https://doi.org/10.58195/iaet.v2i1.133

Global Science Publishing

IAET

Innovations in Applied Engineering and Technology

https://ojs.sgsci.org/journals/iaet

Article

Design of Traffic Improvement Plan for Line 1 Baijiahu Station of Nanjing Metro

Wenjun Dai

Shenzhen Urban Transport Planning Center Co., Ltd, Shenzhen 518000, China

Abstract: The article proposes design improvements for the current issues at Baijiahu Station, reorganizing the layout of surrounding transportation facilities to address the existing disorder. Based on an understanding of Baijiahu Metro Station, the article analyzes the regional conditions, target service users, and potential future service users. Through on-site inspections and predictions based on current pedestrian flow data and conditions, the article forecasts the future demand for various transportation modes at Baijiahu Station. Subsequently, it puts forward improvement measures and plans concerning the layout of public facilities around Baijiahu Metro Station, the integration of subway and surface transportation, and crowd organization. These proposals aim to provide feasible planning solutions for the reconstruction and future development of Baijiahu Metro Station. Finally, the article uses simulation software to compare the effects before and after the improvements. This allows the optimized plan to effectively enhance the service efficiency and quality of the metro station, facilitating the rational integration of the subway into urban transportation and thereby improving the city's public transportation capacity and service standards.

Keywords: subway stations; transportation facilities; transportation connection; future predictions; improving design

1. Introduction

With the advancement of China's economic development and urban construction, the increasing demand for urban residents' travel has placed unprecedented pressure on urban transportation. The subway, as a new mode of transportation outside the more traditional means such as regular city buses and taxis, has rapidly developed in various cities due to its advantages such as environmental friendliness, safety, comfort, speed, and punctuality. Currently, the subway has become an essential component of shared urban transportation and is expected to play an even more crucial role in future urban passenger transportation tasks [1–3].

In the current situation, Baijiahu Station, due to changes in the intensity of surrounding land development, has gradually found that the initial design and planning at the inception of the subway station can no longer meet present needs. Simultaneously, various irregularities exist at Baijiahu Station due to management issues in various transportation connections. These irregularities are mainly manifested in problems such as taxi parking, pedestrian jaywalking, and bicycle parking. The existing disorder significantly affects the traffic speed and safety of the Baijiahu Metro Station section on Shuanglong Avenue. Therefore, optimizing and designing solutions for these irregularities is an urgent issue that needs to be addressed.

Received: 8 August 2023; Accepted: 30 October 2023.

* Corresponding: Wenjun Dai (dd286382@gmail.com)

2. Current Situation and Problem Analysis

2.1. Current Status of Traffic Facilities Layout

Baijiahu Metro Station is located on the north side near the intersection of Shuanglong Avenue with Tianyuan Middle Road and Tianyuan West Road. The station and the 1A and 2 exits are all positioned on the west side of Shuanglong Avenue. Regarding taxi parking, Baijiahu Metro Station currently does not have a dedicated taxi parking lot or a designated passenger pick-up and drop-off lane for taxis. The organization of taxi pick-up and drop-off at the station mainly relies on occupying bus stops or vacant areas on non-motorized vehicle lanes. Additionally, in this area, there is a notable phenomenon of "unauthorized motorcycle taxis" whose stopping locations largely overlap with regular taxis, occupying sidewalks and non-motorized vehicle corridors. In terms of the layout of the taxi pick-up and drop-off area, recently, to prevent taxis from occupying bus stops for passenger pick-up and drop-off, approximately four-fifths of the road width has been delineated as a taxi pick-up and drop-off lane in the middle of the non-motorized vehicle lane between the two exits.

As for bicycle distribution, areas opposite exits 1A and 2 of Baijiahu Station and along the ground line of both exits are entirely occupied by bicycle parking spaces. Recently, bicycle parking sheds have been added near exit 2 and along the route of both exits at ground level. In terms of ground space, bicycle parking spots essentially occupy the pedestrian pathways between exits 1A and 2. Regarding buses, at Baijiahu Metro Station, there are two bay-style bus stops located on both sides of Shuanglong Avenue. The bus routes serving Baijiahu Station include Antong Line, Jiangning Bus 1, Donggu Line, Dongtong Line, Jindan Line, Jinmo Line, Donglu Line, Jiangning You 1, Anlu Line, and Bus 192, among others (shown in Figures 1 and 2).

Figure 1. Distribution of surrounding infrastructure at Baijiahu Metro Station.

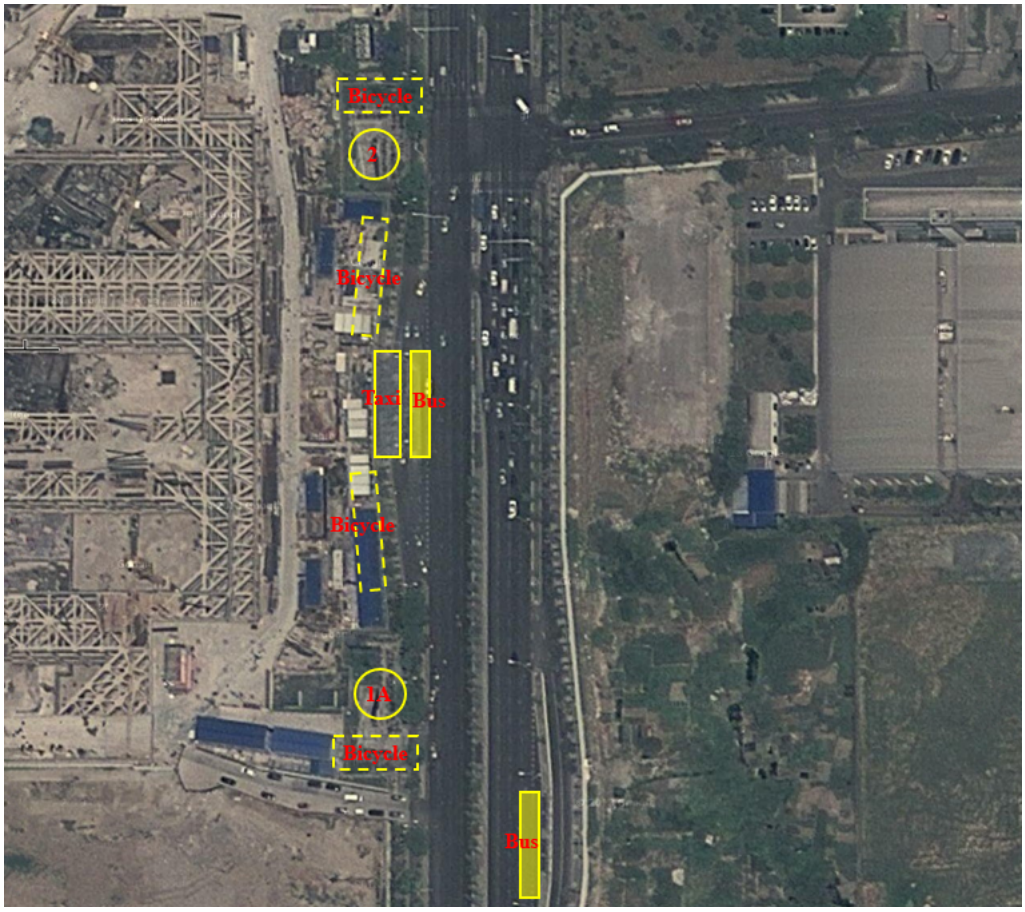

Figure 2. Distribution of surrounding infrastructure at Baijiahu Metro Station.

2.2. Analysis of the Issues

2.2.1. Layout Issues of Public Transportation Facilities

Due to the current scattered distribution of bicycle parking spots, taxi pick-up and drop-off areas, and random taxi parking points, which are concentrated on the west side of Shuanglong Avenue, coupled with the flow of people at the two entrances of Baijiahu Station, the pedestrian flow on the west side of Shuanglong Avenue at Baijiahu Station is significantly higher than on the east side. The chaotic layout of public facilities like this is bound to cause conflicts in the flow of various modes of transportation, leading to increased traffic congestion and chaos, thereby reducing the efficiency of traffic flow. Additionally, as the main facilities are concentrated on the west side of Shuanglong Avenue, it results in uneven and unscientific land use, with the functional density on the west side far exceeding that on the east side of Shuanglong Avenue.

In terms of entrance and exit design, due to the absence of entrances and exits on the east side of Shuanglong Avenue, many passengers arriving at or departing from Exit 1A choose to directly cross the road's green belt to reach the opposite side of Shuanglong Avenue. This increases the danger of traffic operations and significantly impacts the efficiency of vehicles on Shuanglong Avenue, potentially leading to congestion and disorder.

2.2.2. Pedestrian Flow Organization Issues Around the Station

The main flow of people entering and exiting Baijiahu Station primarily occurs through Exit 1A [4–8]. The flow direction of people exiting from Exit 1A includes (shown in Figure 3).

(1) Taking a taxi directly upon exiting.

(2) Walking to the west side bus stop to wait for a bus.

(3) Crossing the road after exiting from Exit 1A and waiting for a bus at the east side bus stop.

(4) Directly retrieving a bicycle and leaving.

Exit 2 generally has only scattered passenger flows exiting, and its flow directions are similar to Exit 1A.

Due to the original intended purpose of Shuanglong Avenue as a fast thoroughfare, pedestrian flows crossing the road are bound to significantly impact its traffic speed. Additionally, due to the layout of bicycle and taxi parking facilities, the overlapping and conflicting flows of pedestrians in multiple directions reduce the passage speed, leading to potential chaos and congestion issues, especially during peak hours.

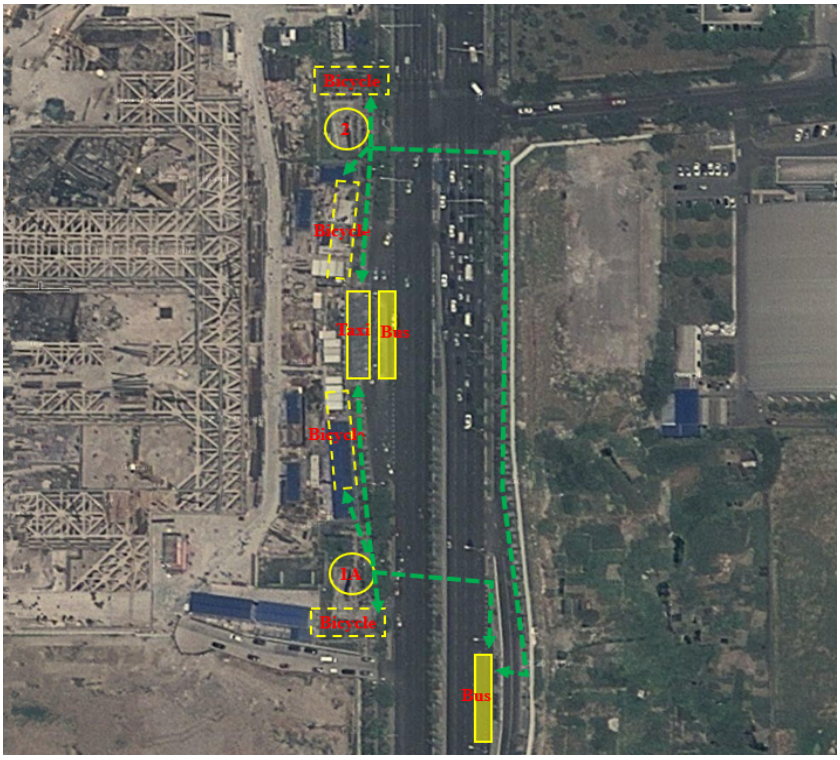

Figure 3. Organization of pedestrian flow at station entrances and exits.

2.2.3. Bus Connection Issues

Baijiahu Station currently has approximately 10 bus routes. Compared to taxis and bicycles, the management and operation of buses are relatively standardized, with dedicated lanes and stops. Their operations generally do not interfere with the normal traffic efficiency of Shuanglong Avenue.

However, as the main operating hours of the major bus routes at Baijiahu Station typically cease before 6 p. m., and the transportation demand from passengers has not completely disappeared before this time, a certain contradiction arises in the supply-demand time range. After the buses stop operating, passengers arriving or departing mostly have to choose to take a taxi to reach their destinations, with short-distance cycling or walking being exceptions.

2.2.4. Taxi Connection Issues

In terms of the layout of taxi pick-up and drop-off areas, recently, to prevent taxis from occupying bus stops for passenger pick-up and drop-off, approximately four-fifths of the road width in the middle of the non-motorized vehicle lane between the two exits has been designated as the taxi pick-up and drop-off lane. However, as a result, the originally spacious non-motorized vehicle lane in this section becomes extremely narrow due to the occupation of the taxi pick-up and drop-off area. It can barely accommodate a single bicycle. This design is prone to causing congestion in the non-motorized vehicle lane during peak commuting hours. Additionally, due to the sudden narrowing of the non-motorized vehicle lane, bicycles and electric scooters may choose to occupy the taxi temporary parking lane or even the motor vehicle lane after this section, posing significant safety hazards.

Moreover, many taxis arriving from the south and dropping off passengers at Baijiahu Station make a U-turn directly in the middle of Shuanglong Avenue, entering the west-side taxi pick-up and drop-off area. This U-turning phenomenon disrupts the traffic speed on the Shuanglong Avenue section near Baijiahu and, as there are

no specific traffic guidance signs at the turning point, U-turning vehicles may directly change lanes and park on the west side, creating significant safety hazards with frequent, short-distance lane changes. The phenomenon of "carpool" taxis not parking in the designated area further contributes to the disorderly flow of people at Baijiahu Station while occupying the already tight west-side land. This scattered parking area essentially occupies the entire non-motorized vehicle lane and pedestrian pathway, easily leading to congestion in both traffic and pedestrian flows.

2.2.5. Bicycle Parking Issues

Bicycle parking at Baijiahu Station is relatively scattered, and the current bicycle parking points along the west side also partially occupy the pedestrian pathway. This can result in some pedestrians borrowing the non-motorized or even the motor vehicle lane to pass through the route where bicycles are parked due to the original pathway being occupied. With various modes of transportation occupying the lanes, it is inevitable that this will lead to confusion in traffic flow, increase the risk of pedestrian walking, reduce the passage speed on this road section, and create safety hazards. The placement of bicycle parking points at exits 1A and 2 may, to some extent, affect the throughput capacity of the two entrances. During peak periods, excessive bicycle parking at both ends may cause bicycles at the two exits to be improperly parked, disrupting the passage at both entrances.

3. Future Traffic Demand Prediction

3.1. Prediction Background

In the current situation, as Jiangning District only has Line 1 of the subway, all subway travel in Jiangning District is concentrated on the south extension of Line 1. Due to the design of the south extension of Line 1, it forms an approximate "L" shape at Baijiahu and Xiaolongwan, extending towards the southeast. Therefore, in the current situation, Baijiahu Station's service coverage includes the Airport Expressway to the west, the Nanjing Ring Expressway to the south, covering the main subway travel flows in the southwestern direction of Jiangning District, as well as the small-scale pedestrian flows around Baijiahu.

After the completion and opening of Line 3 of the subway, it will alleviate some of the passenger transportation pressure from Line 1 in the Jiangning area. In the areas west of Line 3, passengers who originally relied on Line 1 for travel will shift to Line 3. This will significantly reduce the service coverage of Baijiahu Station and alleviate its transportation pressure. After the opening of Line 3, the service coverage of Baijiahu Station will roughly be a circular area centered around Baijiahu Metro Station. Beyond this range, considering the convenience of passenger travel choices, other nearby subway stations will be preferred for travel, replacing Baijiahu Station in this capacity (shown in Figure 4).

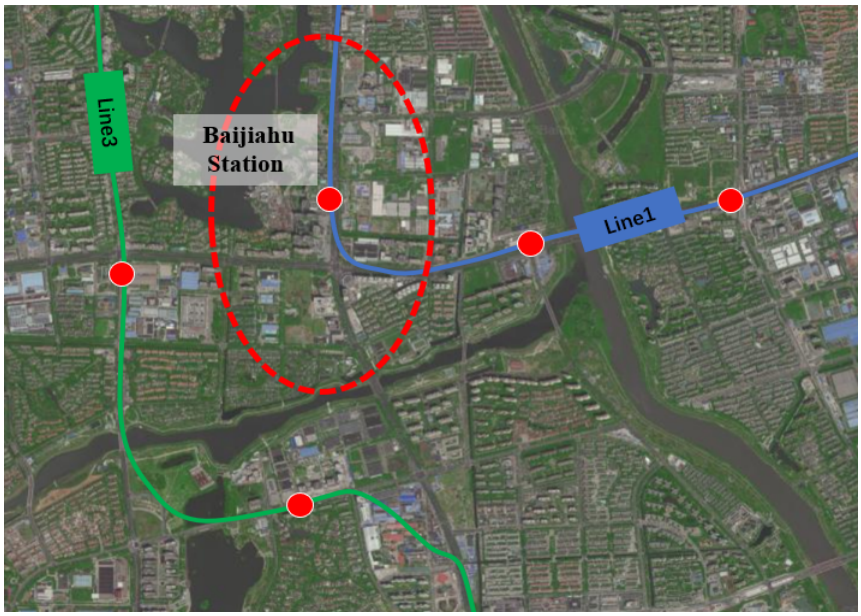

Figure 4. Coverage of Baijiahu station after the completion and opening of subway Line 3.

3.2. Future Traffic Infrastructure Scale Prediction Results

In terms of walking to or from Baijiahu Station, as walking does not require ground stops or waiting facilities like public transportation, there is no need to arrange ground-level public service facilities for walking, only guidance for pedestrian flow.

For buses at Baijiahu, in terms of ground public facilities, since buses do not stay at Baijiahu Station for an extended period, the bus stops on both sides of Shuanglong Avenue can generally meet the demand for bus passage, and there is no need to add bus parking points.

According to bicycle parking space standards (referring to the "Parking Lot Planning and Design Rules"), bicycle parking spaces are sized at 0.6*2 and 0.6*3.2. The single-side parking aisle is 1.5 meters, and the double-side parking aisle is 3.2 meters. The entrance and exit of the bicycle parking lot should be no less than 3 meters, and the parking space should generally be controlled between 15-20 meters. If there are more than 300 bicycles, two entrances and exits are needed, and each entrance should meet a width of 2.5 meters. Considering that the average daily bicycle flow in 2019 was about 936 people, taking into account both arrival and departure, the maximum number of bicycles parked should be approximately half of the bicycle flow, or about 468 bicycles. From this, it can be inferred that the land area occupied by bicycle parking at Baijiahu Station is approximately 912.6 square meters.

In terms of taxi and private car shuttles to Baijiahu Station, based on the current situation, both types do not stay at Baijiahu Station for long. Most private cars and taxis arrive at Baijiahu Station to complete passenger drop-off and pick-up tasks and immediately leave. Only a small number of taxis perform streamlined stopping to pick up passengers at Baijiahu Station. According to the parking space standards for small cars, the typical parking space size is 2.8*6 square meters. At Baijiahu Station, approximately 50 parking spaces can be set aside for taxis and private cars that need to park, with an area of about 840 square meters.

4. Improvement Design for Site Layout

4.1. Improvement Approach

Taking into account the land development and planning situation around Baijiahu Station, a general layout of future land functions is proposed [9–13]. Based on the functional layout, and in conjunction with the main issues, optimization designs are made for the facilities, locations, and scales of various transportation modes at Baijiahu Station. Subsequently, an optimized map of public facility distribution is drawn. Finally, detailed designs are conducted for various aspects according to the identified main issues (shown in Figure 5).

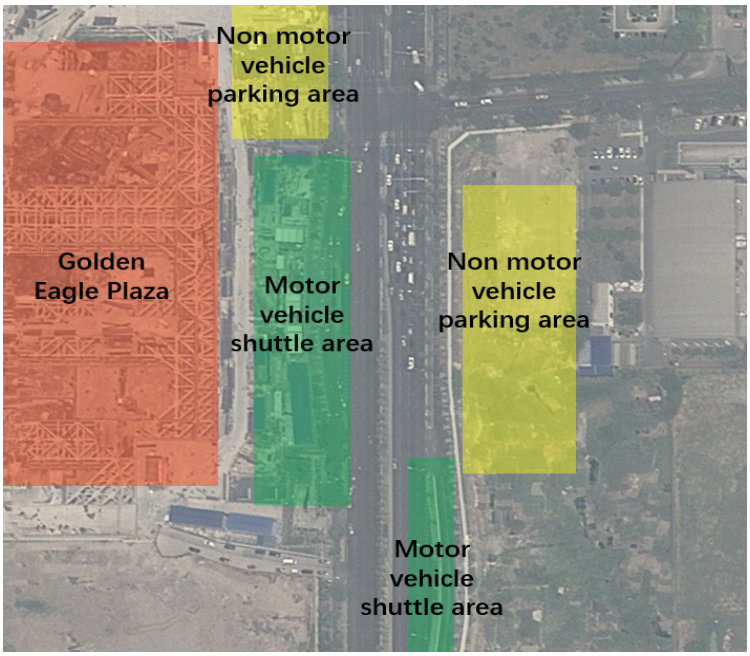

Figure 5. Functional layout.

4.2. Facility Layout Plan

4.2.1. Bicycle Facility Layout Plan

The area allocated for bicycle parking is approximately 912 square meters. Bicycle parking is divided into two directions: from north to south and from south to north.

Given the current situation where the land on the west side of Baijiahu Metro Station is tight, and a large number of bicycles parked near the subway entrance and along the route of exits 1A and 2 significantly interfere with pedestrian flow entering and exiting the subway and using the sidewalks, the distribution of bicycle parking points is reconsidered. A bicycle parking point is set on the west side of Shuanglong Avenue to accommodate bicycles arriving from the north to the south. Simultaneously, a bicycle parking point is added on the east side of Shuanglong Avenue to meet the parking needs of bicycles arriving from the south to the north.

In terms of area allocation, considering that the flow of people at the south entrance and exit is greater than the north side, and the tight land situation on the west side of Shuanglong Avenue near Baijiahu Station, the allocated area for the bicycle parking point on the west side of Shuanglong Avenue is set at 304 square meters, while the area for the bicycle parking point on the east side of Shuanglong Avenue is set at 608 square meters.

4.2.2. Layout Plan for Taxi and Bus Boarding/Alighting Areas

In terms of short-term taxi stops and passenger boarding/alighting at Baijiahu Station, to address the issue of the taxi boarding/alighting area on the west side of Shuanglong Avenue significantly encroaching on the non-motorized lane under current conditions, the mid-section bay at Baijiahu Station should be deepened. While ensuring the smooth passage of the non-motorized lane, the taxi boarding/alighting area should be merged with the west side bus platform. The west side serves as a waiting area for taxis, while the east side serves as a bus waiting area [14–17].

Simultaneously, under current conditions, taxis arriving from the south and heading north, as well as those arriving from the north and heading south, all board/alight on the west side of Shuanglong Avenue. Taxis heading from south to north turn and change lanes near Exit 2, causing traffic disruption. Therefore, to maintain the traffic flow on Shuanglong Avenue, a taxi boarding/alighting lane should be added on the east side of Baijiahu Station. This would prevent disruptions to traffic caused by southbound taxis interfering with the main road. The setup on the east side is essentially the same as the west side, involving deepening the existing bus bay and merging the taxi boarding/alighting area with the bus area.

This configuration ensures that taxis arriving or departing from both sides can avoid making U-turns on the main road, and the deepened bay also resolves the issue of taxis' boarding/alighting areas encroaching on the original non-motorized lane, disrupting the passage of non-motorized vehicles.

4.2.3. Layout Plan for Taxi and Private Car Parking Locations

In terms of taxi and private car arrival and parking at Baijiahu Station, considering the ongoing construction of the Jin Ying Tian Di complex at the upper end of Baijiahu Metro Station, which is expected to be completed and open by the end of the year. The Jin Ying project has an above-ground construction area of 150,000 square meters, including a 100,000 square meter commercial building, a 20,000 square meter five-star hotel, and a 30, 000 square meter boutique residence. The underground construction area is approximately 100, 000 square meters, comprising a 40,000 square meter commercial area and a 60,000 square meter garage and utility rooms.

In the previous prediction, the estimated area for medium to long-term parking for arriving small cars is approximately 840 square meters. The underground garage area of Jin Ying Tian Di can fully meet the land area requirements for medium to long-term parking of small cars arriving at Baijiahu.

Additionally, as Jin Ying Tian Di is planned to be connected underground with Baijiahu, it can be considered to transfer the land area for taxis and private cars requiring medium to long-term parking upon arrival at Baijiahu Station to the underground garage of Jin Ying Tian Di. This solution aims to address the chaotic parking situation for small cars on the surface at Baijiahu.

4.2.4. Subway Entrance and Exit Layout Plan

In the above proposal, a taxi pick-up and drop-off area has been added on the east side of Longteng Avenue. Currently, there is a bus stop on the east side of Longteng Avenue, which will inevitably lead to a large number of pedestrians crossing the road to enter the Baijiahu Metro Station. Under current conditions, many pedestrians on the east side choose to cross the central median directly to access Entrance 1A, causing disruption to the main road.

Therefore, to address the pedestrian crossing needs on the east side of Longteng Avenue, Entrance 1B should be added across from Entrance 1A at the Baijiahu Station. This will prevent the occurrence of pedestrian crossings disrupting traffic on Longteng Avenue [18].

4.3. Optimized Design Proposal

Combining the aforementioned layout adjustments, mark the improved and repositioned bicycle parking points, taxi pick-up and drop-off areas, the deepening of the original bus bay, as well as the new entrances and underground passage in the CAD drawing (shown in Figure 6). Seal off the U-turn gap near Exit 2 on Longteng Avenue, preventing vehicles from making U-turns on the main road and disrupting traffic efficiency. As the medium to long-term parking for cars is located in the underground parking lot of Golden Eagle Plaza, it is not indicated in the Figure 7.

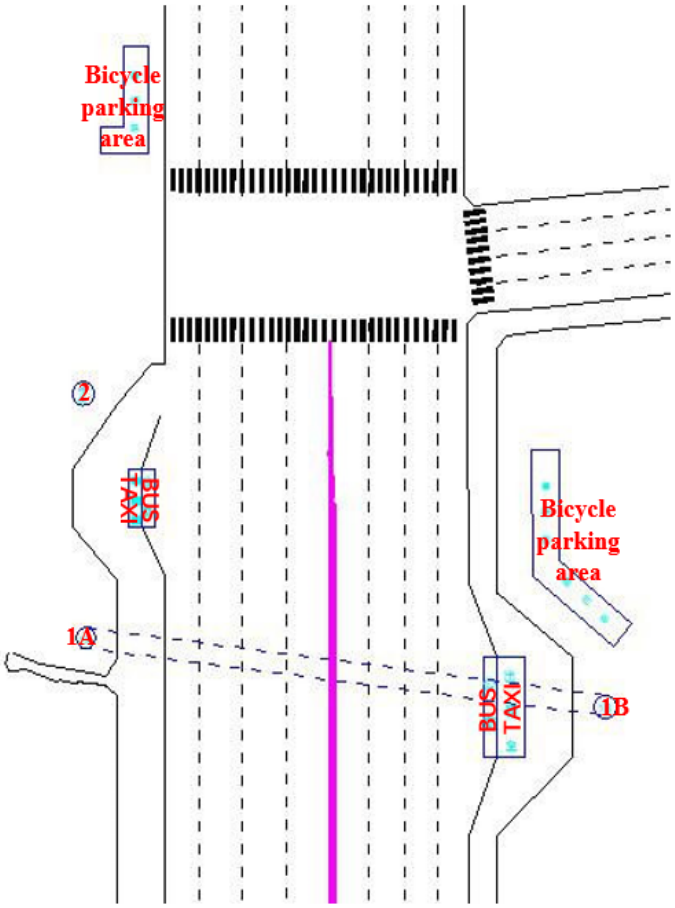

Figure 6. Optimization layout diagram.

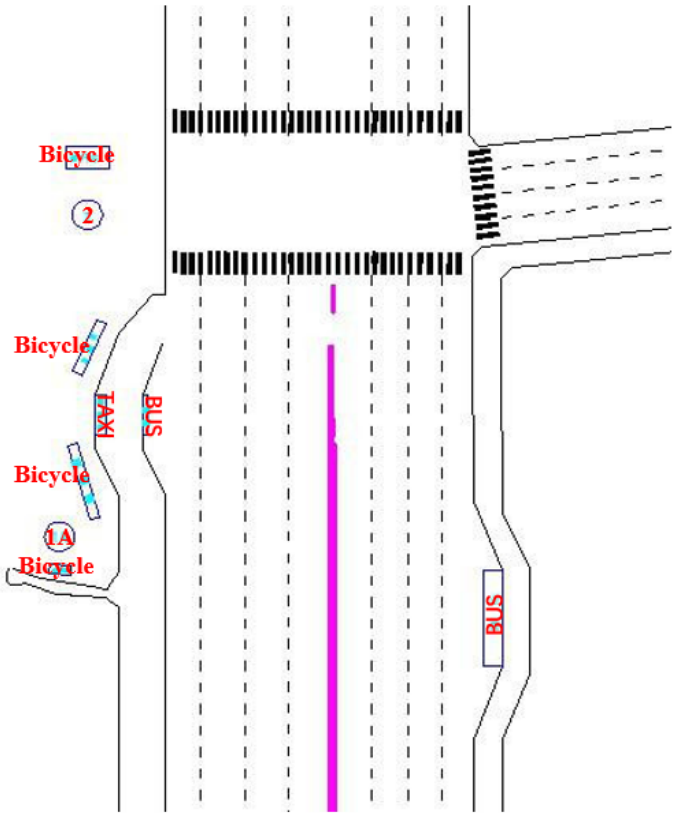

Figure 7. Current facility layout diagram.

5. Simulation Comparative Analysis

Utilizing simulation software VISSIM to model the sections of Longteng Avenue near Baijiahu Station [19, 20]. Construct pedestrian and vehicular flows that have a significant impact on the main road traffic under both the current and the planned design layouts. Compare the efficiency of arterial traffic flow and the organization of traffic patterns under the two layout conditions, evaluating the effectiveness of the improvement proposal in optimizing traffic flow on the main road (shown in Figure 8).

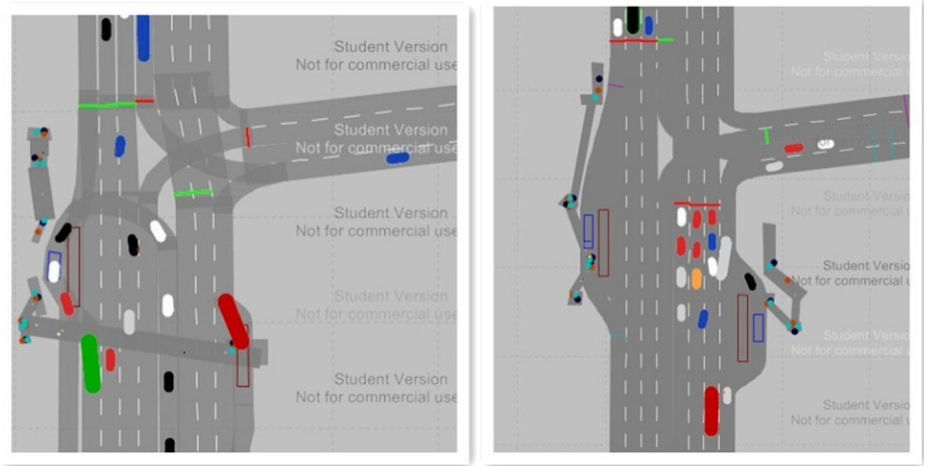

Figure 8. Simulation results before and after improvement.

The left image depicts the traffic organization before improvement, while the right image illustrates the road traffic conditions after the planned design.

In the left image, it can be observed that under current conditions, the interaction between vehicle flow and pedestrian flow is significantly problematic, with pedestrian crossings causing substantial interference to vehicular traffic. Additionally, the U-turn flow in the north-south direction creates considerable disturbance to

the flow on the left side of the road, easily leading to traffic congestion.

In the improved design shown in the right image, the distribution of traffic in each lane is clearer, and pedestrian flow does not significantly intersect with vehicular traffic. This ensures the smooth flow of traffic on the main road. Only the taxi pick-up and drop-off area occasionally experiences short queues. Therefore, through simulation and a comparison of the two scenarios, it can be observed that the improved traffic facility layout and traffic patterns effectively alleviate the issues of pedestrian-vehicle and vehicle-vehicle interactions present in the current conditions. This ensures a smooth flow in the section of Longteng Avenue near Baijiahu Station, significantly reducing the likelihood of congestion and alleviating the chaotic traffic situation on Longteng Avenue.

Based on this comparison, the proposed improvement plan in this study demonstrates feasibility for implementation.

6. Conclusion

This paper proposes a design improvement plan for the current issues at Baijiahu Station, reconfiguring the layout of the surrounding transportation facilities to address the existing challenges. Based on an analysis of Baijiahu Metro Station and its surrounding area, this study examines the regional conditions, service targets, and future service objectives of Baijiahu Metro Station. Through on-site inspections and predictions of future demands for various modes of transportation at Baijiahu Station using current pedestrian flow data and conditions, the paper proposes improvement measures and solutions in areas such as the layout of public facilities around Baijiahu Metro Station, the integration of subway and surface transportation, and the organization of pedestrian flow. This provides feasible planning solutions for the renovation and development of Baijiahu Metro Station. Finally, the paper conducts a comparative analysis of the effects before and after the improvement using simulation software.

In this thesis, the current traffic situation and issues at Baijiahu Station are described and analyzed. Predictions based on current trends are made regarding the flow and structural proportions of various transportation modes connecting to Baijiahu Station in the future. Drawing on these predictions and combining them with CAD, the layout of future surface public transportation facilities at Baijiahu Station is designed, and the organization and flow of various transportation modes around Baijiahu Station are planned in the improved layout.

The paper addresses issues related to the layout of public transportation facilities, the connection between buses and subways, taxi integration and management at Baijiahu Station, bicycle arrival and parking, as well as the organization and management of pedestrian flow around Baijiahu Station under current conditions.

Funding

Not applicable.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

The author declares no conflict of interest.

Reference

1 Kuang J. Integration of Subway Station Area into the City. Master's Thesis, Tianjin University, Tianjin, China, 2007.

2 Xiong Z. Regional Study on the Design of Public Facilities in Chengdu Metro Stations. Master's Thesis, Southwest Jiaotong University, Chengdu, China, 2011.

3 Ni Z. On the Demand for Traffic during Urban Subway Construction Period. *Value Engineering* 2011; **30** (**17**): 92–92.

4 Nadine Schüssler, Kay W Axhausen. Accounting for Similarities in Destination Choice Modelling: A concept. 9th Swiss Transport Research Conference (STRC 2009), Ascona, Switzerland, 9 – 11 September 2009.

5 Li L. Subway Exit Design—Taking Shenzhen Metro Exit Design as an Example. *China Science and Technology Expo* 2011; (**26**).

6 Zhang Q, Han B, Lu F. Characteristics of Interaction between Urban Rail Transit Passengers and Station Environment. *Urban Rail Transit Research* 2011; (**10**)**14**: 44–48.

7 Urban Land Institute (ULI). Foreign Parking Lot Design; China Water Resources and Hydropower Press: Beijing, China, 2003.

8 Zhu H. Research on Evaluation Method of Regional Main Road Network Planning Layout Scheme. Master's Thesis, Jilin University, Changchun, 2006.

9 He P. Urban Design Research on the Area around Subway Stations. Master's Thesis, Nanchang University, Nanchang, China, 2009.

10 Xiang Q. Research and Application of Post-Evaluation Method for Highway Network Planning. Master's Thesis, Chang'an University, Xi'an, China. 2002.

11 Comprehensive Planning Division of the Ministry of Transport. Methods for Compilation of Highway Network Planning. Beijing: Comprehensive Planning Division of the Ministry of Transport, 2010.

12 Crowley JA. Use of Multi-Criteria Decision Analysis in Infrastruction Appraisal. *Australian Road Research* 1995; **17**(**3**): 169–174.

13 Dupuy G, Stransky V. Cities and Highway Networks in Europe. *Journal of Transportation Geography* 1996; **4**(**2**): 107–121.

14 Tang Q. Research on Selection of Transfer Bus Stations and Optimization of Transfer Line Network Based on Rail Transit. Master's Thesis, Southwest Jiaotong University, Chengdu, China, 2012.

15 Luo Z, Xu H, Chen F. Audio Sentiment Analysis by Heterogeneous Signal Features Learned from Utterance-Based Parallel Neural Network. AAAI-2019 Workshop on Affective Content Analysis, Honolulu, HI, USA, 27 January 2019.

16 Chen F, Luo Z, Xu Y, Ke D. Complementary Fusion of Multi-Features and Multi-Modalities in Sentiment Analysis. AAAI-2020 Workshop on Affective Content Analysis, New York, NY, USA, 7 February 2020.

17 Luo Z, Zeng X, Bao Z, Xu M. Deep Learning-Based Strategy for Macromolecules Classification with Imbalanced Data from Cellular Electron Cryotomography. 2019 International Joint Conference on Neural Networks (IJCNN), Budapest, Hungary, 14–19 July 2019.

18 Weng X Zeng H. Instance Analysis of Traffic Performance in Subway Inner Passageways. *China Safety Science Journal* 2011; **21**(**5**): 109–113.

19 Ding Z. Research on Road Network Automatic Generation System Based on VISSIM. Master's Thesis, Beijing University of Technology, Beijing, China, 2009.

20 Luo Z. Knowledge-guided Aspect-based Summarization. 2023 International Conference on Communications, Computing and Artificial Intelligence (CCCAI), Shanghai, China, 23–25 June 2023.