Precisely Matching Supply and Demand for Transit-Style Railway Services in Suburban New Towns from a Commuting-Circle Perspective: The Chengdu-Pujiang Railway

XU Lei, LIU Bing, WANG Fangkai

Abstract. The development of suburban new towns is a central component of China's new urbanization strategy. To improve the capacity of transit-style railway services to integrate suburban new towns into central-city commuting circles, this study develops an evaluation and strategy framework based on precise supply-demand matching. The Chengdu-Pujiang Railway, which connects central Chengdu with the suburban new town of Chongzhou, is used as an empirical case. Multi-source data are first integrated to identify the volume and modal structure of commuting between the new town and the central city. Detailed commuter profiling is then combined with train schedules and ticketing data to evaluate supply-demand matching in four dimensions: time-of-day, capacity, station processes, and feeder connections. The analysis identifies several supply-side mismatches, including too few peak-period services, inflexible train formations, cumbersome security and ticket-checking procedures, and the absence of nighttime feeder buses. From a whole-trip-chain perspective, the paper proposes targeted strategies for precise supply-demand matching. These are summarized as focusing on demand, improving efficiency across the entire chain, adapting dynamically, and innovating to raise service quality. The findings provide both a methodological framework and practical guidance for building metropolitan commuting circles and improving transit-style railway operation in major Chinese cities.

Keywords: transit-style railway operation; supply-demand matching; commuting circle; suburban new town; Chengdu-Pujiang Railway.

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1 Development Needs for Commuting Circles and Transit-Style Railway Operation in Suburban New Towns

1.1 A One-Hour Rail Commuting Circle Is a Key Foundation for Modern Metropolitan Areas

A metropolitan area is an urbanized spatial form within a city cluster, centered on a megacity, super-large city, or other major city with strong regional influence, and generally defined by a one-hour commuting circle①. As an important component of metropolitan areas, suburban new towns are a major instrument for refining China's urbanization strategy and promoting polycentric, cluster-based development. During the 14th Five-Year Plan period, Beijing, Shanghai, Chengdu, and other megacities all issued policies supporting suburban new towns②.

In recent years, using commuting-circle development to guide metropolitan areas and suburban new towns has become a major research topic [1-2]. Studies of commuting-circle boundaries and spatial activity patterns have expanded rapidly. Chai Yanwei et al. [3], for example, proposed three spatial organization models: inner-city, near-suburban, and outer-suburban commuting circles. Guo Liang et al. [4] used mobile-phone big data to identify the spatial distribution of the commuting circle in central Wuhan and measured its ring structure, internal composition, and external morphology. Wu Yimin et al. [5] used commuting-rate indicators to identify the main counties and districts around Beijing that had entered its commuting circle and proposed planning recommendations for commuting corridors, commuter subgroups, and cross-boundary commuting patterns.

At the same time, research on “metropolitan areas on rail” has grown quickly, with particular attention to the relationship between urban rail transit and metropolitan development [6-9]. Studies have also examined how railways can support commuting-circle construction. Wang Deli [10], for example, proposed strategies for using metropolitan and suburban railways to guide one-hour commuting circles in megacities from four perspectives: spatial organization, transport support, functional guidance, and institutional safeguards.

1.2 Transit-Style Railway Operation Is a Key Measure for Integrating New Towns into Regional Spatial Networks

A convenient and efficient transport system is essential for attracting population and functions to suburban new towns and integrating them into the central-city commuting circle [11]. In February 2019, the National Development and Reform Commission's Guidelines on Fostering and Developing Modern Metropolitan Areas called for “commuting circles structured around rail transit, vigorous development of metropolitan and suburban railways, and priority use of existing resources to operate metropolitan and suburban train services.” In December 2021, the Development Plan for a Modern Comprehensive Transport System during the 14th Five-Year Plan further called for active use of mainline and intercity railways to provide commuting services, more station stops and higher stopping frequencies at major passenger-distribution points, and transit-style operation during peak periods to improve commuting service quality.

Since the 18th National Congress of the Communist Party of China, the development of city clusters and metropolitan areas has generated rapidly growing commuting demand at multiple spatial scales. Transit-style railway operation has consequently received increasing attention, and extensive practices have emerged in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, the Guangdong-Hong Kong-Macao Greater Bay Area, and the Chengdu-Chongqing region (Table 1). Over time, the transport function has shifted from early point-to-point intercity business travel toward multilevel, multifunctional commuting services.

Transit-style railway operation seeks to maximize train frequency, simplify ticket purchase, and streamline boarding procedures, thereby approximating the “turn up and go” experience of urban public transport and substantially increasing the attractiveness of rail. For suburban new towns, it can provide efficient links with the central city and punctual, comfortable commuting without requiring large-scale investment in entirely new transport infrastructure. Shanghai's Jinshan Railway, for example, was the first railway in China to provide transit-style commuter service between a suburban new town and the main urban area. During its first decade of operation after opening in 2012, service increased from 15 to 37.5 train pairs per day and ridership rose from 13,000 to 32,000 passenger-trips per day③, steadily strengthening its commuter function.

Table 1. Existing Transit-Style Railway Projects and Their Classification in China

Region	Year	Project	Spatial service level	Primary trip purpose

Region	Year	Project	Spatial service level	Primary trip purpose
Beijing-Tianjin-Hebei city cluster	2008	Beijing-Tianjin intercity trains	Between central cities	Business
Beijing-Tianjin-Hebei city cluster	2023	Northeast Ring Line of Beijing Suburban Railway	Central-city core - suburban new town	Commuting
Yangtze River Delta city cluster	2012	Shanghai Jinshan Railway	Central-city core - suburban new town	Commuting
Yangtze River Delta city cluster	2017	Ningbo-Yuyao intercity trains	Central-city core - suburban new town	Commuting
Yangtze River Delta city cluster	2022	Lianyungang-Huai'an-Yangzhou-Zhenjiang Railway	Between surrounding cities	Business
Guangdong-Hong Kong-Macao Greater Bay Area	2021	Guangzhou-Qingyuan Intercity and Guangzhou East Ring Intercity	Central city - surrounding city	Business
Guangdong-Hong Kong-Macao Greater Bay Area	2022	Ganzhou-Shenzhen High-Speed Railway	Central city - surrounding city	Business
Chengdu-Chongqing city cluster	2010	Chengdu-Dujiangyan Railway	Central-city core - suburban new town	Commuting
Chengdu-Chongqing city cluster	2017	Transit-style EMU service from Chengdu to Deyang	Central city - surrounding city	Business
Chengdu-Chongqing city cluster	2022	Chongqing Northwest Ring Line	Between suburban new towns	Commuting
Other regions	2021	Changsha-Zhuzhou-Xiangtan Intercity Railway	Central city - surrounding city	Business
Other regions	2021	Zhengzhou-Kaifeng-Jiaozuo Intercity Railway	Central city - surrounding city	Business
Other regions	2023	Tourism-oriented transit-style railway on Hainan West Ring Line	Central city - surrounding city	Tourism

1.3 Transit-Style Railway Services for Suburban New Towns Need Better Service Matching

As technologies for integrating multiple rail networks advance, transit-style railway operation offers substantial potential to integrate suburban new towns into central-city commuting circles—hereafter referred to as “commuting-circle integration.” Existing studies of improvement measures can be divided broadly into demand-side and supply-side work. Demand-side studies use multi-source data, including rail passenger origin-destination records [12], mobile-phone signaling [13], and passenger surveys [14], to analyze commuter characteristics, segment markets, and forecast flows. Supply-side studies identify bottlenecks in railway operation and recommend measures such as improving security and ticket-checking procedures [15], optimizing train routing [16], innovating fare systems [17], and reforming operational management [18].

In response to the increasing diversity and heterogeneity of commuting-circle commuters [19], applied research has increasingly evaluated the factors shaping rail commuting demand [20-21] and used the results to target service improvements. Three issues have received particular attention. First, station-to-station supply-demand matching can be strengthened through timetable and stopping-pattern optimization to meet station-specific passenger demand [22]. Second, matching between home or workplace and the station can be improved by analyzing the jobs-housing distribution of commuting-circle commuters and enhancing feeder accessibility [23]. Third, matching commuter comfort is important because severe onboard crowding reduces commuting well-being [24] and limits the productive or restorative use of commuting time [25].

Overall, as metropolitan commuting grows, precisely identifying commuting-circle demand and providing corresponding railway services have become critical to the effectiveness of transit-style railway operation. Although research has shifted from separate supply- or demand-side analysis toward coordinated assessment, a comprehensive supply-demand matching framework is still lacking. This produces a disconnect between demand analysis and strategy formulation. Rigid requirements, such as work start and finish times and acceptable one-way commuting duration, are not always adequately considered, and commuter comfort is often overlooked. Precise adaptation of transit-style railway plans therefore remains difficult.

Against this background, the present study examines the Chengdu-Pujiang Railway, which connects central Chengdu with Chongzhou New Town. Using multi-source data, it evaluates the precise match between commuting-circle demand and the supply of transit-style railway services, and proposes targeted measures to improve operation. The study seeks to provide methodological and practical references for transit-style railway development in China's major cities.

2 Research Methods and Data Sources

2.1 Case Background

In 2023, the Chengdu Municipal Committee of the Communist Party of China and the municipal government called for accelerated development of efficient commuting circles for suburban new towns. Chongzhou, one of Chengdu's priority suburban new towns, was required to improve the transit-style operation of the Chengdu-Pujiang Railway and facilitate commuting between Chongzhou and central Chengdu. Chongzhou lies in western Chengdu, approximately 37 km in a straight line from Tianfu Square, and has a permanent population of about 780,000. The Chengdu-Pujiang Railway is the only railway linking Chongzhou to central Chengdu. It opened in 2018, has a design speed of 200 km/h, a mainline length of 99 km, and 11 stations (Figure 1). After it was connected to the Chengdu railway hub ring line in 2022, Chongzhou Station gained through service to Chengdu South and Chengdu East. Compared with conventional railway operation, some facilities already support transit-style service, including platform screen doors and CRH6A rolling stock, but substantial room remains for matching commuting demand more precisely.

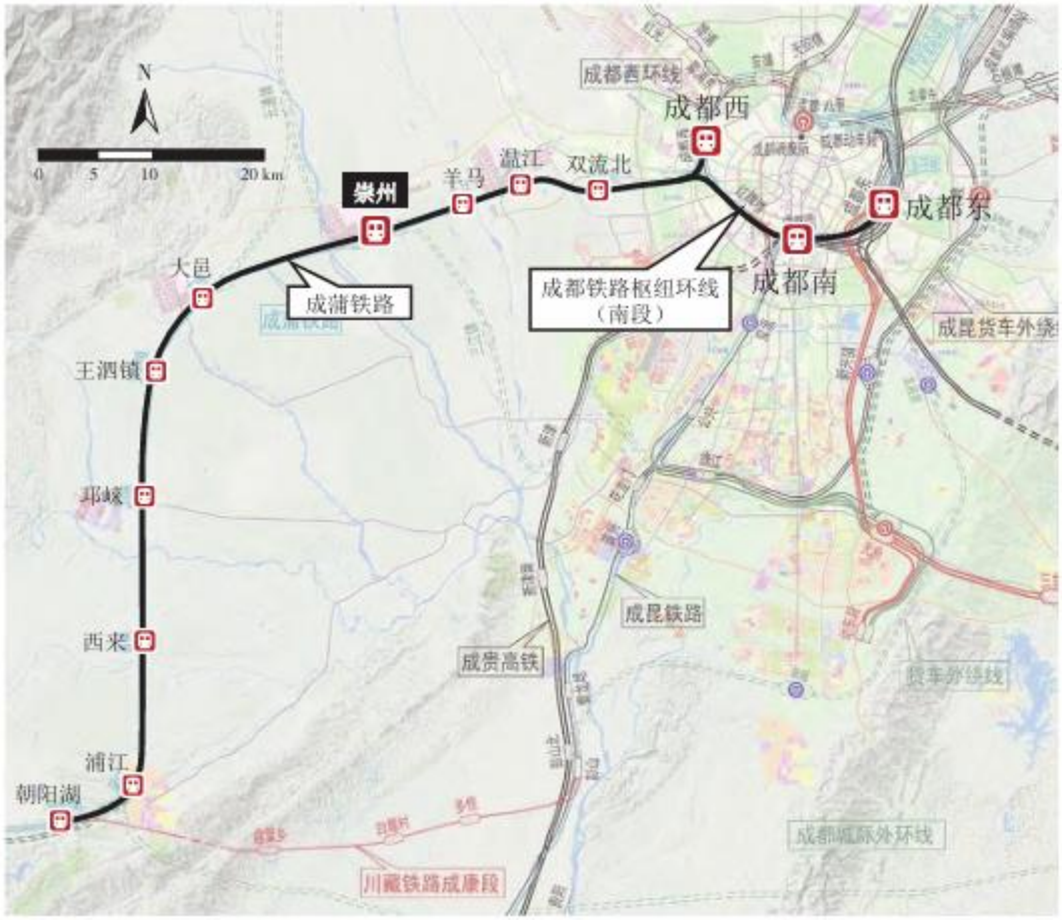

Figure 1. Schematic Diagram of the Chengdu-Pujiang Railway

2.2 Study Area

The study area was defined on the basis of the one-hour rail isochrone from Chongzhou Station④ (Figure 2), with adjustments for administrative boundaries and employment distribution. Residences were limited to the central urban area of Chongzhou, while workplaces included the five central districts of Chengdu—Jinjiang, Qingyang, Jinniu, Wuhou, and Chenghua—as well as Chengdu High-Tech Zone and Tianfu New Area (Figure 3).

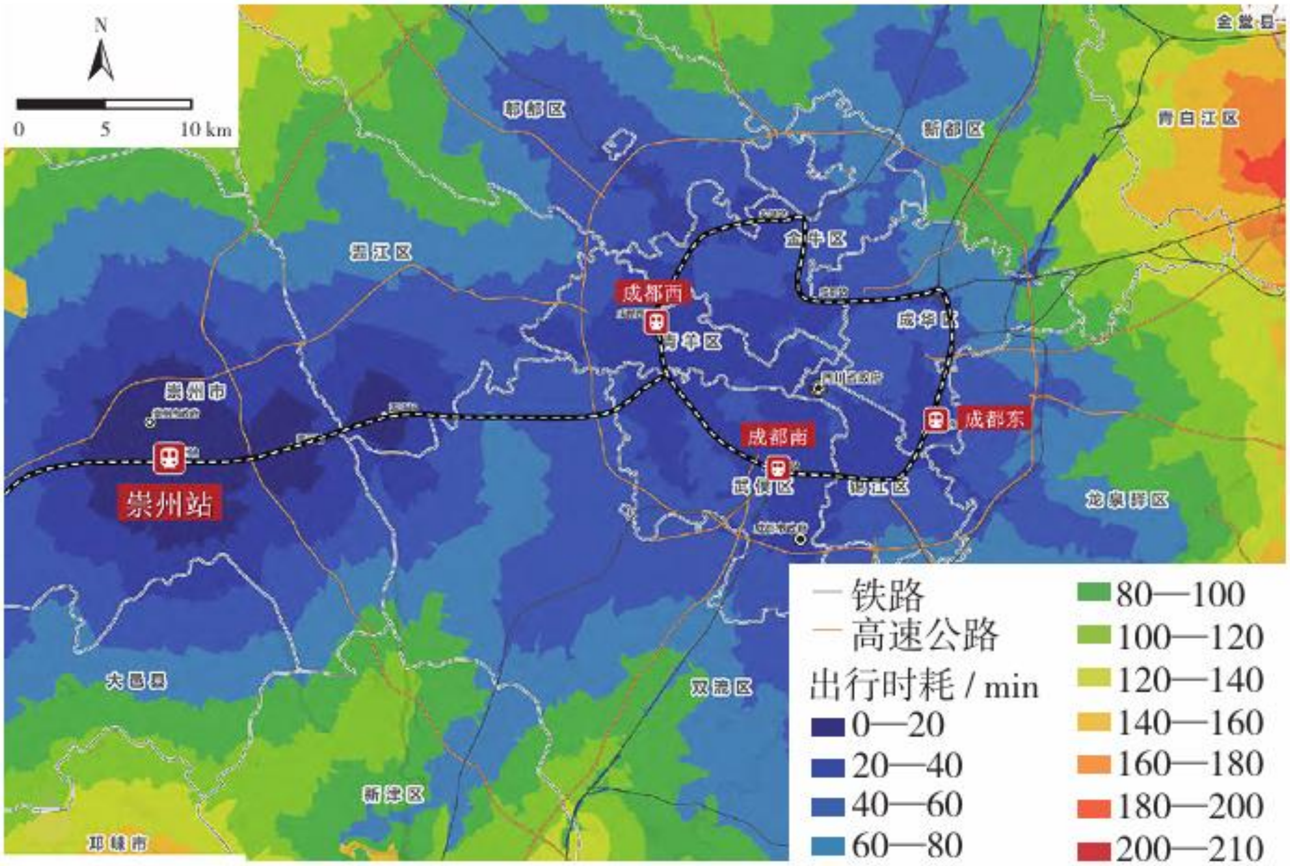

Figure 2. One-Hour Railway-Travel Isochrone from Chongzhou Station

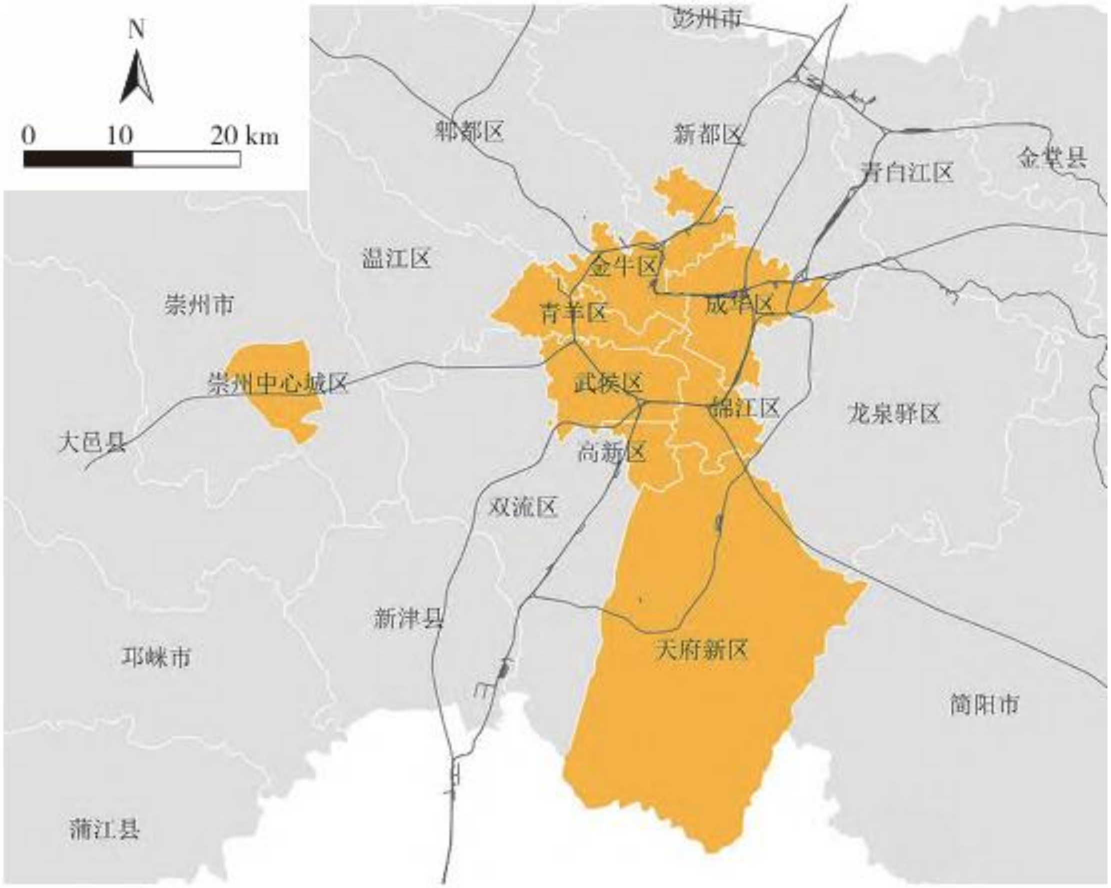

Figure 3. Study Area

2.3 Methodology

First, multi-source data and commuter profiling were used to identify the number of people traveling between Chongzhou and central Chengdu, their travel modes, and the preferences of rail commuters participating in commuting-circle integration. Second, train schedules and ticketing data were combined to assess the precise correspondence between operating services and commuter demand in four dimensions: time-of-day, capacity, station processes, and feeder connections. The resulting matching scores provide a quantitative basis for operational improvement. The technical route is shown in Figure 4.

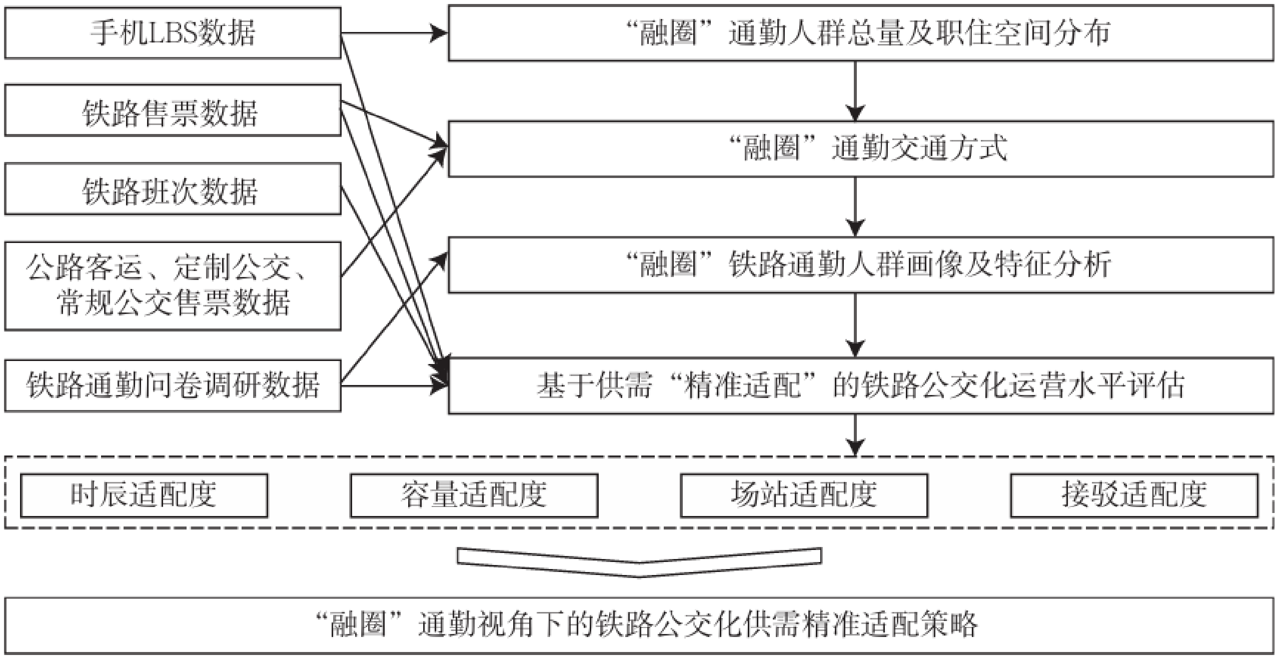

Figure 4. Research Framework

Considering the entire trip chain of suburban-new-town commuters, four matching indicators were developed to evaluate transit-style railway operation and determine how well it satisfies commuting-circle demand.

(1) Time-of-day matching. The analysis covered all trains that stop or pass through Chongzhou Station and identified three types of services with commuting potential. The first consists of trains that stop at Chongzhou but whose times do not align with commuter work schedules and cannot ensure on-time arrival; their stopping times could be optimized. The second consists of trains that do not stop at Chongzhou but pass the station and reach central-city stations at commuter-friendly times; additional stops could be introduced. The third consists of trains that already stop at Chongzhou but make too few stops at Chengdu West, South, and East; more central-city stops could be added.

(2) Capacity matching. For services whose departure times and stopping patterns already match commuter demand, crowding after departure from Chongzhou Station—after Chongzhou passengers have boarded—was assessed to determine whether capacity is adequate. Two indicators were used:

$$\eta_1 = M/S, \quad \eta_2 = M/N$$

Here, $\eta1$ is the seat-occupancy ratio. A value below 1 indicates spare seats, a value of 1 or more indicates that all seats are occupied, and higher values indicate more severe crowding. $\eta2$ is the load ratio. A value below 1 indicates remaining capacity, while a value of 1 or more indicates that the train has exceeded the passenger load corresponding to the acceptable service level; higher values indicate greater crowding. M is the number of passengers, S the number of seats, and N the passenger load at the acceptable service level. Following urban public-transport evaluation standards, N was set at 70% of the train's rated maximum capacity⑤.

(3) Station-process matching. The full time required to enter and exit Chongzhou Station was decomposed to identify the processes most in need of improvement, including the time from feeder drop-

off points to station gates and the time from the gates through each internal step to the platform. Spatial quality and supporting facilities within the station were also evaluated.

(4) Feeder-connection matching. Conventional bus connections at Chongzhou Station were assessed, focusing on the temporal correspondence between bus and train services. The evaluation indicator was the time gap between bus arrival and train departure, or between train arrival and bus departure. A time gap that accommodates the essential station-processing time plus a reasonable buffer indicates good matching; gaps that are too long or too short indicate a need for improvement.

2.4 Data Sources

The analysis combined mobile-phone data, transport-operation data, and questionnaires. Location-based services (LBS) data were obtained from a mobile operator and covered active permanent and floating populations across Chengdu in April 2023. Railway ticketing data supplied by the railway authority included ticket origin-destination records and passenger entries and exits for all stations on the Chengdu-Pujiang Railway. Highway-coach and customized-shuttle ticketing data were supplied by operators, and passenger data for conventional bus connections to the metro were supplied by the bus company. These four operational datasets covered 10-16 April 2023. In addition, the research team conducted a questionnaire survey of rail commuters through an online survey and QR-code responses collected at Chongzhou Station during the morning and evening peaks. A total of 2,913 valid questionnaires were obtained.

3 Analysis of Commuting-Circle Travel Demand in Chongzhou

3.1 Total Travel Volume and Modal Structure

Using mobile-phone LBS data, people making regular weekday trips with stable origins and destinations were identified as commuters. Daytime weekday stay locations were treated as workplaces and nighttime stay locations as residences. The observed sample was expanded using mobile-data penetration rates to estimate actual commuting volumes. The total weekday two-way travel volume between Chongzhou and central Chengdu was approximately 28,100 passenger-trips per day. During the morning peak (07:00-09:00) from Chongzhou to central Chengdu and the evening peak (17:00-19:00) in the reverse direction, commuting-circle travel totaled 9,633 passenger-trips per day, corresponding to approximately 4,000-5,000 commuters.

Among destinations, the area around Chengdu West Station, which is closest to Chongzhou, accounted for 48%. The area around Chengdu South Station, where offices and commercial functions are highly concentrated, accounted for 35%. The vicinity of Chengdu East Station accounted for only 17% because it is farther from Chongzhou and has less industrial concentration.

Five commuting modes were identified: private car, railway, customized shuttle, highway coach, and conventional bus plus metro. The latter four are public-transport modes. Ticketing data were used to estimate their volumes, while private-car travel was derived as the remainder from the estimated commuter total. The resulting structure can be summarized as “private car dominant, railway supplementary, and diversified public transport complementary.” Private cars accounted for 63.0%, whereas rail accounted for only 17.1%, indicating substantially weaker competitiveness than driving (Table 2).

Destination patterns also differed by mode. Rail and private cars can reach a relatively large area within acceptable commuting times, giving commuters broader job-location choices. They were therefore more strongly oriented toward the employment-rich area near Chengdu South Station, which accounted for 48% and 44% of their trips, respectively. Highway coaches and customized shuttles were more constrained by route organization, while conventional bus plus metro was less time-efficient and was consequently concentrated around Chengdu West Station (Figure 5).

Table 2. Weekday Commuting Volume and Modal Split between Chongzhou and Central Chengdu

Travel mode	All-day two-way travel volume (passenger-trips/day)	Commuting-circle trips (passenger-trips/day)	Modal share (%)
Railway	4,854	1,646	17.1
Conventional bus + metro	4,781	1,320	13.7
Highway coach	73	28	0.3
Customized shuttle	910	572	5.9
Private car	17,442	6,066	63.0
Total	28,060	9,633	100.0

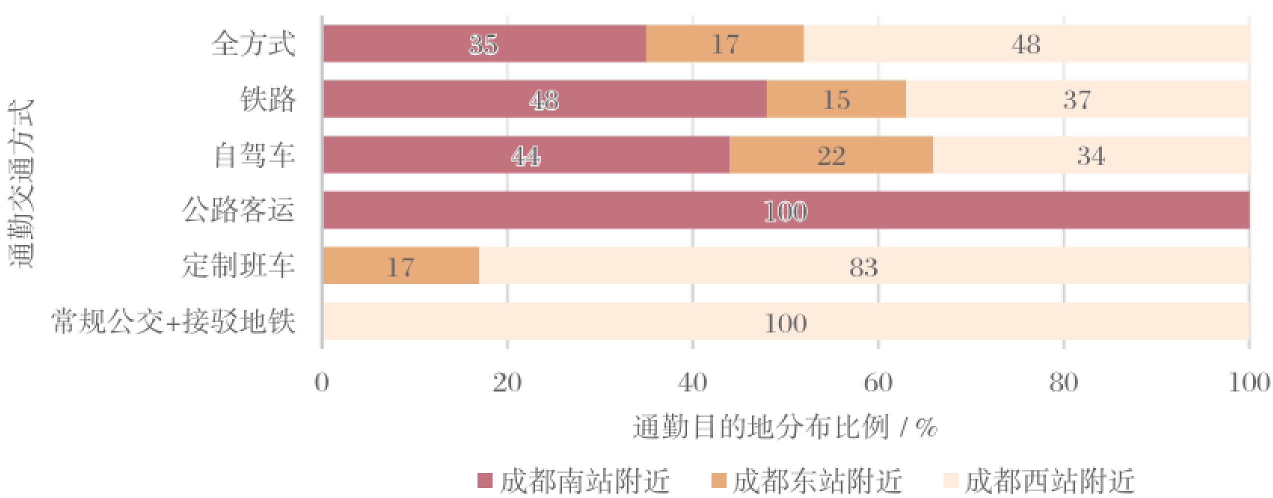

Figure 5. Weekday Commuting Destinations and Modal Differences for Chongzhou Commuters

3.2 Characteristics of Chongzhou Rail Commuters Participating in Commuting-Circle Integration

Questionnaire data were used to analyze commuter characteristics. The commuter profile covered occupation, work start and finish times, and the maximum acceptable one-way commute (Figure 6). Feeder analysis covered travel modes and times from home to the railway station and from the destination station to the workplace (Figure 7).

3.2.1 Commuter Profile: Stable Employment, Fixed Work Schedules, and Acceptance of a One-Hour Commute

Government agencies and public institutions or enterprises were the predominant employers of Chongzhou rail commuters, together accounting for 74%. Work schedules were generally fixed: most commuters started work between 08:00 and 09:00 and finished between 17:00 and 18:00. More than 85% regarded a one-way commuting time of no more than 60 minutes as acceptable.

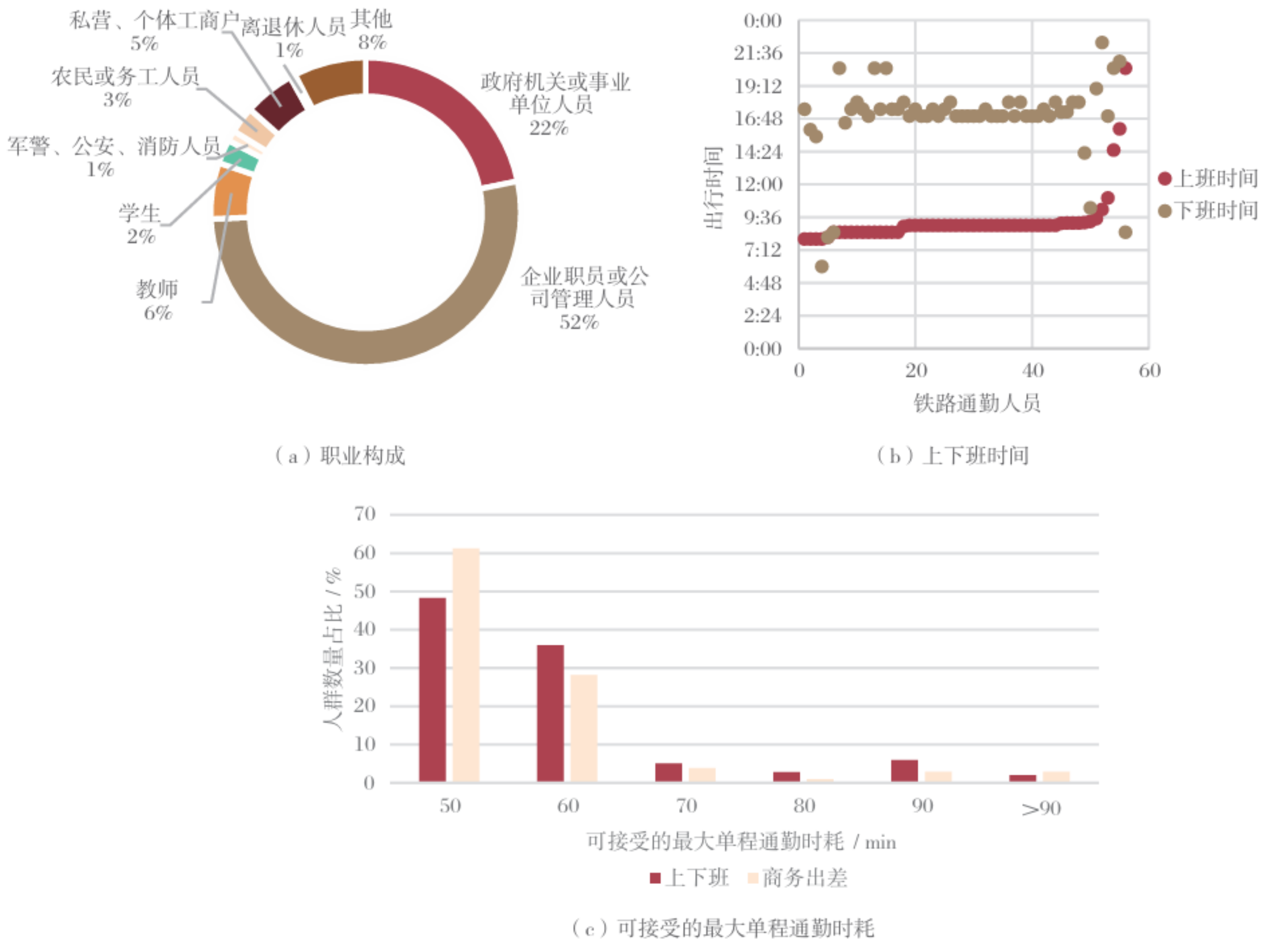

Figure 6. Profile of Rail Commuters Participating in Commuting-Circle Integration

3.2.2 Feeder-Travel Characteristics

Feeder modes. Because Chongzhou Station has no urban rail service, individual motorized modes—taxi, ride-hailing vehicle, and private car—dominated access, accounting for 51.6%, while conventional buses accounted for only 16.1%. By contrast, the three stations in central Chengdu were reached mainly by urban rail, which accounted for 55.3%.

Feeder time. Average feeder times at Chongzhou Station and the three central-city stations were 18 and 25 minutes, respectively. Trips of no more than 20 minutes accounted for 66.2% and 40.5%. According to the 12306 timetable, in-vehicle travel from Chongzhou to Chengdu West, South, and East took 18, 22, and 34 minutes, respectively. Given commuters' expected one-way travel time of no more than 60 minutes, feeder efficiency still requires improvement.

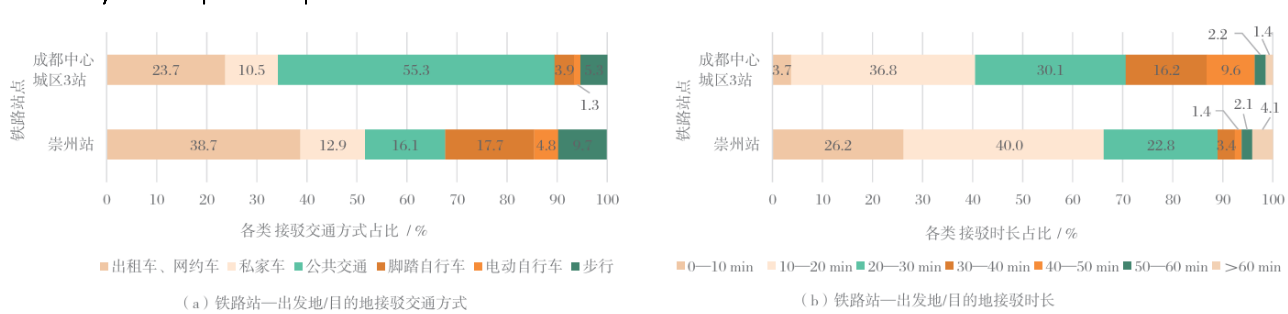

Figure 7. Feeder-Travel Characteristics at Railway Stations

3.3 Evaluation of Supply-Demand Matching in Transit-Style Operation

3.3.1 Too Few and Too Infrequent Services for Commuting-Circle Travel

Analysis of peak-period trains stopping at Chongzhou Station reveals that "the first morning train is not early enough, and evening services are not frequent enough" (Table 3). In the morning peak from Chongzhou to central Chengdu, the first train is C3382 (07:58 Chongzhou-08:20 Chengdu South), which cannot meet the needs of commuters who must arrive at work before 08:30. During the evening peak in the reverse direction, there is no service between D6194 (18:42 Chengdu East, 18:59 Chengdu South-19:22 Chongzhou) and C3372 (20:15 Chengdu South-20:39 Chongzhou), leaving commuters who finish work between 19:00 and 20:00 without an appropriate train.

The number of suitable morning services is also limited: only one train serves Chengdu West and none is suitable for Chengdu East. The Chengdu-Pujiang Railway currently operates 100 trains per day, but only 46 stop at Chongzhou. There is therefore considerable scope to add Chongzhou stops to existing trains and strengthen connections with Chengdu West, South, and East.

Table 3. Trains Stopping at Chongzhou Station That Are Suitable for Commuting

Purpose	Train	Departure	Arrival
Morning commute to work	C3382	07:58 Chongzhou	08:20 Chengdu South
Morning commute to work	C6602	08:19 Chongzhou	08:37 Chengdu West
Morning commute to work	C3384	08:41 Chongzhou	09:03 Chengdu South
Evening return home	C3366	17:32 Chengdu South	17:55 Chongzhou
Evening return home	C6637	18:01 Chengdu West	18:22 Chongzhou
Evening return home	D6194	18:42 Chengdu East; 18:59 Chengdu South	19:22 Chongzhou
Evening return home	C3372	20:15 Chengdu South	20:39 Chongzhou
Evening return home	C3462	21:05 Chengdu East; 21:25 Chengdu South	21:49 Chongzhou
Evening return home	C6643	21:22 Chengdu West	21:38 Chongzhou
Evening return home	C3376	22:05 Chengdu South	22:29 Chongzhou

3.3.2 Train Formations Do Not Adapt Flexibly to Passenger Demand

Most services suitable for commuting use four-car trainsets; only D6194 (18:42 Chengdu East-19:22 Chongzhou) uses an eight-car formation (Table 4). Ticketing data show that none of the services exceeded the acceptable load limit, but several had load ratios above 80%, indicating substantial crowding. Seat-occupancy ratios generally exceeded 100%, meaning that most commuters boarding at Chongzhou had to stand, resulting in a poor experience.

For the three morning services from Chongzhou to central Chengdu, load ratios before arrival at Chongzhou were all below 60%. Train C3382 (07:58 Chongzhou-08:20 Chengdu South) even had a seat-occupancy ratio below 100%, indicating spare seats. After Chongzhou passengers boarded, however, the seat-occupancy ratios of all three services rose to about 150%, while load ratios reached 75-80%, producing high overall crowding.

Table 4. Remaining Capacity of Services Suitable for Commuting

Direction	Train	Cars	Before stop (n)	After stop (n)	Load before (%)	Load after (%)	Seat use before (%)	Seat use after (%)
Morning to work	C3382	4	149	384	31	80	60	155
Morning to work	C6602	4	261	371	54	77	105	150
Morning to work	C3384	4	278	360	58	75	112	145
Evening home	C3366	4	430	267	89	55	173	108
Evening home	C6637	4	306	167	64	35	123	67
Evening home	D6194	8	517	186	54	19	104	38
Evening home	C3372	4	193	87	40	18	78	35
Evening home	C3462	4	404	282	84	59	163	114
Evening home	C6643	4	207	183	43	38	83	74
Evening home	C3376	4	230	175	48	36	93	71

Note: Four-car and eight-car trainsets have 248 and 496 fixed seats, maximum capacities of 688 and 1,376 passengers, and acceptable-service passenger loads of 481 and 963, respectively.

3.3.3 Cumbersome Security and Ticket-Checking Procedures Increase Station Time

The time required to enter and exit Chongzhou Station is shown in Figure 8. Exit procedures are generally efficient and take only about four minutes. Entry takes approximately eleven minutes. The main bottleneck is the tightly restricted platform-access window, which opens eleven minutes before departure and closes five minutes before departure. This creates short, intense ticket-checking queues and substantially reduces the smoothness of entry. Separating security screening from ticket inspection further increases time and complexity. Supporting station services are also incomplete: passengers with spare waiting time have few opportunities for work, reading, light meals, or shopping, and personalized, higher-quality needs are difficult to meet.

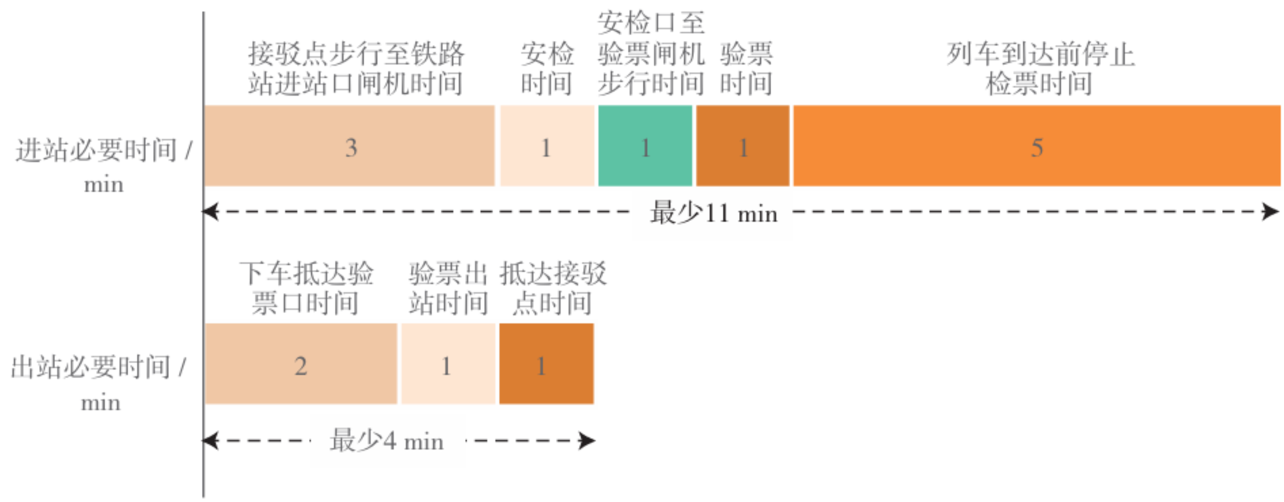

Figure 8. Time Components Required to Enter and Exit Chongzhou Station

3.3.4 Lack of Conventional Bus Connections at Night

Thirty-four conventional bus routes currently connect with Chongzhou Station, but all last departures occur before 18:30. Passengers arriving or departing on later trains therefore have no conventional bus connection. Ticketing records show that 917 passengers use Chongzhou Station after 18:30, including 297 departures and 620 arrivals. Applying the current conventional-bus feeder share of approximately 16% yields an estimated nighttime feeder-bus demand of about 150 passenger-trips (Table 5). Additional nighttime bus services are therefore required.

Table 5. Nighttime Conventional-Bus Feeder Demand at Chongzhou Station

Direction	Train	Chongzhou departure/arrival time	Passengers departing/arriving	Estimated conventional-bus feeder demand
Chongzhou to central Chengdu	C3418	19:00	96	15
Chongzhou to central Chengdu	C3422	19:54	69	11
Chongzhou to central Chengdu	C6686	20:22	81	13
Chongzhou to central Chengdu	C3426	21:32	51	8
Central Chengdu to Chongzhou	D6195	19:22	321	51
Central Chengdu to Chongzhou	C3372	20:39	127	20
Central Chengdu to Chongzhou	C6643	21:38	72	12
Central Chengdu to Chongzhou	C3462	21:49	55	9

Direction	Train	Chongzhou departure/arrival time	Passengers departing/arriving	Estimated conventional-bus feeder demand
Central Chengdu to Chongzhou	C3376	22:29	45	7
Total	—	—	917	147

4 Precise Matching Strategies for Commuting-Circle Integration on the Chengdu-Pujiang Railway

The Chengdu-Pujiang Railway faces limitations in service frequency, uniform train formations, cumbersome inspection procedures, and poorly timed feeder connections. Improvements should therefore follow the principle of precise supply-demand matching and respond directly to commuting-circle demand, enabling rail to play its full role in a rail-based metropolitan area. From a whole-trip-chain perspective, the proposed measures operate at two levels: optimizing train services and optimizing stations. Train-service measures improve time-of-day matching and capacity matching through timetable, stopping-pattern, and train-formation changes (Figure 9). Station measures improve station-process matching and feeder matching by streamlining waiting procedures and introducing nighttime buses (Figure 10).

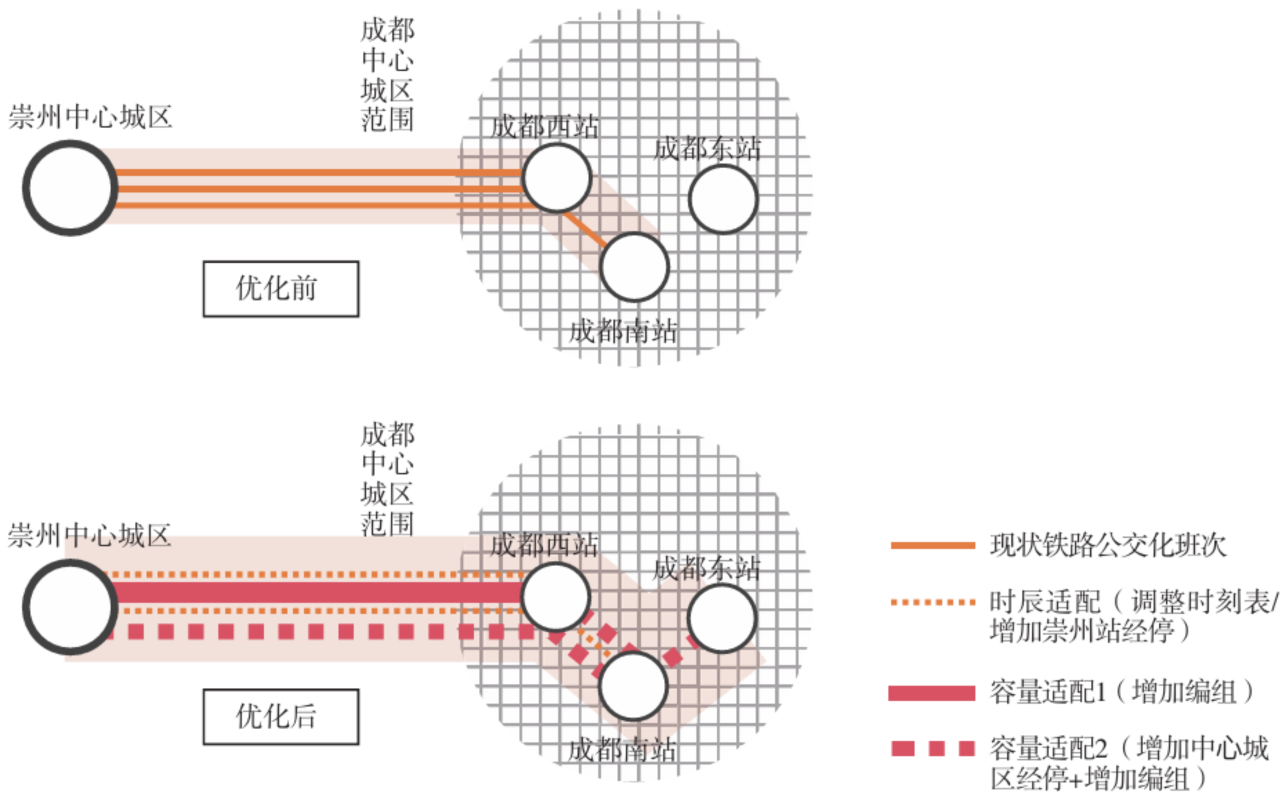

Figure 9. Transit-Style Railway Improvement Strategies through Train-Service Optimization

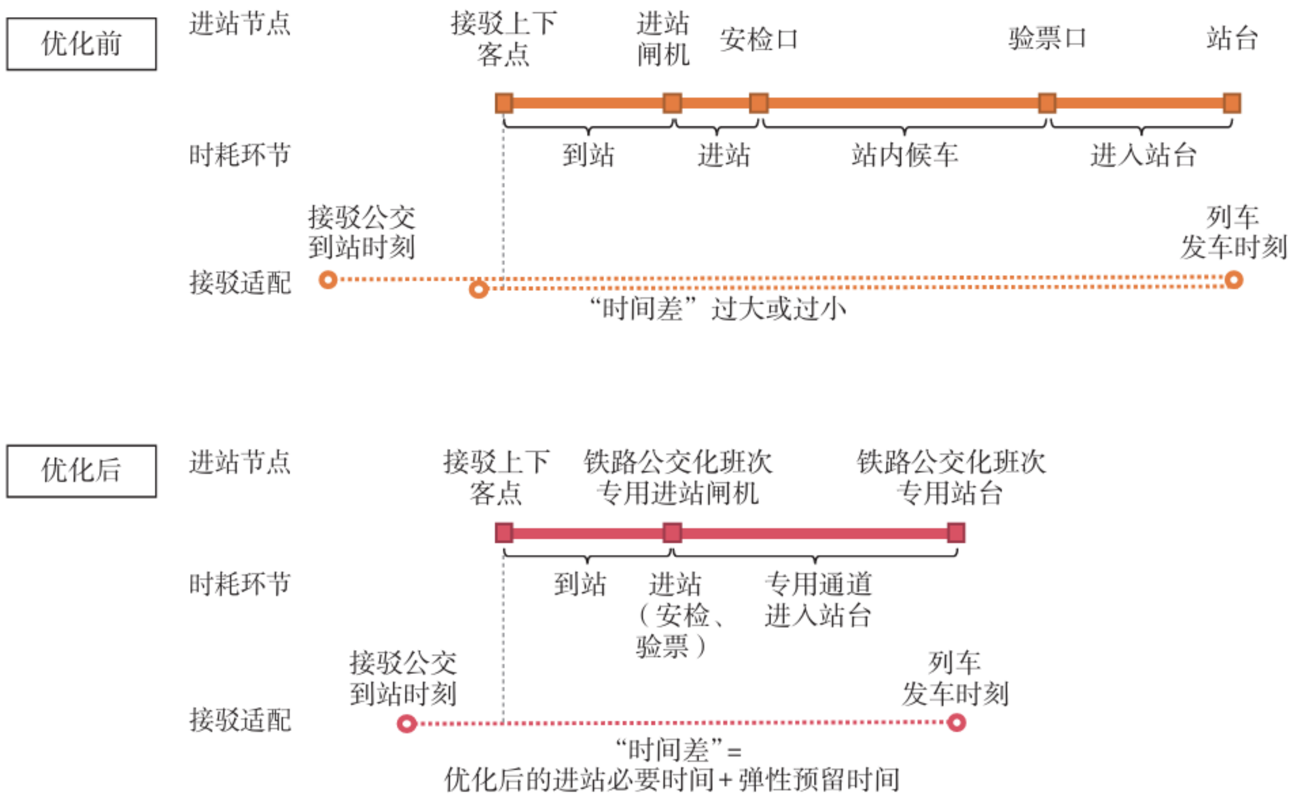

Figure 10. Transit-Style Railway Improvement Strategies through Station Optimization

4.1 Add Peak-Period Services to Improve Time-of-Day Matching

Existing schedules should be optimized under the constraint of commuter work start and finish times, increasing the number of suitable morning and evening peak services. Train C3384 (Ya'an-Chengdu South) should depart Chongzhou at 08:10 rather than 08:39, bringing arrival at Chengdu South forward from 09:03 to 08:34. Train C6606 (Qionglai-Chengdu West) should depart Chongzhou during the 07:00-08:00 period rather than at 09:43.

Trains that currently pass through Chongzhou without stopping but operate at commuter-friendly times should add a Chongzhou stop. Examples include C3380 (07:27 Qionglai-08:00 Chengdu South), C3382 (07:03 Ya'an-08:20 Chengdu South), and C6639 (18:30 Chengdu West-18:48 Ya'an).

4.2 Optimize Stopping Patterns and Train Formations to Improve Capacity Matching

For trains whose times match commuter schedules and that already stop, or could stop, at Chongzhou, the number of stops at Chengdu West, South, and East should be increased and train formation adjusted to passenger volume. Train C3380 (07:27 Qionglai-08:00 Chengdu South), for example, should stop at Chongzhou, be extended to Chengdu East, and expand from four to eight cars. Train C3382 (07:03 Ya'an-08:20 Chengdu South) should similarly be extended to Chengdu East and expanded from four to eight cars. These changes would address the present lack of commuter service to Chengdu East.

4.3 Streamline Station Waiting Procedures to Improve Station Matching

Under the current system of waiting in the station hall and closing ticket checks five minutes before departure, passengers arriving close to departure are highly likely to miss their train. This is a major source of inefficiency. Dedicated platforms should therefore be assigned to commuting-circle services. Passengers could wait on the platform in advance, without being restricted to a specific train, and board the next available service. Security screening and ticket inspection should also be integrated to reduce interruptions in the entry path.

These measures could reduce the minimum station-entry time for commuting-circle travelers from about eleven minutes to approximately six minutes, significantly improving efficiency and the perceived reliability of rail travel. Supporting station facilities should also be upgraded by integrating ticket halls, waiting areas, and other spaces into diverse settings that provide personalized services for passengers with additional time.

4.4 Coordinate Feeder Services with Train Arrivals and Departures

Analysis of trains and passenger flows after 18:30 shows that feeder demand is relatively small and dispersed. Night bus routes should be added and closely coordinated with railway schedules. Precise control of the time gap can improve feeder matching. Following the principle of “essential station-processing time plus a three-minute flexibility buffer,” buses serving passengers departing Chongzhou should arrive at the station about nine minutes before train departure, while buses serving returning passengers should depart approximately seven minutes after train arrival.

Based on the spatial distribution of homes and workplaces, bus routes should be differentiated by distance. Long-distance passengers can be served by limited-stop express routes, while short-distance passengers can be connected through short linked routes that provide near door-to-door service.

5 Conclusion

Transit-style railway operation is an efficient, economical, and comfortable travel option with strong practical relevance as China vigorously develops suburban new towns and metropolitan commuting circles. This study evaluates the performance of the Chengdu-Pujiang Railway and develops an analytical framework based on precise supply-demand matching from the perspective of integrating a suburban new town into the central-city commuting circle. The framework offers a new technical approach for the study and practice of transit-style railway operation in China.

Sustainable operation depends on attracting a relatively stable commuter market. Between Chongzhou and central Chengdu, the rail share remains low relative to private cars, indicating substantial latent demand. At the same time, peak-period railway capacity is already approaching saturation, constraining the service that rail can provide to suburban-new-town commuters. The key to strengthening support for the commuting circle is therefore the degree of precise supply-demand matching. In addition to meeting the general expectation of car-comparable efficiency, services must respond to differentiated preferences for quality and cost through a diversified product portfolio.

Transit-style railway operation is an important instrument for integrating multiple networks and strengthening links between new towns and central cities. Four principles are recommended to safeguard and improve its commuter function.

(1) Focus on demand. Commuting circles in China's major cities differ in maturity, and suburban new towns vary in functional positioning and development stage. The composition and spatiotemporal distribution of commuters therefore differ substantially. Demand assessment should be city-specific. Residentially oriented new towns should focus on weekday morning and evening peak commuting, while education-oriented new towns should pay greater attention to weekend travel between campuses and the central city. Such distinctions provide a precise basis for operational strategy.

(2) Improve efficiency across the full chain. Rail commuting consists of multiple stages. In addition to in-train and in-station time, the first and last mile at both ends cannot be neglected. Under an acceptable one-way commuting-time constraint, improving feeder accessibility and covering more residential and employment areas [26] expands the effective commuting-circle area, increases the potential commuter population, and raises rail ridership.

(3) Adapt dynamically. Implementing transit-style railway service will attract more commuters to rail and create development momentum around stations similar to urban-rail TOD. The jobs-housing distribution and temporal patterns of commuting-circle travelers will continue to change. Regular analysis of demand evolution and dynamic optimization of operational plans are therefore essential.

(4) Innovate to improve quality. International research increasingly recognizes the positive utility of commuting [27], viewing it as personal relaxation time and a valuable transition period [28]. Innovative combinations of quality and cost—such as guaranteed seating with a moderately higher fare—can prioritize comfort and further consolidate the attractiveness of rail commuting.

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Notes

① The definition of a modern metropolitan area follows the National Development and Reform Commission's Guidelines on Fostering and Developing Modern Metropolitan Areas (Development and Planning [2019] No. 328).

② In 2021, Shanghai issued the Implementation Opinions on Accelerating the Planning and Construction of New Towns during the 14th Five-Year Plan; Beijing issued the Implementation Plan for Promoting High-Quality Development and Enhancing the Comprehensive Carrying Capacity of New Towns in the Plains. In 2022, Chengdu issued the Implementation Opinions on Improving and Strengthening the Central City, New Urban Districts, and Suburban New Towns and Further Enhancing Urban Functions.

③ See The Paper, "Pioneering Transit-Style Railway Operation: Shanghai Jinshan Railway Carries 85 Million Passengers in Ten Years," 28 September 2022, https://www.thepaper.cn/newsDetail_forward_20092699.

④ The study area was based on a one-hour railway isochrone and adjusted for administrative boundaries and actual travel conditions. Main parameters were as follows: railway speed was calculated from station-to-station distances and timetables and set at 110 km/h; conventional-bus feeder speed within Chongzhou was 15 km/h; and metro feeder speed within central Chengdu was 35 km/h.

⑤ Using the CRH6A electric multiple unit commonly employed in transit-style railway operation as an example, each car has 62 seats and a rated maximum capacity of 172 passengers. The "passenger load at an acceptable service level" used in this study is 120 passengers. Accordingly, a car with 62 passengers has a seat-occupancy ratio of 100%; a car with 120 passengers has a load ratio of 100%, representing the upper limit of acceptable crowding; and 120-172 passengers correspond to a load ratio above 100%, or a severely crowded oversaturated state.

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