

Article

Research on Optimization Strategies of Regional Cross-Border Transportation Networks—Implications for the Construction of Cross-Border Transport Corridors in Xinjiang

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Abstract: Facility connectivity plays a pioneering role in the Belt and Road Initiative proposed by General Secretary Xi Jinping in 2013. Xinjiang, as the core area of the Silk Road Economic Belt bordering eight Eurasian countries, plays a crucial role in cross-border transportation and humanistic exchanges and is the focus of the national connectivity initiative. While the current analysis on regional accessibility has become more diversified, analyses on long-distance cross-border corridors are still relatively rare. Therefore, this paper takes the Xinjiang Uygur Autonomous Region (XUAR) of China as the main study area extending westward to the five Central Asian countries. Modified accessibility accounting methods and gravity models are used to analyze the current status of accessibility and the strength of economic ties between Xinjiang and the five Central Asian countries. The results showed that the distance decay effect of transportation accessibility between Xinjiang and the five Central Asian countries is obvious; the constraints of “natural geography + transportation economy” affect the accessibility level from each state in Xinjiang to the five Central Asian countries and shows a trend of strength in the north and weakness in the south. From the optimization of the regional planning road network in a reverse projection, G3033 and other highways and the construction of the Yi-A railroad will improve the status quo of “east-west access but not north-south access” in Xinjiang. The “corridor effect” and spatial polarization characteristics of economic connection intensity from Xinjiang to the five Central Asian countries are significant. This study has important theoretical and practical significance for the construction of cross-border corridors.

Keywords: cross-border transport corridors; GIS analysis; accessibility; modified gravity model; China-five Central Asian countries



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1. Introduction

Transportation is the foundation for the survival of human society and is a safeguarding industry in the economic and social development of a region [1]. Accompanied by the development of national transportation infrastructure, the complex modes of transportation work together to form an efficient, comprehensive transportation system, which is both an important foundation for the construction of a strong transportation country and an inevitable choice to promote the opening up and collaboration with the outside world [2]. As an important node for realizing Asia–Europe connectivity, Xinjiang is an important link for promoting the cross-border transportation market and developing cross-domain logistics in Central Asia. These factors are of great strategic significance in realizing China’s economic stability and prosperity.

At present, along with the continuous promotion of the “One Belt, One Road” initiative, Xinjiang has changed from the end of the national road network in the west to a bridgehead for opening up to the west and was identified as the core area of the Silk Road Economic Belt in 2015 [3]. Combined with Xinjiang’s development orientation of “linking the east with the west”, the Ministry of Transportation in Xinjiang sought to build a strong pilot traffic system and facilitate the building of a cross-regional comprehensive transportation channel construction to support national internal and external circulation and enhance the country’s facility-connectivity capacity. At present, all 15 first-class national ports in Xinjiang have access to secondary roads and above, two ports have access to railroads, and other cross-border railroads and high-grade highways are entering the planning or design stage one after another. With China’s bilateral and multilateral trade cooperation with Central Asian countries continuing to deepen, the demand for a Xinjiang–Central Asia five region transportation market has become increasingly strong. However, according to the survey, the overall quality of transportation infrastructure in the five Central Asian countries is at the lower-middle level (Table 1), and the level of regional connectivity has become a bottleneck restricting cross-border openness and cooperation [4]. Xinjiang and the five Central Asian countries are located in the same hinterland of the Eurasian continent. The sparse road network is widely distributed, the node spacing is large, the road network accessibility is low, and the regional development is presented as a loose polycentric spatial structure. In addition, the mechanism of the supporting role of Xinjiang’s transportation infrastructure development on the national economy and social development is significantly different from that of the inland areas. And the economic and social geographic phenomena of regional spatial units under different spatial scales are also closely related to the spatial units of neighboring regions. Therefore, the analysis of the neighboring effects of transport corridors and road network resources of multi-scale spatial units is crucial for the rational planning and optimization of the level of connectivity between Xinjiang and Central Asia’s five countries’ transport infrastructures.

Table 1. Logistics performance index for five Central Asian countries (representing the quality of trade- and transport-related infrastructure, with a value range of 1–5).

	Kazakhstan	Uzbekistan	Turkmenistan	Tajikistan	Kyrgyzstan
2010	2.66	2.54	2.24	2	2.09
2012	2.6	2.25	2.31	2.03	2.49
2014	2.38	2.01	2.06	2.36	2.05
2016	2.76	2.45	2.34	2.13	1.96
2018	2.55	2.57	2.23	2.17	2.38

Note: Data from the World Bank (<https://data.worldbank.org.cn/> accessed on 10 May 2024).

Along with the further development of the “flow space” theory, basic transportation planning research has gradually crossed over to the direction of spatial structure [5,6] and spatial and temporal evolution [7,8]. The different spatial and temporal scales of road network morphology variables on the economic development of the region along the measurement conditions are caused by the variability, and determining the spatial scope of the multi-scale region to build the effectiveness of the transport corridor articulation has become an important frontier field of transportation management [9,10]. Hence, further in-depth research on this area is necessary. In the historical study of transportation road network optimization, algorithms are mostly used to optimize the microcirculation within the urban traffic zone [11]. In contrast, optimization studies with cross-border transportation corridors as the research object have been relatively fewer. Determining how the existing road network structure can be used to improve the access capacity of transportation infrastructure services to achieve the overall optimization of the road network has become increasingly urgent.

As one of the important indicators for measuring the service level of regional transportation infrastructure, traffic accessibility has been widely used in the research of urban

land use [12,13], transportation road network optimization [14,15], and spatial transportation planning [16,17]. Scholars at home and abroad have used the accessibility index to assess the spatial effects of transportation infrastructure, focusing on the evolution and spatial-temporal convergence effects of accessibility brought about by the improvement of transportation road networks of different scales [18,19]. Relevant research has concentrated on the county and city levels [20,21], and research on cross-regional transportation networks and accessibility has been limited. In terms of research methods, those based on transportation accessibility are mainly quantitative, including GIS spatial technology [22], network analysis and cost raster weighted integration [23], economic gravity [24], weighted regression [25], and weighted travel time [26]. With the development of spatial measurement technology, the inverse distance weight method of spatial measurement, coupled coordination model, etc., have also gradually become important means of transportation accessibility research. However, the above accessibility research methods are mostly based on the time-cost model to consider the layout of a certain urban node, and pay relatively little attention to the strength of transportation links between different nodes (especially between cross-border regions). Currently, the literature on the Belt and Road initiative has focused on transport infrastructure along the Belt and Road and few studies have focused on transport accessibility and optimal construction of transport corridors. These studies have focused on the economic spillover effect [27,28], cross-border investment (FDI) growth [29,30], and the strategic value of infrastructure construction [31,32], and the relatively economically developed city clusters along the Maritime Silk Road [33,34]. Less research has focused on the relatively backward land transport along the Silk Road Economic Belt, with particular focus on the Northwest Corridor Belt [35] and the entire Silk Road Economic Belt [36] as the starting point for discussion.

In summary, the current research on the model algorithms related to traffic accessibility and road network optimization has been relatively perfect. However, research on their application to cross-border transportation, especially from the perspective of China and the five Central Asian countries, has been lacking. How can we evaluate the soundness of the inter-regional cross-border transportation corridor network after the given cross-border infrastructure is completed? What role does transportation infrastructure play in cross-border economic exchanges?

In order to answer these questions, this paper takes the “mobility space” theory as a benchmark, which takes the optimization of cross-border road networks between Xinjiang and five Central Asian countries as a main line and measures and analyzes the development status of cross-border transport corridors and the backward projection after optimization in two dimensions, so as to provide data references for the optimization of cross-border transport corridors between China and the five countries of Central Asia (as shown in Figure 1). The main contribution of this paper is twofold:

- Using the transportation accessibility assessment model combined with policy orientation, it points out the existing problems of the current Xinjiang–Five Central Asian countries transportation corridor;
- Analyzes the influencing factors leading to the limited accessibility of Xinjiang–Five Central Asian countries in combination with the current situation of Xinjiang’s cross-border port infrastructure construction;
- Analyzes the economic effects of improved transport corridors by using backward projection and the results of the gravity model.

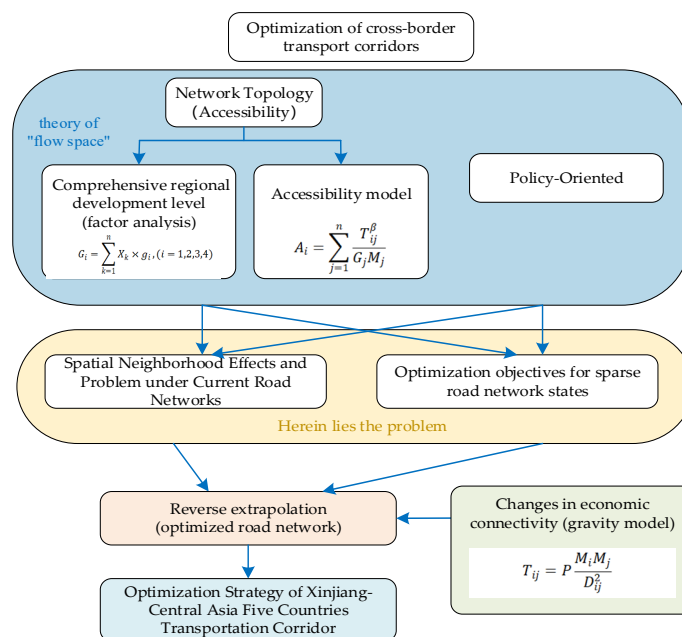


Figure 1. Framework of mechanism for optimization of Xinjiang–Central Asia transport corridor.

The rest of this paper is organized as follows: Section 2 provides an overview of the study area and the model used and introduces the data sources. Section 3 analyzes the spatial pattern of traffic accessibility in Xinjiang–Central Asia’s five cross-border transport corridors and identifies the problems of the current Xinjiang transport road network. Section 4 optimizes the cross-border transport corridors for the problems of the existing road network, analyzes their feasibility comparatively, and conducts economic linkage measurement analysis of the transport road network before and after optimization by using the gravity model to explore the internal logic mechanism between road network and economic and social development to provide theoretical support for the optimization of the transport infrastructure under the conditions of a sparse road network. Finally, conclusions are drawn, highlighting the shortcomings and potential for future research.

2. Materials and Methods

2.1. Study Area

The implementation of the Silk Road Economic Belt Initiative has brought opportunities for the accelerated development of its western provinces and autonomous regions while maintaining the existing development achievements. The Belt and Road Initiative has further promoted the balanced development of China’s domestic resources and production. Located in the core area of The Belt and Road, Xinjiang is an important window for China to open to the West, with its superior geographical location and rich tourism resources (Figure 2). The border areas of Xinjiang include nine border prefectures, including Hami Region, Changji Hui Autonomous Prefecture, Altay Region, Tacheng Region, Bortala Mongolian Autonomous Prefecture, Ili Prefecture, Aksu Region, Kizilsu Kirgiz Autonomous Prefecture, and Kashgar Region. The border lines with eight countries are more than 5600 km long (Data from the website of the People’s Government of Xinjiang Uygur Autonomous Region: <https://www.xinjiang.gov.cn/> accessed on 21 December 2023), and 17 state-level first-class ports can be found along the Belt and Road Important Node on the landline (Table 2).

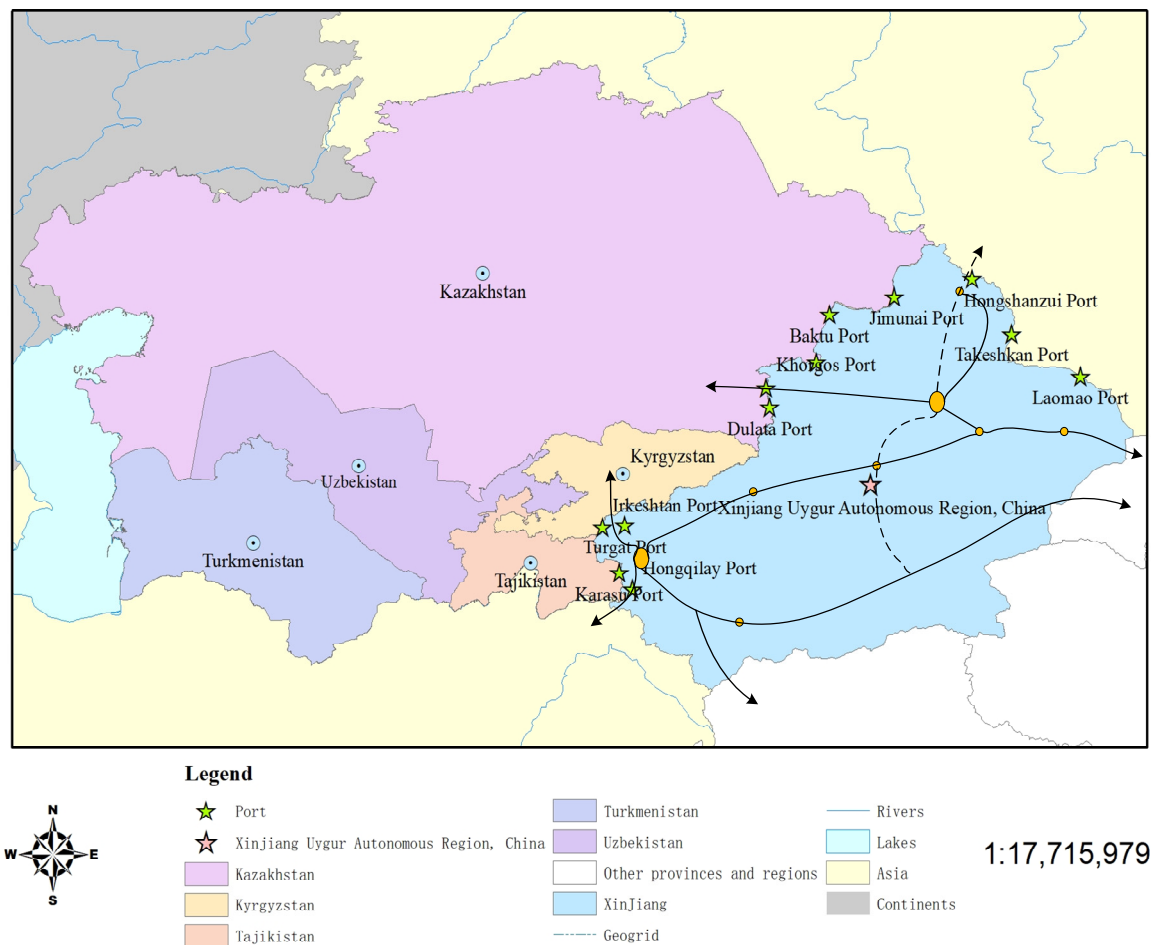


Figure 2. Scope of study area.

Table 2. List of first-class ports in Xinjiang–five Central Asian countries.

No.	Name of Domestic Ports	Major Trading Countries	Name of Foreign Ports	Mode of Transport	State/City	Port Level
1	Khorgos	Kazakhstan	Khorgos	Roads, Railways, Pipelines	Iliju	A class of land ports
2	Alashankou	Kazakhstan	Dostyk	Roads, Railways, Pipelines	Bozhou	
3	Bakhtu	Kazakhstan, Russia	Barkot	Highways	Tacheng Region	
4	Jimnai	Kazakhstan, Russia, Mongolia	Mehrabchigai	Highway, Pipeline	Altai Region	
5	Turata	Russia, Uzbekistan	Koryzat	Highway	Yili Prefecture	
6	Tulgaat	Kyrgyzstan	Turugart	Highway	Kesu	A class of airports
7	Ilkhestan	Kyrgyzstan, Uzbekistan	Ilkhestan	Highway	Kashgar Region	
8	Karasu	Tajikistan, Uzbekistan	Kolbay Pass	Highway	Kashgar Region	
9	Hongqilaf	Pakistan	Sust	Highway	Kashgar Region	
10	Akhetubek	Kazakhstan	Alenshevka	Highway	Altai Region	
11	Muzhart	Kazakhstan	Nalingole	Highway	Ili Prefecture	
12	Urumqi	—	—	Aviation	Urumqi	

Data show that by the end of 2022, the bilateral trade volume between China and the five Central Asian countries reached 70.2 billion US dollars, increasing by about 40% year on year, hitting a record high, and the direct investment continued to remain stable. For the

core area of the Silk Road Economic Belt, building and forming the Silk Road economic transportation hub is one of the necessary conditions to accelerate the promotion of the Belt and Road Initiative, and the improvement and development of cross-border transportation channels is the key to allowing full use of its geographical advantages. Therefore, studying the current situation of transport infrastructure connectivity between Xinjiang and the five Central Asian countries is of great significance.

2.2. Research Methods

2.2.1. Network-Weighted Accessibility

Network-weighted accessibility refers to the calculated road network density and GDP indicators being embedded into the weighted-average travel time accessibility model as weighted terms, which will better reflect the development status of regional transportation accessibility by considering the transportation network status and urban development level.

(1) Measurement of comprehensive urban development indicators

One of the methods to evaluate the comprehensive development strength of a city is the factor analysis method, which is developed based on the principal component analysis, and its basic principle is to extract several major factors to analyze and solve a complex problem. Hence, this paper uses SPSS v26.0 software to perform Kaiser–Meyer–Olkin (KMO) and Bartlett sphericity tests on the selected indicators with the help of factor analysis to evaluate the comprehensive development level of each state in the core area.

The scores of the four common factors G_1 , G_2 , G_3 , and G_4 are obtained by multiplying the collected regional data with the scores of each common factor in the component score coefficient table, and the expressions of G_1 , G_2 , G_3 , and G_4 are as follows [37]:

$$G_i = \sum_{k=1}^n X_k \times g_{ik}, (i = 1, 2, 3, 4) \quad (1)$$

where G_i represents the score of the i th common factor, X_k represents the collected and collated k th data of each region, and g_{ik} represents the score coefficient of component i .

According to the variance contribution rate of the four factors and the above calculation of G_1 , G_2 , G_3 , and G_4 , the comprehensive strength score G of each region is calculated. The formula for calculating G is as follows:

$$G = \frac{Y_1}{R} G_1 + \frac{Y_2}{R} G_2 + \frac{Y_3}{R} G_3 + \frac{Y_4}{R} G_4 \quad (2)$$

where Y_i ($i = 1, 2, 3, 4$) is the percentage of variance in the sum of squares of the rotational loads of the four components, and R is the cumulative percentage of the last term in the sum of squares of the rotational loads.

Because the final calculated comprehensive strength score will have a negative value, to facilitate the subsequent calculation, the score will be de-negativized without changing the original ranking order. The formula is as follows:

$$G' = \frac{Y - Y_{min}}{Y_{max} - Y_{min}} \quad (3)$$

where G' is the de-negativised score, Y_{min} is the smallest of the original scores, and Y_{max} is the largest of the original scores.

(2) Accessibility model

Currently, the following three common definitions are used for the accessibility index: (1) the mutual influence or interaction potential between nodes [38], (2) the number of opportunities a node can obtain in a transport network [39], and (3) the difficulty for a node to overcome the spatial barrier when reaching another node [40]. The measurement methods of accessibility are also divided into three types corresponding to the definitions: (1) the gravity model, combining the gravitational scale of supply and demand and considering the spatial effects [41], (2) the cumulative opportunity model, which refers to

the number of resources that can be obtained from a certain node and considers facilities and spatial barriers between the supply and demand sides [42], and (3) the cost resistance model, which calculates the cumulative resistance to public facilities through the shortest paths [43].

The reachability values chosen in this paper are calculated as follows:

$$T_i = \sum_{j=1}^n \frac{t_{ij}}{n}, i \in (1, 2, 3, \dots, n), j \in (1, 2, 3, \dots, n) \quad (4)$$

where t_{ij} denotes the minimum time required from node i to node j , and n represents the number of nodes in the region.

The level of transport accessibility depends on the development of transport and is also affected by the geographical location conditions and the level of economic development. The city, as a combination of transport and other elements of the complex, cannot be evaluated only from the economic aspects of a single element of the quality of its development but from a comprehensive point of view. Therefore, to better measure the level of urban accessibility and fully consider the impact of urban quality on accessibility, this paper constructs a system of indicators for evaluating the comprehensive development quality of a city based on previous studies. The comprehensive accessibility calculation formula of this paper is as follows:

$$A_i = \sum_{j=1}^n \frac{T_{ij}^\beta}{G_j M_j} \quad (5)$$

where A_i is the integrated accessibility index of node i , M_i is the road network density impact factor, T_{ij} is the travel impedance factor (minimum travel time, Equation (4)) between node i and node j , G_j is the level of comprehensive development of node j (Equation (2)), β is the travel friction coefficient of the node cities, reflecting the extent to which the spatio-temporal barrier affects the accessibility relationship between any node cities, usually denoted as 1, and n is the total number of nodes.

2.2.2. Economic Linkage Measurement Model-Gravity Model

Models for the measurement of economic ties have emerged in endless succession according to different research needs. The representative models include the Ryley-Convers, the potential l, and the gravity models.

By considering the comprehensive conditions of the study area, this paper chooses the gravity model [4] to measure and analyze the economic linkages. The change in intra-regional traffic accessibility provides support and conditions for reshaping the pattern of economic linkages. In the process of applying the gravity model to measure economic linkages, scholars usually use population and GDP as two indicators to measure the quality of cities, but in real life, considering only these two indicators is one-sided and exaggerates the role of population and GDP in the attractiveness of a city. Therefore, combining the data available in the study area and the research needs of this paper, this paper will correct the spatial distance and quality in the attractiveness model. The spatial distance in the model is corrected by the shortest traveling time in the weighted-average traveling time model. The quality in the model is replaced by the indicator of the comprehensive development level of the city, and the corrected model is shown as follows:

$$T_{ij} = P \frac{M_i M_j}{D_{ij}^2} \quad (6)$$

where T_{ij} denotes the size of the gravitational pull between cities i and j ; the larger the value of T_{ij} the stronger the economic linkage and vice versa. M_i and M_j denote the level of comprehensive development of city i and city j , respectively. D_{ij} denotes the accessibility

between city i and city j , which is characterized here. P is a constant, which in this paper takes the value 1.

2.3. Data Sources

This paper collected two types of data: GIS vector data used in mapping and result visualization analysis and statistical data used in the calculation process.

1. GIS vector data. The map of China and the Xinjiang Uygur autonomous region is derived from the National Geographic Information Bureau of Surveying and Mapping Standard Map Service website (<http://bzdt.ch.mnr.gov.cn/>). The data of Xinjiang's administrative divisions (2020) were obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (<https://www.resdc.cn/>). Xinjiang's 15 prefectures (cities) are taken as the research units, with each unit's administrative center abstracted as the representative of that research unit, serving as nodes in the transportation network. To ensure the coherence of this study, changes in administrative divisions are not considered in data processing and analysis, only involving changes in some administrative nodes. The highway and railroad data come from the New Atlas of Highway Mileage in the Core Uygur Autonomous Region (2020) published by China Map Publishing House. By vectorizing the atlas and editing the well-digitized Xinjiang traffic maps, the various types of road networks in Xinjiang will then be restored, and a spatial database of Xinjiang's comprehensive traffic road network will be established, which will ultimately lead to the formation of an effective map of Xinjiang's road network. And the required GIS vector data (including road network data, city node data, and administrative district data) for the five Central Asian countries are mainly a combination of OpenStreetMap (OSM) online vector map data and the Global Road Inventory Project (GRIP) dataset. Data URL: <https://www.openstreetmap.org/>;
2. Statistics. The economic statistics required for this study include the GDP, GDP per capita, value added of the three industries, and foreign trade exchanges of Xinjiang and the five Central Asian countries, which are mainly used for the subsequent measurement of economic linkages using the gravity model. Traffic statistics include highway and railway mileage data, passenger and cargo volume data, etc. The above statistics are obtained from statistical yearbooks of provinces and regions of the National Bureau of Statistics (2021). The trade, GDP, population size, and other data, such as railway total mileage data from the World Bank public database (<https://dataworldbank.org/>) for each of the five Central Asian countries were obtained.

3. Analysis of Measurement Results

3.1. Overall Accessibility Structure Analysis

3.1.1. Overall Perspective of Xinjiang

The five Central Asian countries are landlocked in Asia and Europe and, thus, do not have developed water transport systems. The high cost of air transport also means the volume of air cargo transport in Central Asia is also relatively small. Land transport is the main means for its external links, and railway and road infrastructure are important supports for its foreign trade. Therefore, this paper selects two modes of transport, railway and road, to measure and analyze the traffic accessibility of Xinjiang and the five Central Asian countries. To facilitate the following analysis of transport accessibility from Xinjiang as a whole to the five Central Asian countries, this paper uses factor analysis to measure the comprehensive urban development levels of Xinjiang's prefectures (the results of which are shown in Table 3) and calculates the accessibility indices between the Xinjiang Uygur Autonomous Region (XUAR) and the five Central Asian countries based on the proportion of weights of the prefectures (municipalities).

Table 3. Composite level scores and rankings by region.

Regions	G	Ranking
Karamay	126.740	8
Shihezi	74.169	11
Kizilsu Autonomous Prefecture	52.906	14
Kashi	521.552	2
Akesu	261.469	4
Hotan	143.101	7
Bayingolin Mongol Autonomous Prefecture	184.928	6
Hami	104.885	9
Turpan	71.594	12
Ürümqi	762.442	1
Hui Autonomous Prefecture of Changji	230.645	5
Altay	74.864	10
Bortala Autonomous Prefecture	69.0516	13
Kazak Autonomous Prefecture of Ili	264.184	3
Tacheng	30.940	15

Construction is the decisive factor for accessibility due to the level of infrastructure. Figure 3 shows that the level of accessibility has a positive correlation with the level of transportation infrastructure construction. As a whole, the accessibility of the Xinjiang Uygur Autonomous Region to the five Central Asian countries varies greatly (the extreme difference reaches 11.703). It has the highest level of accessibility to Kazakhstan (11.614) and the lowest level of accessibility to Turkmenistan (23.317).

**Figure 3.** Accessibility values between Xinjiang and five Central Asian countries.

With the continuous promotion of the Belt and Road Initiative, the transportation infrastructures of the five Central Asian countries are being improved, with Kazakhstan being far ahead of the other four countries in terms of the degree of improvement of its transportation infrastructure. Kazakhstan has the best railroad facilities in Central Asia, with a total mileage of 15,100 km of trunk lines and a density of 5.53 km per 1000 square kilometers. However, the most important mode of transport in Kazakhstan is not railroad transport but road transport, and its road network is the second largest in the CIS region, only after Russia. Its superior transportation road network conditions, coupled with China's continuous promotion of its transportation corridor construction has long

placed the accessibility from Xinjiang Uygur Autonomous Region to Kazakhstan in the leading position. Compared to Kazakhstan, Kyrgyzstan and Tajikistan do not have excellent transportation infrastructure. Kyrgyzstan's railroad transportation is extremely underdeveloped; the road mileage is only 34,000 km, but it is responsible for 90% of the total amount of freight and 99% of the total amount of passenger traffic. Road transport is the most important mode of transport. Tajikistan is a country with a mountainous area accounting for about 93% of its territory, and the north–south traffic is very inconvenient. Its transportation system relies mainly on highways, and road and railroad transportation are underdeveloped. However, due to the short distance between these two countries and Xinjiang Uygur Autonomous Region, their traffic accessibility also shows an ideal level, 17.997 and 17.255, respectively. Although the total length of railroads in Uzbekistan is 6500 km, and the mileage of its highways is the highest among the five countries in Central Asia, the road conditions are poor. Turkmenistan has a railway network that runs from east to west and from north to south, and the road network is distributed in the shape of an irregular “big” zigzag. It is only in the past decade that the government has begun to pay attention to the construction of highways, which are still in the process of development. Xinjiang Uygur Autonomous Region does not have borders with Uzbekistan and Turkmenistan and is separated by Kyrgyzstan and Tajikistan, which are far from each other. Therefore, even though the transportation network of Uzbekistan and Turkmenistan is better than that of Kyrgyzstan and Tajikistan, the transportation accessibility from Xinjiang to these two countries is low, and the accessibility value is as high as 23.316 and 23.0848, respectively.

3.1.2. Localized Perspectives from the Sub-Provinces

In terms of Xinjiang prefectures (cities), the accessibility from Xinjiang Uygur Autonomous Region prefectures (cities) to the transportation hubs of the five Central Asian countries is divided into five gradients for exploration (Figure 4). From the viewpoint of the accessibility sub-region of the study object, the high-accessibility areas are all located in Urumqi and its surrounding areas at the southern edge of the Junggar Basin. In contrast, the low-accessibility areas are located in the southern Tarim Basin and the Kunlun Mountains, indicating a clear trend of weak south and strong north. As shown in Figure 5, accessibility presents significant spatial heterogeneity. Traffic accessibility from Xinjiang regions to the transport hub nodes of the five Central Asian countries shows obvious distance characteristics. It is not difficult to see from the figure that the regions present a high level of accessibility to the close nodes. In contrast, the hub nodes located far from each other (e.g., Oral, Balkanabat, etc.) have a low level of accessibility.

In the new period, under the promotion of the Belt and Road Initiative, the Xinjiang Uygur Autonomous Region has been able to open up new channels to and from Xinjiang, with the G7 Jingxin Expressway and the G30 Lianhuo Expressway serving as the connecting lines for each other. The highway project of the Horgos Port Section of the G218 Line has made it possible to form a connection between the western part of China and the inland areas. It serves as an important logistics channel between China and the European countries, and together with the Lanzhou–Xinjiang Railway and the Jinghe–Alashankou Highway constitute the basic skeleton of the China–Europe liner, forming an important logistics corridor between China and European countries. The G3012 Aksu–Kashgar Expressway, G3013 Kashgar–Irkeshtan Port Expressway, and other road networks connected with Kashgar provide a good foundation for the construction and development of the China–Pakistan economic corridor, which has become an important transportation road network to Central, West, and North Asia in China. In this context, among the states (cities) in Xinjiang, the Ili Kazakh Autonomous Prefecture, where the Horgos Port is located, and the Bortala Mongol Autonomous Prefecture, where the Alashankou Port is located, belong to the high-accessibility region, with accessibility values of 15.654 and 16.365 (as shown in Table 4), respectively. In contrast, the Hami and the Hotan Regions are slightly inferior in terms of accessibility to the five countries of Central Asia (with accessibility values of

22.506 and 21.489, respectively) because they are located in the southeastern part of Xinjiang, which is the core hub for connecting with inland regions. However, the development of comprehensive transportation is still relatively backwards in terms of external access (21.489) because they are located in the southeast of Xinjiang. While this area serves as the core hub of Xinjiang and the inland region, its comprehensive transportation development is still relatively backwards, its external channel is not smooth, the scale of development is insufficient, the level of transportation services is low, and the distance with the five Central Asian countries is relatively far, and, hence, the influence of the distance decay effect means the longer road mileage determines its lower level of accessibility.

Table 4. Accessibility to the five Central Asian countries from all states.

Object	Name	Accessibility
1	Kashi	17.360737
2	Hotan	21.489181
3	Kazak Autonomous Prefecture of Ili	15.654174
4		20.911101
5	Hami	22.506004
6	Altay	21.167596
7	Karamay	18.476972
8	Shihezi	18.341318
9	Hui Autonomous Prefecture of Changji	19.228795
10	Bayingolin Mongol Autonomous Prefecture	20.495445
11	Tacheng	18.916465
12	Bortala Autonomous Prefecture	16.365121
13	Akesu	19.950989
14	Kizilsu Autonomous Prefecture	17.26055
15	Ürümqi	19.449279

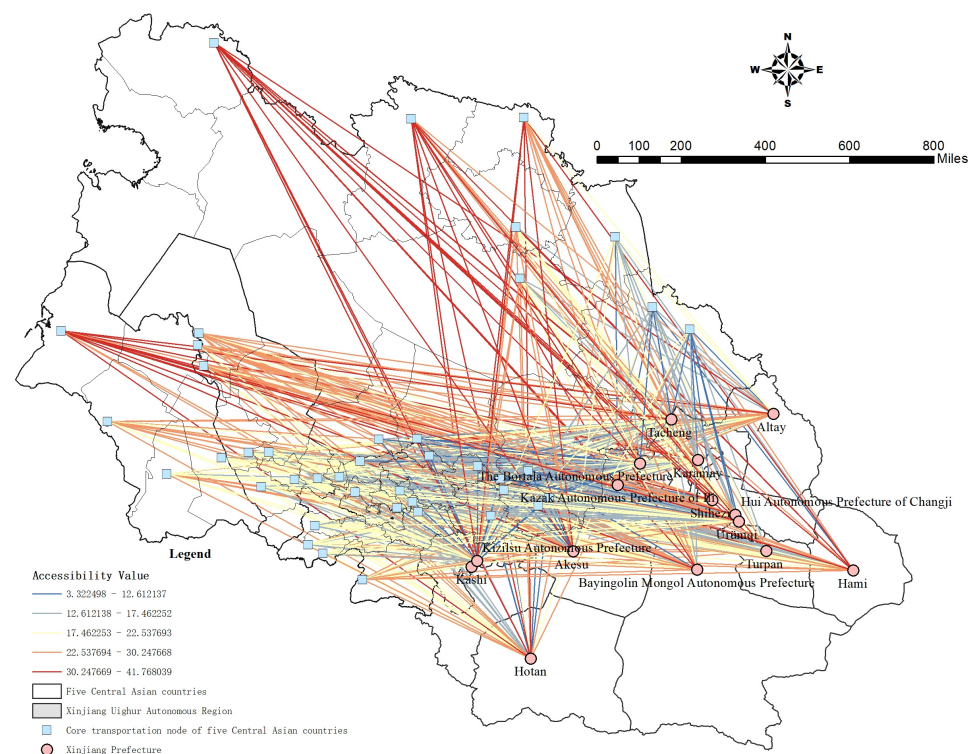


Figure 4. Distribution of accessibility.

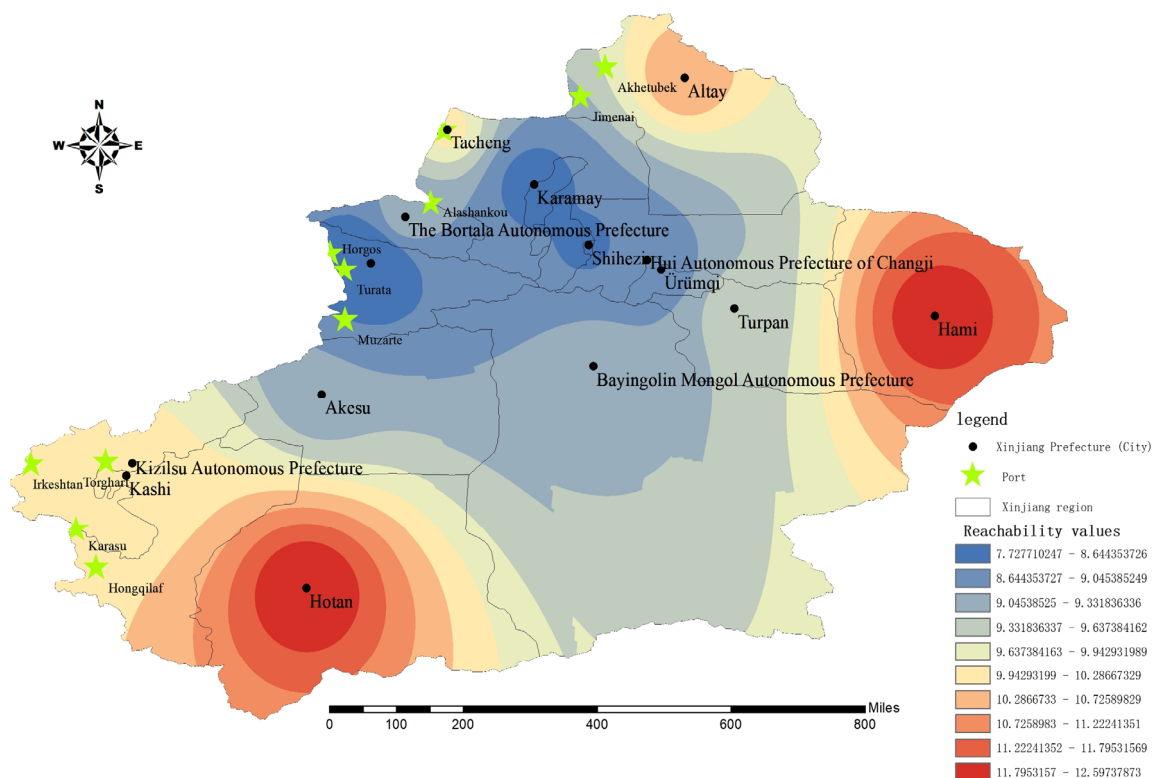


Figure 5. Distribution pattern of accessibility to ports by state.

Kazakhstan, as an important proponent of the Belt and Road Initiative and one of the first countries to support and participate in its construction, needs to consider its accessibility. A famous international highway, the “Double Western Highway”, connects western China with western Europe, passes through Urumqi and Khorgos in Xinjiang and reaches St. Petersburg, Russia, via core nodes such as Almaty in Kazakhstan, placing Urumqi, Shihezi, Karamay, Ili Kazakh Autonomous Prefecture, and Bortala Mongol Autonomous Prefecture at the top of the list of Xinjiang regions reaching Kazakhstan (accessibility values of 19.297, 18.392, 17.844, 17.885, and 17.786, respectively).

3.2. Import and Export Shore Access Structures

3.2.1. Regional Nodes in Xinjiang–Import and Export

The total number of import and export ports in Xinjiang is 17, among which 11 ports have access to five Central Asian countries, as shown in Figure 5. Among them, the two ports of Aheitubek and Muzarte are not yet open. Hence, to comprehensively measure the overall level of Xinjiang’s opening up to the west, this paper takes the two closed ports into consideration to explore the distribution pattern of transportation accessibility after the ports are fully opened, with a view to providing reference for the subsequent opening up and construction of ports.

Looking at the overall situation of accessibility to the ports from all states in Xinjiang, accessibility shows obvious spatial heterogeneity (e.g., Figure 5), with a persistent step-over state of high in the center and low along the edges. At the same time, the accessible spatial layout is “corridor-type”, with buildings being the determining factor of accessibility due to the level of infrastructure. The nodes with high accessibility are corridor-type layouts, which basically overlap with various railroad or highway lines. For example, Urumqi has a high level of accessibility to Bortala Mongol Autonomous Prefecture and Ili Kazakh Autonomous Prefecture, which coincides with the Central Asia Railway route.

The Tianshan Mountain range runs east–west and stretches for more than 1700 km, dividing the core area into north and south, making it “east–west but not north–south.” Hence, the north–south Tianshan subregion should be considered when exploring the

pattern of changes in the accessibility of the Xinjiang Uygur Autonomous Region from one region to another and to each border crossing point. The transportation infrastructure of the northern Tianshan Mountains urban agglomeration is developing at a faster pace, and the overall degree of transportation accessibility is higher. Among the land ports that have opened in Xinjiang, only the two major ports of Horgos and Alashankou have road and railroad transportation capacity. The rest are all road transportation, and the infrastructure conditions limit the transportation capacity, restricting the development of bilateral trade. This phenomenon can be clearly seen in Figure 5, and the level of accessibility of the areas around the Horgos and Alashankou ports is significantly higher than that of the other regions (Ili Kazakh Autonomous Prefecture: 7.727125; Bortala Mongol Autonomous Prefecture: 9.288233; and Karamay City: 8.267107). Locally, the level of transportation accessibility in the northern border region is significantly higher than that in the southern border region, due to the positive correlation between transportation accessibility and the level of comprehensive urban development. In contrast, the urban agglomerations in the southern border area have slower economic development and lower levels of comprehensive urban development than those in the northern border area due to poorer geographic conditions such as natural resources.

3.2.2. Import and Export Bank–Five Central Asian Countries

The XUAR has a large number of ports connected to the five Central Asian countries, but the differences in the degree of improvement in transportation infrastructure and the level of accessibility are more obvious. Figure 6 shows the results of accessibility measurement, and indicates that the average accessibility levels of the Horgos Port and Alashankou Port to the five Central Asian countries (15.582 and 15.914, respectively) are higher than those of other ports because, as an important pivot of the China–Europe liner, these two ports are the only cross-border ports with both road and rail transportation capacity in the whole of Xinjiang, and their excellent infrastructure determines their higher accessibility.

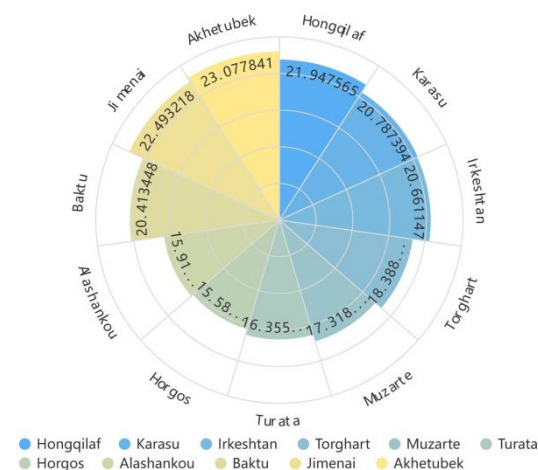


Figure 6. Value of accessibility to the five Central Asian countries by border crossings.

As can be seen from the figure, Muzarte port, which is currently closed, is located at the forefront of the accessibility level (17.31862). Its unique geographic location means it can be connected to the Layinbek County of Almaty City, Kazakhstan. It is the most convenient port for the trade of materials from the north and south borders to the countries in Central Asia, and the opening of this port could have a good diversion effect for the freight traffic of the Khorgos and Alashankou Ports. After its opening, it can form a better diversion effect on the cargo volume of the Khorgos and Alashankou Ports. The accessibility of the Aheitubek Port, another port that has not yet been opened, is less than ideal, being at the very end (23.077841), a pattern that highlights the results of the coupling of “natural geography + transportation and economy.” The Aheitubek port is located in the southern

foothills of the Altai Mountains, which has complicated topographical conditions, and is located in the high-latitude region of Xinjiang, making it basically impossible to realize year-round accessibility. Thus, how its transportation infrastructure can be addressed and strengthening its level of disaster prevention have become priorities for this port.

4. Optimized Road Network Accessibility Outlook

The above analysis shows that transportation accessibility has a significant positive effect on the urban economy. Therefore, this paper takes the promotion of Xinjiang's high-quality development as the fundamental goal. Then, the conclusions of the calculations in Section 3 for the internal road network of Xinjiang and the cross-border transportation channels of the ports were combined with the backward projection of the delineation of the road network project depicted in ArcGIS 10.2 and merged into the existing basic road network to establish an OD cost matrix for the calculation to improve the level of transportation infrastructure interconnection of Xinjiang and the five countries in Central Asia and provide data reference for the construction of Xinjiang cross-border transportation corridors.

4.1. Optimization Strategy Analysis

Road network optimization methods have three forms: discrete form (DNBP), which adds new sections to the existing road network, continuous form (CNBP), which expands the capacity of existing sections, and the hybrid form (MNBP), which combines the two. In this paper, these three forms are considered as the basis for optimizing the internal road network of the Xinjiang Uygur Autonomous Region to enhance the smoothness of the external corridors and strengthen the economic and trade links between China and Central Asia (as shown in Figure 7).

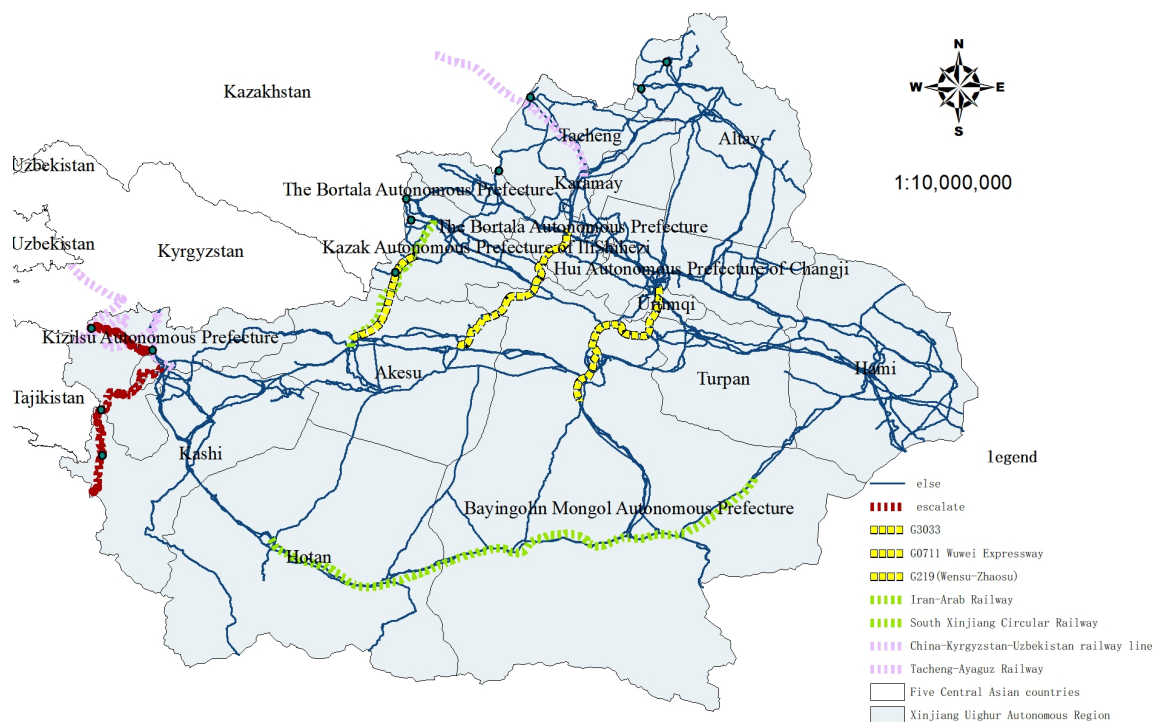


Figure 7. Optimized road sections.

The Xinjiang Development and Reform Commission (NDRC) pointed out in the important document, “Promoting high-level opening up of Xinjiang’s ports to the outside world and making new and important contributions to the construction of the core area”, that it would vigorously push forward the construction of the China–Jiujiang–Uzbekistan, China–Pakistan, and Tacheng–Ayaguz railroads and continuously increase the railroad

capacity of Xinjiang's ports. From the point of view of discrete forms of adding new sections, the role of railroad transportation cannot be ignored in the network of road connections between Xinjiang and the five Central Asian countries. In 1997, at the proposal of Uzbekistan, China–Jiay–Ukraine reached an agreement on the joint construction of a railroad. However, because of political, gauge, and financial problems, the construction of the railroad has continued to be delayed. Construction has not yet begun. Therefore, this paper uses ArcGIS software to depict the Sino–Japanese–Ukrainian Railway and add it to the road network data from Xinjiang to the five Central Asian countries to analyze the improvement of the transportation system in Xinjiang after the completion of the Sino–Japanese–Ukrainian Railway. In December 2015, China and Kazakhstan signed the “Outline of China–Kazakhstan Cooperation Plan (2015–2020)”, proposing the construction of the “Karamay–Baktu–Ayaguz” railroad project, which is the first railroad from Karamay–Baktu in Xinjiang, China to be built in Xinjiang. The railroad will run from Karamay to Tacheng in Xinjiang and then pass through Baktu Port (Chinese side) and Bakhti Port (Kazakh side) to reach Ayaguz in Kazakhstan. The section of the railroad from Karamay to Tacheng (K-Tar Railway) opened in May 2019. The Tacheng–Ayaguz Railway passes through the Baktu Border Crossing, and the completion of this section of the railroad will make the Baktu Border Crossing another major border crossing connecting Xinjiang with Kazakhstan after the Horgos and Alashankou Border Crossings. In the continuous form of expanding the capacity of the original road section, Section 3.1.1 shows that Tajikistan is mountainous, is affected by the natural geographic conditions and the level of infrastructure development, is characterized by highways that dominate its transportation, and that the nearest railroad is also far from Xinjiang. The construction of railroads can only be connected with Tajikistan through Kyrgyzstan (China–Pakistan Railway). Therefore, from the perspective of optimizing the road network in Tajikistan, the expansion of the capacity of the original road section is being considered to enhance traffic accessibility.

In addition to the infrastructure construction of border ports, the well-developed and perfect transportation system within Xinjiang Autonomous Region and the interconnected transportation network are more capable of providing a guarantee for the fast and convenient trade of goods and can greatly improve the convenience of moving goods from the place of origin to the border of China. The above analysis shows that a problem of “east-west through the north and south do not reach” exists in the internal road network in Xinjiang. To optimize the internal road network in Xinjiang, the north–south access to the transport system is formed to enhance the level of accessibility of Xinjiang and the five countries in Central Asia. From the railroad perspective, the regional government work report puts forward accelerating the construction of modern infrastructure systems. One of the important works is to actively build the east link west out of the railroad network. This paper depicts the following railroad line layout scheme as a measure: (1) South Xinjiang Ring Railway is the main railroad line in the autonomous region, the formation of which will significantly improve the traffic conditions in South Xinjiang and will drive the development of resources along the railroad line and the tourism industry; (2) Yi-Ah Railway Project as a “ring up within the border, in and out of the border quickly” will be an important component in the formation of a large railway after the completion of the railroad. As an important part of the project, the large capacity transportation channel formed after the completion of the project can save the transportation distance between the north and south of the border by about 1000 km. It will also serve as an important channel to promote the coordinated development of the north and south of the border. From the perspective of the highway, this paper considers the perspective of “access to the north and south.” It adds three highways planned for construction, G3033, G0711 Wuwei Highway, and G219 Wensu–Zhaosu section to measure the degree of impact of the construction of these three highways on Xinjiang's road network.

4.2. Analysis of Optimized Traffic Accessibility Results

4.2.1. Optimized Xinjiang–Five Central Asian Countries Accessibility Analysis

From the perspective of Xinjiang as a whole, Table 4 shows that the accessibility values from Xinjiang to each of the five Central Asian countries have decreased after optimization, which means the accessibility level of the road network to the five Central Asian countries has increased significantly. Among them, the optimized accessibility to Kyrgyzstan and Uzbekistan has the most obvious upward trend. The difference between before and after the optimization reaches 3.389 and 5.723, respectively, which is due to the optimized road network of Xinjiang with the support of the Sino–Kyrgyzstan–Uzbekistan Railway, which upgraded and improved the transportation network between Xinjiang, Kyrgyzstan, and Uzbekistan. In addition, the construction of the Sino–Kyrgyzstan–Uzbekistan Railway will form another branch of the Second Asia–Europe Continental Bridge, which is also known as the southern corridor of the Second Continental Bridge. The western extension of the Sino–Kyrgyz–Uzbekistan Railway corridor can be extended to the Balkan Peninsula via Iran and Turkey and across the Istanbul Strait or via Turkmenistan. The Table 5 also shows that the accessibility value from Xinjiang to Turkmenistan has decreased from 23.317 to 20.061 after optimization, and the accessibility capacity has been significantly improved. After the construction of the Sino–Japanese–Ukrainian Railway, the international access to Xinjiang changed from one to two, and this change will certainly have a great influence on the future economic and social development of Xinjiang. Xinjiang is increasingly becoming a bridge and hub for the western part of the country and even the whole country to connect with Central Asia, West Asia, and Europe, and it is at the forefront of China’s opening up to the West.

Table 5. Xinjiang–Five Central Asian Countries accessibility optimization before and after comparison.

Start	End	Pre-Optimized Accessibility	Post-Optimized Accessibility
Xinjiang Uygur Autonomous Region	Kazakhstan	11.61346598	10.82303792
	Kyrgyzstan	17.99716368	14.60792621
	Tajikistan	17.25514973	16.14067615
	Turkmenistan	23.31664126	20.06065256
	Uzbekistan	23.0848437	17.36132805

The Xinjiang Transportation “14th Five-Year Plan” development plan pointed out that to form a “fast in and out of the border, the north and south of the border unimpeded, entry and exit links, the border ring through”, the main skeleton of the channel network, the road network pattern of east–west connectivity and north–south smoothness will be comprehensively constructed. To promote the construction of comprehensive transportation channels, we should not only consider the construction of cross-border transportation channels for import and export but also measure the degree of perfection of the internal circulation channels. Therefore, in terms of the dimensions of each state, the optimized road sections are located in Aksu and Bayin’guoleng Mongol Autonomous Prefecture, considering the problem of connecting the north and south of the border. The data in Figure 8 show that after optimization, the accessibility of Aksu and Bayin’guoleng Mongol Autonomous Prefecture to the five Central Asian countries increased faster compared with other regions, with accessibility levels of 17.154135 and 18.982982. This indicates that transportation infrastructure construction has a positive relationship with the accessibility level. In addition, for the Southern Xinjiang region, although the Southern Xinjiang Loop Railway has been completed and opened to traffic, the international Class II and III railroads (with a design speed of 120 km/h) account for more of the main lines, resulting in a lower level of accessibility to the five Central Asian countries for the urban clusters around the Southern Xinjiang Loop Railway. Therefore, this paper expands the capacity of the railroad section of the South Xinjiang Ring Road and considers the change in the accessibility situation when its speed is upgraded to 140 km/h. The table shows that the level of accessibility from the

city clusters along the South Xinjiang Ring Road Railway to the five Central Asian countries has improved to a greater extent (Turpan area: 19.111573 and Hotan area: 19.657947), and the overall spatial agglomeration effect has been significantly strengthened.

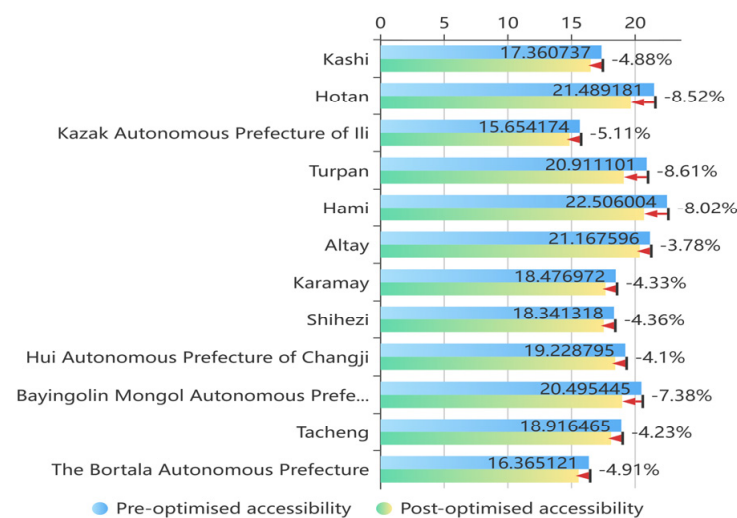


Figure 8. Changes in accessibility from each state to the five Central Asian countries before and after optimization.

4.2.2. Optimized to Analyze Accessibility from a Port Perspective

The port is the gateway of the country's opening up to the outside world and a bridge for foreign exchanges and economic and trade cooperation. It is the intersection of transportation routes of the transportation network of different modes of transportation and has become an important part of the country's or region's external transportation system. Thus, analyzing the cross-border transportation accessibility in Xinjiang from the perspective of the ports is necessary.

Figure 9 shows that the traffic accessibility from each state to the ports before and after the optimization has undergone obvious changes, and the overall pattern of spatial distribution gradually decreases from the west to the east, with significant spatial differences. Specifically, the high-accessibility area after optimization gradually shifts to the south because the planning and construction of G3033, the G0711 Wuwei Expressway, and the G219 Wensu–Zhaosu Expressway have broken the natural geographic barrier, making the northern and southern borders accessible, further enhancing the level of traffic accessibility from the southern border areas to the ports. Influenced by the distance attenuation effect, the Hotan, Hami, and Altay regions are located in the lowest echelon before and after optimization. But from the specific value point of view, and influenced by the overall road network improvement, the traffic accessibility level of this region to the ports also has a certain degree of enhancement. The difference in accessibility before and after optimization is 2.169939, 0.957563, and 1.619628, respectively. In the three regions with lower levels of accessibility, the degree of accessibility improvement in the Hotan region is the most obvious. The difference between before and after optimization is larger because this paper will increase the operating speed of the South Xinjiang Loop Railway to 140 km/h. In contrast, the South Xinjiang Loop Railway, as an important trunk line in the Hotan region, will lead to the improvement of the overall accessibility of the Hotan region by enhancing the operating capacity of its road sections.

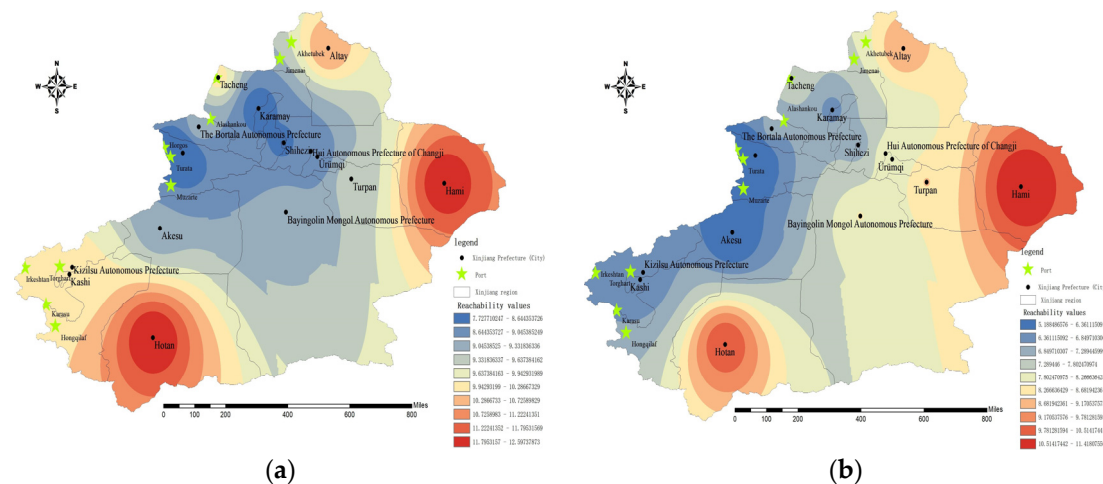


Figure 9. The distribution pattern of traffic accessibility from each prefecture to the cross-border port before and after optimization. (a) Accessibility before optimization. (b) Accessibility after optimization.

From the dimension of transportation performance of each port, after optimization, Horgos Port and Alashankou Port, as the two major ports of accessibility to the five Central Asian countries, are still at the forefront (Figure 10). A greater improvement than before optimization (the value of accessibility after optimization is 13.892568 and 14.552781, respectively) can be observed. The construction of the Sino–Japanese–Ukrainian Railway will leave the country through Irkeshtan Port, which means that Irkeshtan Port will become the first import and export bank in the South Xinjiang region that has the capacity of both highway and railroad transportation, increasing its traffic accessibility level. The difference before and after optimization reached 3.30932. In addition, to share the transportation pressure of Khorgos Port and Alashankou Port, the construction of the “Kelamayi–Baktu–Ayaguz” railroad project proposed by China and Kazakhstan will greatly improve the transportation capacity of Baktu Port, and its accessibility value to the five Central Asian countries has been reduced to 17.551606. At the same time, after expanding the level of road transportation along the border between Xinjiang and Tajikistan, the level of accessibility of cross-border crossings in the region has been significantly improved, with the difference between the before and after values of accessibility of the Karasu crossing reaching 2.627112 and that of the Hongqilav crossing reaching 3.23266.

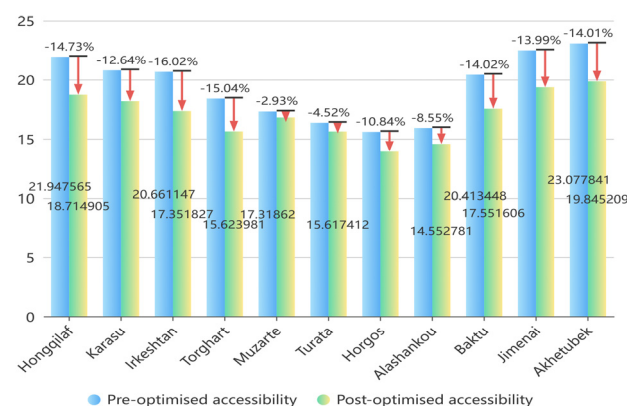


Figure 10. Changes in accessibility to the five Central Asian countries via ports before and after optimization.

Two key projects in the planned road network are located in the Ili Kazakh Autonomous Prefecture, where the Mulzat Border Crossing is situated, and from the above analysis, it can be seen that the overall accessibility level of the region has been significantly

improved, but in terms of the Mulzat Border Crossing, the optimization of the road section does not have a large impact on the Mulzat Border Crossing, and the difference between the before and after values of its optimization is only 0.507328. Hence, the improvement of cross-border traffic levels can not only rely on the optimization of intra-regional road networks, but also the coordinated construction of inter-regional transport corridors is particularly important.

4.3. Analysis of Results Based on Gravitational Modeling

The intensity of inter-regional economic ties is closely related to the level of economic development between the two places and the level of accessibility. In this paper, the matrix of the intensity of economic ties between Xinjiang and the five Central Asian countries before and after the optimization of the road network can be obtained according to Equation (6). The spatial simulation and analysis maps of the total economic output of the cities along the routes (see Figure 11) were also determined to explore the impact effect of the construction of the transport corridors on the economic development of the region.

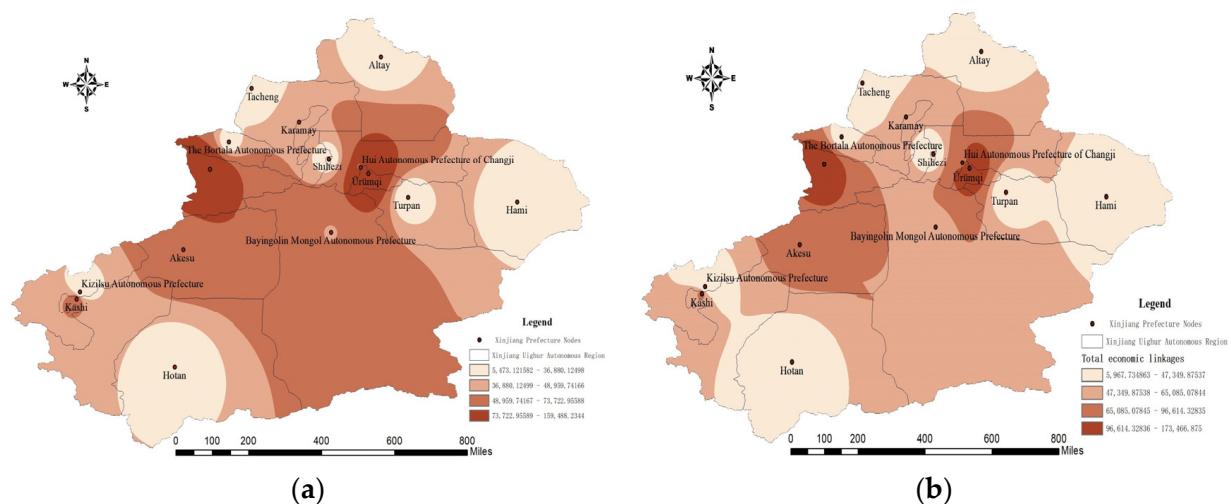


Figure 11. Total volume of economic ties between the states (cities) and the five Central Asian countries before and after optimization. (a) Total pre-optimization economic linkages. (b) Total economic linkages after optimization.

From the perspective of Xinjiang as a whole, a positive correlation can be observed between the strength of regional economic ties and the construction of transportation corridors. Table 6 shows the degree of economic ties between Xinjiang and Kazakhstan is much higher than that of the other four countries, with the total value of economic ties amounting to 44,273.391. Although China's Xinjiang Uygur Autonomous Region has better location conditions bordering Kyrgyzstan and Tajikistan, the low level of economic development in Kyrgyzstan and Tajikistan restricts the total economic linkage intensity (the total value of economic linkage is 2104.943 and 2013.368, respectively) and the huge gap between these two countries and other countries.

Table 6. Xinjiang–Central Asia five countries accessibility optimization before and after comparison.

Origin	Destination	Economic Gravitation
Xinjiang Uighur Autonomous Region	Kazakhstan	44,273.39148
	Kyrgyzstan	2104.943609
	Tajikistan	2013.367931
	Turkmenistan	15,498.79247
	Uzbekistan	10,548.44348

In terms of the states, the figure shows that the total amount of economic ties between the cities along the cross-border transportation corridors in Xinjiang and the five Central Asian countries shows the following spatial characteristics:

- (1) Significant “corridor effect”. Before and after the optimization of the road network, the total amount of economic ties between Xinjiang states (cities) and the five Central Asian countries varies significantly, with Urumqi, Ili Kazakh Autonomous Prefecture, Aksu, and other cities with larger economic ties concentrated along the China–European liner and the Sino–Japanese–Ukraine Railway, which shows that transportation corridors have become an important link for enhancing the economic ties between the cities. The resulting economic axis, that of the Longhai–Lanxin Economic Belt and the Belt and Road Economic Corridor, play an important role in reshaping the spatial and economic connection patterns of cross-border urban agglomerations in the Xinjiang Uygur Autonomous Region;
- (2) Spatial polarization is remarkable. The results before and after the optimization of the road network show a spatial distribution pattern with Urumqi and Yili–Aksu as the double core radiating outwards, with the centrality of Urumqi and Yili–Aksu obvious and increasing, and with the closest external economic ties, with the total amount of economic ties ranking in the first two places. Compared with this, the transportation network density in the southern Xinjiang region has a bigger gap than that of the city cluster on the north slope of Tianshan Mountain and the eastern Xinjiang region. The passenger transportation structure of some cities is still dominated by highways, with the slow flow of economic factors and not very close links between each other. Hence, an obvious regional imbalance in the economic development of the city clusters in the Xinjiang Uygur Autonomous Region exists, and the economic development potential of other cities needs to be further enhanced.

5. Discussion

This paper measures the level of cross-border transportation corridor construction between Xinjiang and five Central Asian countries by applying the accessibility factor. The study shows that, on the whole, the accessibility status is positively correlated with the level of transportation infrastructure construction and city size and negatively correlated with the city distance, with an obvious distance attenuation effect. In terms of the accessibility sub-region of the study object, the high-accessibility areas are all located in Urumqi and its surrounding areas at the southern edge of the Junggar Basin, while the low-accessibility areas are located in the south of the Tarim Basin and the Kunlun Mountains. The accessibility level from each prefecture in Xinjiang to the five Central Asian countries shows a strong north and weak south trend, with a “corridor” spatial layout.

From the backward projection of the optimization of the regional planning road network, the construction of the G3033, G0711 Wuwei Highway, G219 Wensu-Zhaosu section, and Yi-A railroad will improve the phenomenon of “east-west access but north-south inaccessibility”, which will drive the accessibility of the Aksu region and the urban agglomerations of the Southern Xinjiang region to the cross-border border crossings. The construction of the Baktu–Ayaguz project and the Sino–Japanese–Ukrainian Railway project will initially realize the road network pattern of “one axis (Lanzhou–Xinjiang Railway and Lanzhou–Xinjiang High-speed Railway), three outbound routes (the central Lanzhou–Xinjiang line, the northern Linha line, and the southern Geku line), two loops (the northern and southern Xinjiang loops), and two outbound routes (the Alashankou and the Khorgos Ports), comprehensively upgrading the cross-border transportation corridors of Xinjiang. The absence of major changes before and after the optimization of the road network at the Mulzat crossing implies that the optimization of cross-border transport corridors requires the joint efforts of the countries on both sides, which demonstrates the importance of coordinated construction of interregional transport corridors.

Therefore, Xinjiang must rely on policy opportunities, give full play to the collection and distribution functions and hub advantages of the China–EU train consolidation center,

and build a “channel + hub + network” system to build a logistics hub system, forming a “fast inbound and outbound, smooth north and south of the border, inbound and outbound, within the border ring up” as the main skeleton network of large channels and provide strong support for Xinjiang’s high-quality economic development and integration into the new development pattern. Specific recommendations are as follows:

- (1) Create the core area of the Silk Road Economic Belt, from “economic and trade cooperation + transportation corridor + logistics hub” organic integration. At present, the Asia–Europe Land Bridge Economic Corridor around the transportation road network has been perfect. However, to promote economic and trade exchanges between China and European countries, the construction of logistics corridors in the region needs to be sped up. China’s economic corridors to Central Asia are mostly still in the initial stage of construction, so the level of construction should be improved, the construction process should be accelerated, and the goal of access should be realized as soon as possible;
- (2) The focus is on enhancing the construction of the southwest corridor in the core area of the Silk Road Economic Belt and strengthening the level of transportation accessibility in the desert hinterland, such as the Hotan and Kashgar regions, as well as the southern part of the Bayin’guoleng Mongol Autonomous Prefecture. Due to the natural geography of deserts or high mountain ranges, the urban characteristics of “large dispersion and small agglomeration” vastly increases the distances between cities and towns in this region. The time cost is higher than in other regions, and thus, economic links between urban development and urban development are heavily dependent on the ability of transportation to reach them;
- (3) To further improve the construction capacity and level of the middle corridor of the Silk Road Economic Belt, the construction of high-grade railroads and highways is moderately ahead of schedule, and a highly efficient combination of railroads and highways is being built. The Tianshan Mountain Range is located in the middle corridor of the Silk Road Economic Belt, and the geological conditions are harsh; hence, determining the most suitable construction technology for the complex terrain and the breaking of geographic zoning are the most important factors in the construction of the transportation road network in the core area. Therefore, improving the level of construction in this region will not only promote the economic development of the desert hinterland and mountainous towns in the core zone but also enhance the level of accessibility of the core zone to Central and West Asian countries, such as Kazakhstan, Bangladesh, China, India, and Myanmar;
- (4) Mutual political trust is the basis for cooperation between the two countries. Because of its unique geographical location, Central Asia has become the center of international geopolitical competition. Political stability is a prerequisite for economic development, and transportation development is also a prerequisite for political stability. The shelving of the Sino–Japanese–Ukrainian Railway could be attributed to political reasons. Therefore, in terms of political mutual trust, strengthening bilateral communication, avoiding violent conflicts, establishing and maintaining friendly partnerships with Central Asian countries, and working together towards the goal of realizing intra-regional interconnection and economic prosperity, unity and cooperation, and common development are important.

6. Conclusions

This paper explores the overall spatial and local spatial evolution structure of cross-border transportation access in Xinjiang through the analysis of the temporal accessibility distribution pattern of Xinjiang–Central Asia five countries and finds that the development of Xinjiang and the five countries in Central Asia presents a loose polycentric spatial structure. It is generally believed that transport corridors have a strong positive correlation with regional economic development, and this paper utilizes the gravity model to carry out the analysis of economic linkage measurement and elucidate the mechanism and driving

force between transport corridors and regional economic space. Finally, based on the overall spatial structure of cross-border transport corridors within Xinjiang Autonomous Region, Xinjiang, and the five Central Asian countries and the real conditions of the formation of transport corridors, this paper conducts a backward deduction in conjunction with the planning of the road network project to form an optimization strategy by considering the measurement of the economic linkage.

Therefore, this study breaks through the basic theories and methods of road network optimization under the sparse road network model, provides management support for the optimization of the Xinjiang–Central Asia road network and the formulation of regional multilateral policies, and enriches the related research on cross-border transport corridors in western China. In addition, this study is of great practical significance for accelerating the integration of Xinjiang into the new development pattern of the “double cycle”, the implementation of the Western development strategy, the deployment of the Belt and Road Initiative, and the construction of cross-border transportation connectivity.

However, this study only focuses on Xinjiang and five Central Asia countries. It does not comprehensively cover Xinjiang–Europe, China–Mongolia–Russia, and Xinjiang–South Asia, and, hence, might not cover the entire Xinjiang Uygur Autonomous Region’s “port economic belt.” In the future, economic and trade cooperation between Xinjiang and Europe, Mongolia and Russia, Southeast Asia, and South Asia should be explored further.

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