly constrain the sustainable operation of the lines after opening. On the one hand, excessively low fare revenue cannot cover the high fixed and variable costs of intercity railways, causing losses to intensify as passenger demand is cultivated. On the other hand, sustained losses will weaken the operator’s ability to reinvest and its motivation to improve service quality, ultimately harming the long-term healthy development of the intercity railway.

2) Integer-stepped pricing violates the “user pays” principle and results in unfair pricing

The integer-stepped, distance-based pricing model currently used by Shenzhen

rail transit was originally designed to facilitate fare payment and change-giving in the cash payment era. However, with the widespread adoption of mobile payment (statistics show that over 98% of Shenzhen Metro passengers use transit cards or QR codes for payment), physical change is no longer a necessary constraint on fare setting. The integer-stepped pricing model groups continuous travel distances into discrete fare brackets by setting several fixed fare thresholds (e.g., 2¥ for 4 km, 3¥ for 8 km). This “one-size-fits-all” grouping approach results in passengers traveling shorter distances within the same fare bracket paying the exact same fare as those traveling distances close to the bracket’s upper limit. This creates an implicit subsidy from short-distance passengers to medium- and long-distance passengers—*i.e.*, short-distance passengers pay a fare exceeding their actual cost share, while medium- and long-distance passengers do not fully bear the marginal costs they incur. This violates the basic fairness principle of “those who use, pay; those who use more, pay more”, distorting the economic function of fares as a cost signal.

3) Homogenized fares lead to unhealthy competition between systems, resulting in resource misallocation

In the context of regional integration and the “four-network integration” of rail transit, the Shenzhen metropolitan area is committed to building a multi-level rail transit network composed of urban rail, intercity railways, and other systems. Lines of different system types differ in passenger flow allocation, operating cost verification, and require differentiated pricing [8]. If the Shenzhen metropolitan area intercity railway simply adopts the same fare system as urban rail, it will directly trigger unhealthy “passenger flow competition” between the two systems. Under the same fare, passengers will choose the intercity railway, which offers shorter travel times and greater comfort. This situation would disrupt the functional division in network planning, where “metros serve short-distance distribution and intercity railways serve medium- to long-distance rapid direct connections”. It would result in low-level competition based solely on a single price element. The intercity railway would be forced to shoulder short-distance passenger flows that should be handled by the metro, leading to inefficient use of high-cost capacity. Meanwhile, metro lines, failing to leverage their short-distance distribution advantages, would face the dual pressure of diluted passenger flows and idle capacity. This resource misallocation would ultimately harm the overall transport efficiency and synergistic benefits of the metropolitan area rail transit network.

3.2. Adaptability Analysis of the Pearl River Delta Intercity Railway Fare Scheme

Traditional Pearl River Delta intercity railways were originally subject to government-guided prices. They have now been removed from the government pricing catalog and are independently priced by enterprises, adopting a single-rate model of “6¥ for 10 km, and 0.66¥/km beyond 10 km (observed)” In practice, a 10% (observed) discount is applied, resulting in a discounted rate of 0.6¥ per passenger-

kilometer, which is twice that of the Shenzhen urban rail transit. On the one hand, intercity stations are widely spaced, resulting in limited coverage along the routes. On the other hand, the high fares have low appeal for commuter passengers, leading to low passenger ridership on intercity railways. Taking the GDS intercity railway as an example, its recent average daily ridership is approximately 12,000 (observed) passenger trips. Based on the current operation of 25 train pairs per day with a train capacity of 1488 passengers, the average daily load factor is only 16.1% (observed). This fare scheme is adapted to low-frequency, occasional travel demands such as business and tourism, but does not align with the core commuter-oriented characteristics of the Shenzhen metropolitan area intercity railway. The main issues are as follows:

1) Pricing logic disconnected from core passenger demand, failing to accommodate high-frequency commuting

Traditional Pearl River Delta intercity railways (e.g., Guangzhou-Zhuhai, Dongguan-Huizhou) primarily serve long-distance travel between central cities within the urban agglomeration, with passengers mainly being business and leisure travelers whose travel characteristics are low-frequency, occasional, and less price-sensitive. This passenger profile justifies a relatively simplified single-rate pricing model (e.g., 0.6¥/km), which to some extent references price comparisons with road or air transport. However, the core characteristic of the Shenzhen metropolitan area intercity railway lies in its strategic positioning of “entering urban centers, connecting to the network, and serving commuters.” The lines penetrate deep into city centers, with initial operations primarily within Shenzhen’s administrative boundaries, shifting the main function to serving high-frequency, time-sensitive commuting demand. This fundamental change in service attributes requires the fare strategy to undergo a logical shift from “serving occasional travel” to “serving essential travel”. The existing intercity railway fare types, structures, and pricing strategies can no longer meet the needs of competition and development in the intercity passenger transport market, nor can they adequately satisfy the increasingly diverse travel demands of passengers. Continuing with the current pricing model ignores commuters’ inherent demands for fare stability, predictability, and long-term discounts.

2) Single high rate exceeds residents’ affordability, suppressing reasonable passenger demand

Based on the single discounted rate of 0.6¥/km, with an average travel distance of 20 km and 22 round-trip commuting days per month, the monthly commuting expenditure would be 528¥ (observed). According to statistics, the average monthly disposable income per capita in Shenzhen in 2025 is 7078¥ (observed), meaning that intercity commuting expenses would account for 7.5% of residents’ disposable income. International studies indicate that the median commuting cost as a proportion of residents’ income is approximately 5% [9]; exceeding this threshold is considered indicative of a risk of excessive transportation burden. Excessively high commuting costs produce two negative effects: they suppress reasonable

long-distance commuting demand, and they force price-sensitive essential commuters back to road transport or the metro, increasing pressure on metro lines along the corridor. Given that the intercity service operates primarily within Shenzhen's administrative boundaries in the near term, excessively high fares lead to low ridership, high empty-load factors on trains, and significant resource waste.

4. Pricing Objectives and Principles for the Shenzhen Metropolitan Area Intercity Railway

Pricing Objectives

The fare setting for the Shenzhen metropolitan area intercity railway needs to establish a strategic system of coordinated and synergistic objectives across three dimensions: financial, functional, and social. The core lies in achieving an organic balance of multiple values through scientific pricing [10]. From the financial dimension, the fare level should at least be able to cover the daily operating costs of the intercity railway and sustain the basic operation of the lines. From the functional dimension, fares need to serve as an economic lever to regulate passenger flow distribution, guiding passenger flows to be reasonably shared among different tiers of lines through differentiated price signals, thereby achieving a functionally complementary pattern where “metros densely serve the city, and intercity railways provide rapid connectivity”. From the social dimension, the fare system must take into account the economic affordability of the target passenger groups, keeping commuting expenses within a reasonable range, and reflect policy preferences for high-frequency commuters and low-income groups through diversified concessionary measures.

1) Principle of balancing cost-orientation and affordability. Fare setting should seek a dynamic balance between operating costs and passenger affordability. On the one hand, the fare level should reflect the investment scale and operating costs of the intercity railway, avoiding excessive reliance on fiscal subsidies. On the other hand, a linkage mechanism should be established between fares and residents' income levels as well as the consumer price index, to prevent excessively rapid fare increases from exceeding residents' affordability.

2) Principle of unifying the user-pays principle and social equity. The pricing mechanism should embody the basic fairness concept of “those who use, pay; those who use more, pay more”, achieving a reasonable allocation of costs among passengers traveling different distances and at different frequencies. Through the design of concessionary fare structures, appropriate preferences should be given to high-frequency commuters and long-distance travelers, reflecting the policy of universal accessibility in public transport.

3) Principle of coordinating hierarchical differentiation and network integration. In the context of “four-network integration” of metropolitan area rail transit, fare setting needs to properly handle the dialectical relationship between “differentiation” and “integration”. On the one hand, a moderate fare differential should

be maintained between intercity railways and urban rail transit, using price signals to guide the rational division of passenger flows. On the other hand, fare structures, payment methods, and concessionary policies should achieve interoperability, providing passengers with a seamless travel experience of “one network, one ticket”.

4) Principle of reconciling flexibility and stability of expectations. The fare strategy should be sufficiently flexible to allow for dynamic optimization and adjustment based on factors such as changes in passenger flow, market demand, and operating costs. At the same time, for high-frequency commuters, predictable and stable fare levels should be provided, avoiding frequent fluctuations that could affect passengers’ travel decisions.

5. Pricing Strategy for the Shenzhen Metropolitan Area Intercity Railway

5.1. Dual-Track Parallel Approach of Regional Integration and Cross-Metropolitan Area Connectivity to Establish a Differentiated Network Fare Mechanism

Given the characteristics of internal interconnectivity within the Shenzhen metropolitan area intercity railway and the connection between cross-metropolitan area lines and external networks, a fare mechanism of “integration within the metropolitan area, differentiation across metropolitan areas” will be implemented, balancing pricing fairness and operational convenience.

1) Same-network, same-price for interconnected lines within the metropolitan area

The SH intercity railway, SD intercity railway, and Dapeng branch line achieve physical cross-track operation and network-based operations. Passengers have multiple travel path options. If different fare standards were applied to different lines, the same origin-destination (OD) pair would result in different fares depending on the path chosen, violating pricing fairness. Therefore, a “same-network, same-price” policy will be implemented for these three interconnected lines, unifying the base fare rules to ensure that the same travel distance results in the same fare, thereby guaranteeing pricing fairness.

2) Maintaining existing fare systems for cross-metropolitan area connections

The southern extension of the GDS intercity railway operates through connection with the existing GDS intercity railway, involving connectivity with intercity lines of the Guangzhou metropolitan area. Moreover, the existing GDS intercity railway uses the 12306 ticketing system, and its fare system differs significantly from that of the Shenzhen metropolitan area internal network. To reduce the coordination costs of cross-metropolitan area fare setting, and to avoid passenger confusion in ticket purchasing and operational complexity, the southern extension will retain the existing fare system of the GDS intercity railway, achieving smooth connection between lines across metropolitan areas.

5.2. Distance-Based Pricing with a Rate-Based Fare Calculation: Establishing a Fare System Coordinated with Urban Rail Transit

To address the adaptability issues of the existing fare systems, this paper proposes a fare system centered on “distance-based pricing with rate-based fare calculation.” Through coordinated design with urban rail transit fares, functional complementarity and reasonable passenger flow sharing can be achieved.

1) Using 0.66¥/km as the base rate to achieve precise fare calculation

Given that mobile payment has become ubiquitous and physical change is no longer a constraint on fare setting, the traditional integer-stepped pricing model should be completely abandoned in favor of continuous, precise fare calculation based on actual travel distance. Using the Pearl River Delta intercity railway’s 0.66¥/km(observed) as the base rate, fares are calculated precisely according to actual travel distance, retaining one or two decimal places, with automatic deduction via electronic payment. This pricing method, firstly, achieves precise cost allocation under the “user pays” principle, allowing passengers traveling different distances to pay according to the resources they actually consume. Secondly, it eliminates the “cliff-edge” pricing at integer thresholds, making marginal cost changes smoother and more reasonable. Thirdly, it provides a precise foundation for subsequent complex concessionary strategies.

2) Applying distance-based discounts to establish tiered rates and guide reasonable passenger flow sharing

On the basis of continuous precise pricing, a tiered rate structure of “distance-based pricing with decreasing rates as distance increases” should be added as an adjustment strategy to further guide reasonable passenger flow sharing and avoid homogenized competition with urban rail transit.

In setting the distance-based segmentation points, the analysis draws on passenger flow structure distribution data (Figure 4) and commuting demand characteristics of Shenzhen metropolitan intercity railways and subways.

Among metro passengers, 60%(observed) of trips are within 10 km(observed), whereas for intercity railways, trips under 10 km account for only 23% - 28% (forecast). This indicates that 10 km serves as the functional boundary between metro short-distance distribution and intercity medium-long-distance rapid

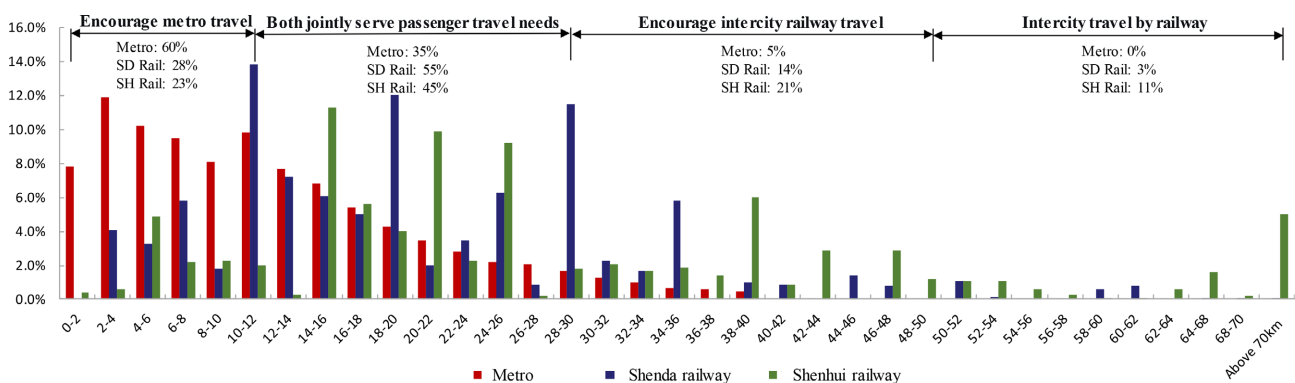


Figure 4. Comparison of travel distance distribution between intercity railway and urban rail transit.

transit. Therefore, 10 km is set as the initial segment with a fare moderately higher than that of the metro, guiding short-distance passengers to use the metro and preventing intercity resources from being occupied by short trips.

The 30 km point corresponds to the peak range of intercity commuting trips. Intercity railways show that 45% - 55% (forecast) of trips fall within the 10 - 30 km range, compared to 35% (observed) for the metro. This confirms that the 0 - 30 km range is the core coverage of medium-to-long-distance commuting. Offering fare discounts within this range maximally benefits high-frequency commuters and reduces their commuting burden.

Beyond 50 km (observed), there is no metro travel. Moreover, a 50 km intercity trip with a travel time of 40 minutes is considered “relatively satisfactory” [11]. Passengers on such trips are primarily business travelers and occasional users, who are less sensitive to fare. Hence, beyond 50 km the base rate is restored, market-oriented pricing is adopted, and no further discounts are provided.

In summary, the three segmentation points of 10/30/50 km follow a three-tier logic of “functional separation, commuting core, business/occasional travel return”. This logic aligns with passenger flow distribution and price sensitivity, and is supported by clear demand-side evidence.

This distribution pattern reveals the functional boundary between the two systems—the metro dominates short-distance distribution, while the intercity railway provides medium- to long-distance rapid connectivity. Design of the tiered rate structure follows a differentiated approach of “moderate price differentiation for short distances to guide passenger choice, preferential discounts for medium to long distances, and market-based pricing for long distances”:

- **0 - 10 km (short-distance segment):** The fare is set higher than the metro’s base fare. Moderate price differentiation guides short-distance passengers to choose the metro, preventing intercity railway capacity from being occupied by short-distance passenger flows.
- **10 - 30 km (medium-distance segment):** A certain discount is applied to reduce the financial burden on **medium**-distance commuters, aligning with the core commuting demand of the intercity railway.
- **30 - 50 km (medium-to-long-distance segment):** Deeper discounts are applied to effectively reduce travel costs for long-distance commuters, reflecting the policy of universal accessibility.
- **Beyond 50 km (long-distance segment):** Travel time exceeds 40 minutes, with passengers primarily being business and leisure travelers making occasional trips. This passenger group is less price-sensitive. The rate returns to the base rate of 0.66¥/km, applying market-based pricing.

5.3. Dual Coordination of “Higher Frequency, Greater Benefits” and “Specific Floating Adjustments” to Create a Diversified Ticket Product System

Given the diversity of passenger composition and the heterogeneity of travel purposes on the Shenzhen metropolitan area intercity railway, a single price structure

cannot satisfy differentiated demands. On the basis of continuous precise pricing and distance-degressive tiered rates, a differentiated concessionary product system targeting different travel frequencies and travel purposes is further established.

1) Higher frequency, greater benefits: multiple measures to reduce commuting costs

The core passenger flow of the metropolitan area intercity railway is primarily commuters, characterized by high frequency, essential travel, and high price sensitivity. For this group, an accumulative “more rides, greater benefits” concession mechanism is established. Through ticket system innovation, the travel costs of high-frequency commuters are kept within a reasonable range, reflecting the policy orientation of ensuring people’s livelihoods while also improving line operational efficiency through stable passenger flow. Three types of concessionary products can be specifically designed:

- **Distance-based multi-ride tickets.** For passengers traveling more than 30 km, periodic tickets are offered at four gradient levels: 20, 30, 40, and 50 rides (valid for 30 days from activation). The discount per ride is 10%, 20%, 30%, and 40% off the original fare for the corresponding distance segment, respectively. Passengers select the paid distance segment via their mobile phones and purchase the corresponding number of rides. If the actual travel distance segment falls within the pre-purchased distance amount, one ride is deducted; if the travel distance exceeds the pre-purchased amount, one ride is deducted and the passenger pays the difference for the excess distance. This approach not only reduces travel costs for high-frequency, long-distance commuters but also allows the operator to collect revenue in advance.
- **Commuter monthly passes.** For high-frequency commuters who travel daily between fixed OD pairs, the probability of purchasing a monthly pass is significantly higher than for other groups [12]. A “commuter monthly pass” product is designed for this group. Passengers pay a fixed monthly fee and can take an unlimited number of rides on the specified intercity segment within that month. The monthly pass price is benchmarked at 40 - 50 times the single-journey fare for that segment (calculated based on 44 trips per month—22 working days with round trips—resulting in a discount of approximately 30% - 40% off the published fare). This significantly reduces commuting costs while providing the operator with stable ridership expectations and cash flow. The commuter monthly pass can be managed using a real-name system, with identity information bound to a mobile app to prevent resale and misuse. This product complements the distance-based multi-ride ticket—the latter is suitable for medium- to long-distance passengers with irregular travel frequency, while the monthly pass serves the “essential travel” needs of daily commuters.
- **Intercity-metro transfer discounts.** To deeply integrate intercity and metro networks and reduce the travel cost of transfer passengers while avoiding duplicate minimum fares caused by segmented pricing, this paper adopts a “virtual transfer” model. Under this model, passengers only need to tap their card

to record the transfer at the interchange station without being charged immediately; the fare is settled uniformly upon exiting the network at the destination. For the metro segment, the existing fare scheme (as described in Section 3.1) applies independently. For the intercity segment, the fixed minimum fare within the first 10 km is removed and replaced with linear pricing at 0.6¥/km. For distances beyond 10 km, the original tiered rates are applied cumulatively (assuming 0.5¥/km for 10 - 30 km, 0.45¥/km for 30 - 50 km, and 0.66¥/km for above 50 km (assumed)). The core logic of this design is as follows. The original intercity minimum fare of 6¥ for the first 10 km implies a hidden rate of 0.6¥/km. However, this fixed threshold forces short-distance transfer passengers (e.g., those traveling only 2 km on the intercity line) to pay 6¥, creating an unreasonable “double minimum fare” problem. By converting the minimum-fare zone into linear pricing, passengers pay according to actual distance traveled. This preserves the original rate level while eliminating the fixed threshold.

Consider a passenger traveling from station O to D: first taking the metro for 6 km (cost 3¥), then transferring at station E to the intercity line for 8 km (as illustrated in Figure 5). Under the original rules, the intercity segment would incur the minimum fare of 6¥ (even for 8 km, charged as the 10 km minimum), resulting in a total of $3 + 6 = 9¥$. Under virtual transfer, the 8 km intercity trip is priced linearly at 0.6¥/km, *i.e.*, 4.8¥, giving a total of $3 + 4.8 = 7.8¥$ —a reduction of 1.2¥ compared to the original scheme. If the intercity segment is 15 km, the original rules yield: 6¥ (first 10 km) + $0.5 \times 5 = 8.5¥$. Virtual transfer gives: $10 \times 0.6 = 6¥$, plus $5 \times 0.5 = 2.5¥$, total RMB 8.5—the same price. Thus, virtual transfer primarily benefits short-distance intercity transfer passengers (within 10 km), avoiding the unfairness of overpaying due to the minimum fare. Compared to across-board discounts or fixed reductions, this model simplifies the settlement logic. Intercity and metro segments are calculated independently according to their own fare rules; the discount is achieved solely by adjusting the treatment of the minimum fare for the intercity segment in transfer scenarios. The settlement process is clear, easy to implement, and avoids any significant impact on intercity operating revenue from large transfer discounts.

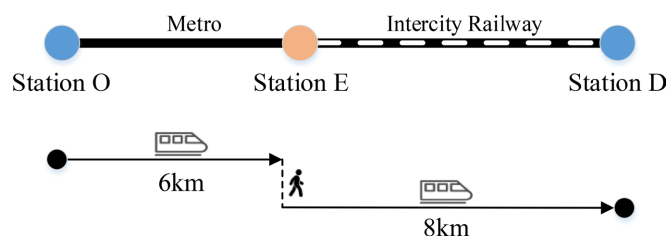


Figure 5. Schematic diagram of metro-intercity transfer.

2) Specific floating adjustments: differentiated surcharges to regulate supply and demand in specific scenarios

The SD intercity railway and the Dapeng branch line respectively serve travel demand to the airport and the Dapeng New District tourist area. Passengers on

these routes generally have a higher willingness to pay than commuters. By designating airport or tourist dedicated carriages, passengers enjoying special services such as airport access or tourism bear the corresponding cost premium, avoiding a scenario where ordinary commuters indirectly subsidize such premium services through base fares, thereby achieving fairer cost allocation.

In terms of implementation, the surcharge applies to designated carriages. The airport surcharge applies to the airport-dedicated carriages on the SD Intercity Railway, while the peak-season tourist surcharge applies to the tourist-dedicated carriages on the Dapeng Branch Line during weekends and public holidays. Passengers who choose to ride these dedicated carriages pay a surcharge (e.g., 10% - 20% (assumed) of the base fare for the airport surcharge, and 10% - 15% (assumed) for the tourist peak-season surcharge), whereas commuters using ordinary carriages continue to pay the base fare. The AFC system identifies eligible trips through either a “carriage-level second tap” or “pre-purchase ticket selection” model. Passengers can tap/swipe their card again at the carriage-level validation machine located in the dedicated waiting area on the platform; the system then automatically marks the trip as using a dedicated carriage and adds the corresponding surcharge to the base fare upon exit. Alternatively, passengers can purchase an electronic ticket for the dedicated carriage in advance via a mobile app and scan it at entry to obtain the premium authorization. The incremental revenue generated from these variable mark-ups under special scenarios can serve as a supplementary source for operation and maintenance costs, enhancing the line’s self-sustaining capacity and reducing reliance on fiscal subsidies.

5.4. Linkage with Changes in Socio-Economic Cost Indicators and Establishment of a Regular Review and Adjustment Mechanism

Intercity railways have long operation cycles and complex factors affecting cost fluctuations. If fares remain rigid for an extended period, they will repeat the mistake of urban rail transit, where “costs and revenues are severely mismatched”. Therefore, it is necessary to establish a dynamic adjustment mechanism linked to operating costs, price indices, and residents’ income levels, enabling timely, moderate, and predictable fare adjustments. A comprehensive fare review should be conducted every 3 - 5 years, comprehensively assessing the necessity and magnitude of fare adjustments based on factors such as changes in operating costs, shifts in passenger flow structure, and the status of fiscal subsidies. Clear triggers for fare adjustments should be set, such as “cumulative increase in operating costs exceeding 10%” or “loss per passenger exceeding a predetermined threshold”, at which point the fare adjustment process would be initiated. The trigger mechanism should be open and transparent, enhancing the predictability of adjustments and avoiding social disputes caused by “sudden fare adjustments”. Through this dynamic adjustment mechanism, the fare level remains dynamically aligned with operating costs and socio-economic development, preventing both excessive fiscal

burdens due to prolonged deviation of fares from costs and excessive price increases beyond residents' affordability.

This section analyzes the fare-setting strategy for metropolitan intercity railways. Since the intercity railways have not yet opened, above distance-based fare segmentation scheme is based on passenger flow forecast data provided by a professional consulting firm and lacks validation with actual post-opening data. After the lines become operational, adjustments can be made to this study based on actual passenger flow. It is worth noting that, in the near term, the Shenzhen metropolitan intercity railways will serve areas within Shenzhen's administrative boundaries and will primarily cater to urban commuting trips. Fare setting therefore needs to focus on the affordability of commuting passengers. The fare affordability for urban rail transit commuters in inland Chinese cities ranges from 2.33% to 5.22%, and in Shenzhen it is approximately 4.39% [13]. This study proposes that the average fare level of the intercity railways should not exceed 5% of commuters' disposable income. On the other hand, the passenger flow composition of intercity railways is complex and diverse. Fare setting should comprehensively consider the travel demand characteristics of passengers and meet the needs of different passenger groups by flexibly adjusting fare levels and offering a variety of ticket types [14].

6. Conclusion

As an important component of the multi-level rail transit network in the Greater Bay Area, the Shenzhen metropolitan area intercity railway exhibits a composite functional characteristic of "intercity + suburban express." Its passenger flow is primarily composed of high-frequency commuters, and its operating model requires metro-style, network-based operations. The existing urban rail transit fare system is ill-suited to these needs due to rigid fares, the drawbacks of integer-stepped pricing, and homogenized competition. The existing Pearl River Delta intercity railway fare system, rooted in a pricing logic designed for business and leisure travelers and characterized by a single high rate, is also unable to meet the development needs of the metropolitan area intercity railway. In response to the passenger flow and operational characteristics of the Shenzhen metropolitan area intercity railway, this study proposes four pricing principles and an integrated four-pronged pricing strategy. These provide a direct reference for fare setting for the Shenzhen metropolitan area intercity railway and offer insights for other metropolitan areas in China. This study focuses on the qualitative construction of a strategic framework. Future research may quantitatively calibrate the parameters of the tiered rate structure (e.g., discount rates, multi-ride ticket gradients) based on actual passenger flow data collected after opening and surveys of passenger willingness to pay, thereby enhancing the effectiveness of the strategy's implementation.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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