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Classification of Regional Logistics Hub based on CRITIC-Grey Clustering Model: A Case Study of Xinjiang, China

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Abstract

With the construction of the Silk Road Economic Belt in China, Xinjiang has come to own some of the most important logistics hubs to connect with Eurasian states. For this reason, a regional logistics evaluation index system is needed to enhance the status and role of these logistics hubs. The purpose of this paper is to construct a grey clustering evaluation model based on center-point mixed triangle whitening weight function and to divide the gray state of 11 regions of Xinjiang. The research results provide a certain reference for the construction of Xinjiang's trade logistics center. The study uses literature research, expert interviews to determine the evaluation index system of regional logistics hub hierarchy and applies criteria importance though intercrieria correlation (CRITIC) to determine the weight of each criteria. According to the mixed triangle whitening weight function based on a center point, a grey clustering model is constructed to classify the logistics hubs of the 11 regions in Xinjiang. The results show that there is a big difference in the logistics hubs of different regions in Xinjiang and it further illustrates the scientificity and rationality of the method proposed in this paper.

Keywords

Silk Road Economic Belt; Regional Logistics Hub Hierarchy; Grey Cluster Analysis; Xinjiang.

1. Introduction

In the Vision and Action of Promoting the Joint Construction of the Silk Road Economic Belt and the 21st Century Maritime Silk Road, Xinjiang was highlighted as an important trade and logistics center, and the only core area of the Silk Road Economic Belt. It provides a rare historical opportunity for the development of Xinjiang's economy and promotes the rapid development of Xinjiang's logistics industry. The freight volume of Xinjiang has increased from 837 million tons in 2013 to 976 million tons in 2018. However, in the process of rapid development Xinjiang's logistics industry is still facing many problems, such as relatively underdeveloped infrastructure, high logistics costs, unbalanced regional logistics development, and lack of logistics talents.

According to the National Logistics Hub Layout and Construction Plan, a logistics hub is a logistics facility group and logistics activity organization center that integrates various functions, such as cargo collection, storage, distribution, and transshipment. Building a logistics hub network with scientific and reasonable functions, complete functions, and open sharing, and that is intelligent, efficient, green, and safe, and creating a logistics system comprised of "channel + hub + network," can help to realize the optimal allocation of logistics resources and the systematic organization of logistics activities, improve the quality of logistics services, reduce logistics and transaction costs for the whole of society, and provide strong support for optimizing the spatial layout of the national economy and building a modern economic system.Therefore, building a logistics hub network with a scientific layout and reasonable development can lead to the implementation of a channel + hub + network logistics operation system, realize the optimal allocation of logistics resources, improve the quality of logistics services, and reduce logistics and transaction costs in Xinjiang.

Research on regional logistics development evaluation and grading has been studied by scholars. Xu (2009), Dong (2010), Wang (2011), Geng (2012), Li (2012) used the principal component analysis and the factor analysis to evaluate the logistics development level of Chongqing, Sichuan, Xinjiang, Hebei and Yunnan in China.

Grey clustering method is widely used in development evaluation. Hu et al (2019) evaluated the air quality of 74 cities in China. Dong et al. (2018) used the grey clustering model to analyse the provincial agricultural science and technology levels in 2017 and 2019 in China. Su and Xie (2018) built the grey clustering evaluation model of nonlinear whitening right function to evaluate the safety of civil aircraft and the algorithm steps of the evaluation model are given. Hsieh (2018) employs the grey clustering analysis to refine the grey relational analysis, and create the innovative grey-clustering macroeconomic assessment model to detect the slight fluctuation in the ten economies through evaluating the 7-year major ten nation-performance competitive indicators. Xin (2016) used grey fixed weight clustering method to evaluate remanufacturability of the auto parts. Więcek-Janka (2016) presented the model of successors' competencies in family firms, used the Grey Clustering to classify the competences according to their relation of similarities. Zhan et al (2015) used the grey cluster model to comprehensively examine the eco-tourism resources of the 9 forest nature reserves in Huangshan City. Liu and Zhao (2014) built dynamic information aggregation decision-making methods based on variable precision rough set and grey clustering. Zhan et al (2013) researched on the differences of the development of leading industries and energy consumption among China's provinces based on grey clustering.

Gao (2011), Wang (2009), Li (2011), Zhang (2014), Li (2016) used factor analysis and cluster analysis to evaluate the development level of logistics in Shandong, Shaanxi, Fujian, Inner Mongolia and Xinjiang, and propose different levels for each prefecture-level city. Zhou (2014), Gao and Zhang (2014), Lu (2015) used the grey clustering to study the hierarchical classification of logistics hub cities in Guangxi, Jiangxi and Hubei provinces.

In summary, principal component analysis, factor analysis and grey cluster analysis have broad application value in regional logistics hub grading. However, there are few literatures on the classification of logistics hubs. “One Belt and One Road” has brought historic opportunities for the development of logistics industry in Xinjiang. The classification and development of Xinjiang logistics hubs is conducive to promoting the high-quality development of “One Belt, One Road”. Therefore, the comprehensive application of grey clustering research on the classification of Xinjiang logistics hub has certain innovations, which can provide some reference for the follow-up scholars.

2. Model Introduction

Grey clustering is a method of estimating and summarizing the greying numbers owned by clustering objects for different clustering indicators according to the defined grey categories, and classifying the logistics development status into different regions. In this study, based on CRITIC–grey clustering, the regional logistics hub is classified into different categories.

2.1. Introduction of Grey Clustering Model

Definition 1: There are n decision objects, m clustering indicators, and s different grey clusters. According to the sample observation value $x_{ij}(i=1,2,\cdots,s, j=1,2,\cdots,m)$, the object i is classified into the grey cluster $k(k\in\{1,2,\cdots,s\})$, which is called grey clustering.

Definition 2: For the grey cluster $k(k \in \{1,2,\cdots,s\})$, the object most likely to belong to the grey cluster k is called the center point of the grey cluster k, and may be the center point or not the center point.

The steps for grey clustering based on central point blending triangle whitening weight function modeling are as follows:

Step 1: For indicator j, set its value range to $[a_j, b_j]$, for the number of grey clusters s, determine the turning point λ_j^1, λ_j^s of grey cluster 1, grey cluster s, and the center point $\lambda_j^2, \lambda_j^3, \cdots, \lambda_j^{s-1}$ of grey cluster $k(k \in \{2,\cdots,s-1\})$;

Step 2: For grey cluster 1 and grey cluster s, the lower-limit measure and the upper-limit measure whitening weight functions $f_j^1[-,-,\lambda_j^1,\lambda_j^2]$ and $f_j^s[\lambda_j^{s-1},\lambda_j^s,-,-]$, respectively, are constructed.

Let x be an object of indicator j. When $x \in [a_j, \lambda_j^2]$ or $x \in [\lambda_j^{s-1}, b_j]$, the grey cluster 1 and grey cluster s membership degree $f_j^1(x)$ or $f_j^s(x)$ can be calculated using formula (1) or formula (2), respectively. The formulae are as follows:

$$f_j^1(x) = \begin{cases} 0 & x \notin [a_j, \lambda_j^2] \\ 1 & x \in [a_j, \lambda_j^1] \\ \dfrac{\lambda_j^2 - x}{\lambda_j^2 - \lambda_j^1} & x \in [\lambda_j^1, \lambda_j^2] \end{cases} \tag{1}$$

or

$$f_j^s(x) = \begin{cases} 0 & x \notin [\lambda_j^{s-1}, b_j] \\ \dfrac{x - \lambda_j^{s-1}}{\lambda_j^s - \lambda_j^{s-1}} & x \in [\lambda_j^{s-1}, \lambda_j^s] \\ 1 & x \in [\lambda_j^s \ \ , b_j] \end{cases} \tag{2}$$

Step 3: For grey cluster $k(k \in \{2,\cdots,s-1\})$, while at the same time connecting the center point $(\lambda_j^{k\text{-}1},0)$ of point $(\lambda_j^k,1)$ and grey cluster $k-1$ (or the turning point $(\lambda_j^1,0)$, $(\lambda_j^k,1)$ of grey cluster 1 and the center point $(\lambda_j^{k+1},0)$ of grey cluster $k+1$, or the turning point $(\lambda_j^s,0)$ of grey cluster s), the index j is obtained. The triangular whitening weight function of cluster k is $f_j^k[\lambda_j^{k-1},\lambda_j^k,-,\lambda_j^{k+1}]$, $j=1,2,\cdots,m$, $k=2,3,\cdots,s-1$.

Let x be an observation of indicator j. When $k=2,3,\cdots,s-1$, the membership $f_j^k(x)$ of grey cluster k can be calculated using formula (3). The formula is as follows:

$$f_j^s(x) = \begin{cases} 0 & x \notin [\lambda_j^{k-1}, \lambda_j^{k+1}] \\ \dfrac{x - \lambda_j^{k-1}}{\lambda_j^k - \lambda_j^{k-1}} & x \in [\lambda_j^{k-1}, \lambda_j^k \ \ ] \\ \dfrac{\lambda_j^{k+1} - x}{\lambda_j^{k+1} - \lambda_j^k} & x \in [\lambda_j^k \ \ , \lambda_j^{k+1}] \end{cases} \tag{3}$$

Step 4: Using the CRITIC method, determine the weight $\omega_j, j=1,2,\cdots,m$ of indicator j.

Step 5: Calculate the object $i(i=1,2,\cdots,n)$ for the clustering coefficient σ_i^k of grey cluster k. The formula is as follows:

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$$\sigma_i^k = \sum_{j=1}^{m} f_j^k(x_{ij}) \cdot \omega_j \tag{4}$$

Where $f_j^k(x_{ij})$ is the whitening weight function of indicator j grey cluster k.

Step 6: From $\max_{1\le k\le s}\{\sigma_i^k\}=\sigma_i^{k^*}$, decide that object i belongs to grey cluster k^*; when there are multiple objects belonging to grey cluster k^*, it is also possible to determine the merits or demerits of the objects of k^* grey cluster according to the size of the clustering coefficient (Liu(2014), Xiao(2005)).

2.2. Introduction of the CRITIC Method

The specific calculation steps of the CRITIC method are as follows:

Step 1: Calculate the degree of influence of indicator j. The formula is as follows:

$$D_j = \xi_j \sum_{i=1}^{s}(1-r_{ij}) \tag{5}$$

Where ξ_j is the standard deviation of indicator j, r_{ij} is the correlation coefficient between i and j indicators, and D_j is the degree of influence from indicator j to the whole system, so the larger D_j, the larger the corresponding indicator weight.

Step 2: The weight ω_j of indicator j is calculated as follows:

$$\omega_j = \frac{D_j}{\sum_{j=1}^{m} D_j} \tag{6}$$

3. Empirical Analysis of the Regional Logistics Hub Hierarchy

3.1. Index System Design, Data Source, and Weight Calculation

Various scholars have constructed evaluation index systems according to different research perspectives. The literature contains about 30 indicators for measuring regional logistics (Li, 2016; He, 2014; Song, 2017). Considering data availability and objectivity, and the characteristics of Xinjiang region and regional logistics development, nine indicators were chosen for this study. The grey clustering model is used to merge and collect the selected indicators, and the index system is thereby established. This includes three first-level indicators—logistics demand, logistics supply, and development potential—and nine second-level indicators. The nine secondary indicators are positive indicators; relevant data can be obtained from The Xinjiang Statistical Yearbook and The Statistical Bulletin of National Economic and Social Development in Various Regions.

Table 1: List of Clustering Indicators

Dimensions	Index	Code	Unit
Logistics Demand	GDP(Gross Domestic Product)	X_1	100 million yuan
	Agricultural output value	X_2	100 million yuan
	Industrial output value	X_3	100 million yuan
	Total retail sales of social consumer goods	X_4	100 million yuan
	Total import and export trade	X_5	10 thousand dollars
Logistics Supply	Total value of transportation, warehousing, and postal services	X_6	100 million yuan
	Freight volume	X_7	10,000 tons
Development Potential	Per-capita GDP	X_8	yuan
	GDP growth rate	X_9	%

Due to the insufficiency of logistics statistical systems in China, the gross value of the logistics industry is replaced by the total value of transportation, warehousing, and postal industry production, and the material flow is replaced by regional freight volume. The data for each indicator of the 11 regions in Xinjiang are shown in Table 2.

Table 2: Index Values of the Various Regions in Xinjiang for 2017

Index	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Urumqi City	2731	25	634	1073	680712	377	84500	77756	11.05
Turpan City	267	47	99	51	926	13	1645	42417	20.58
Hami City	480	39	188	93	11568	37	5464	77495	18.91
Changji Hui Autonomous Prefecture	1191	210	449	266	64097	51	13410	74284	6.54
Ili Kazakh Autonomous Prefecture	1711	419	317	384	689830	57	11382	36310	9.49
Bortala Mongolian Autonomous Prefecture	313	58	52	46	142990	20	1687	65711	12.81
Bayingolin Mongolian Autonomous Prefecture	976	178	409	114	37573	30	7217	68879	7.90
Aksu Prefecture	915	225	245	147	31265	28	7611	32736	15.38
Kizilsu Kirgiz Autonomous Prefecture	119	14	28	22	39762	3	1413	19396	18.26
Kashi Prefecture	837	264	86	187	312491	21	3968	18268	10.15
Hotan Prefecture	266	59	16	42	987	3	3461	10707	12.64

Notes: Data taken from the Xinjiang Statistical Yearbook 2018 and The Statistical Bulletin on National Economic and Social Development for each region for 2017. The Altay region and the Tacheng region belong to Ili Kazakh Autonomous Prefecture, and some data in Karamay were missing, so these three regions are not used as clustering objects

Using the CRITIC method, the weights ω_j of the indicators are 0.0646, 0.1656, 0.0823, 0.0630, 0.1070, 0.0671, 0.0689, 0.1458, and 0.2357.

3.2. Hierarchical Division of Regional Logistics Hub based on Grey Clustering Model

According to the research aims, it is proposed to divide the regional logistics hub into a general logistics hub (weak grey cluster), important logistics hub (medium grey cluster), and core logistics hub (strong grey cluster). According to the mixed triangle whitening weight function based on a center point, a grey clustering model is constructed to classify the logistics hubs of the 11 cities in Xinjiang. This is done according to the following steps:

(1) Determine the range of values for each indicator, and the turning point and center point of each cluster.

According to the actual data for regions in 2017, the range of values of each indicator is determined. The center point $\lambda_j^2 (j=1,2,\cdots,11)$ of the weak grey cluster, the turning point $\lambda_j^1, \lambda_j^3 (j=1,2,\cdots,11)$ of strong grey cluster, and the medium grey cluster are determined after repeated discussion. The specific results are shown in Table 3.

Table 3: Range of Values, Turning Points and Center Points of each Indicator

Index	Ranges	Turning point and center point		
		λ_j^1	λ_j^2	λ_j^3
X_1	[119,2731]	110	800	2800
X_2	[14,419]	13	150	420
X_3	[16,634]	15	200	640
X_4	[22,1073]	20	100	1100
X_5	[926,689830]	920	60000	690000
X_6	[3,377]	3	30	380
X_7	[1413,84500]	1400	5000	85000
X_8	[10707,77756]	10700	40000	78000
X_9	[6.54,20.58]	6	12	21

(2) Determine the center point mixed triangle whitening weight function.

According to the turning point and the central point of each indicator, the whitening weight function of indicator $j(j=1,2,\cdots,11)$ on grey cluster $k(k=1,2,3)$ is obtained, as follows:

$f_1^1[-,-,110,800]$, $f_1^2[110,800,-,2800]$, $f_1^3[800,2800,-,-]$;

$f_2^1[-,-,13,150]$, $f_2^2[13,150,-,420]$, $f_2^3[150,420,-,-]$;

$f_3^1[-,-,15,200]$, $f_3^2[15,200,-,640]$, $f_3^3[200,640,-,-]$;

$f_4^1[-,-,20,100]$, $f_4^2[20,100,-,1100]$, $f_4^3[100,1100,-,-]$;

$f_5^1[-,-,920,60000]$, $f_5^2[920,60000,-,690000]$, $f_5^3[60000,690000,-,-]$;

$f_6^1[-,-,3,30]$, $f_6^2[3,30,-,380]$, $f_6^3[30,380,-,-]$;

$f_7^1[-,-,1400,5000]$, $f_7^2[1400,5000,-,85000]$, $f_7^3[5000,85000,-,-]$;

$f_8^1[-,-,10700,40000]$, $f_8^2[10700,40000,-,78000]$, $f_8^3[40000,78000,-,-]$;

$f_9^1[-,-,5,12]$, $f_9^2[5,12,-,22]$, $f_9^3[12,22,-,-]$.

(3) Determine clustering coefficients.

Combined with the actual data for 11 cities in Xinjiang in 2017, the whitening weight function of indicator $j(j=1,2,\cdots,11)$ on grey cluster $k(k=1,2,3)$ is brought into equations (1)–(3), and the membership degree $f_j^k(x)(j=1,2,\cdots 11, k=1,2,3)$ is obtained. Combined with the weight value of each index ω_j, the clustering coefficient $\sigma_i^k (k=1,2,3)$ of the 11 cities is calculated.

According to $\max\limits_{1\le k\le 3}\{\sigma_i^k\}=\sigma_i^{k^*}$, the grey cluster of each region is determined, as shown in Table 4.

Table 4: Grey Clustering Coefficients of Various Regions in Xinjiang

Cluster object	Clustering coefficient σ_i^1	σ_i^2	σ_i^3	Grey cluster
Urumqi City	0.1831	0.2267	0.5902	Strong
Turpan City	0.4708	0.3178	0.2114	Weak
Hami City	0.2627	0.4289	0.3084	Medium
Changji Hui Autonomous Prefecture	0.1839	0.5664	0.2496	Medium
Ili Kazakh Autonomous Prefecture	0.1028	0.5455	0.3517	Medium
Bortala Mongolian Autonomous Prefecture	0.3544	0.5138	0.1318	Medium
Bayingolin Mongolian Autonomous Prefecture	0.1787	0.6454	0.1759	Medium
Aksu Prefecture	0.0931	0.7639	0.143	Medium
Kizilsu Kirgiz Autonomous Prefecture	0.641	0.2114	0.1476	Weak
Kashi Prefecture	0.263	0.6176	0.1195	Medium
Hotan Prefecture	0.6355	0.3495	0.015	Weak

(4) Divide Xinjiang's regional logistics hubs into levels.

According to the grey clustering coefficient for each region, the logistics hubs in Xinjiang are divided into three levels, as shown in Table 5. The strong clustering coefficient of Urumqi is 0.5902, which is much higher than those of the medium cluster and the weak cluster. Urumqi is the only core logistics hub in Xinjiang.

Table 5: Classification of Logistics Levels in Various Regions of Xinjiang

Logistics level	Region
Core logistics hub	Urumqi City
Important logistics hubs	Hami City, Changji (Changji Hui Autonomous Prefecture), Ili (Ili Kazakh Autonomous Prefecture), Bortala (Bortala Mongolian Autonomous Prefecture), Bayingolin (Bayingolin Mongolian Autonomous Prefecture), Aksu (Aksu Prefecture), Kashi (Kashi Prefecture)
General logistics hubs	Turpan City, Kizilsu (Kizilsu Kirgiz Autonomous Prefecture), Hotan (Hotan Prefecture)

4. Conclusions and Suggestions

4.1. Conclusions

(1) Xinjiang has initially formed a three-level logistics hub network

Through the use of CRITIC-Grey Clustering model, the actual data of 11 cities in Xinjiang are analyzed. It is found that Xinjiang has formed a three-tier logistics hub system, with Urumqi as the core logistics hub, Hami, Changji, and Ili, etc., as important logistics hubs, and Turpan, Kizilsu, and Hotan as general logistics hubs.

(2) The distribution of Xinjiang logistics hubs presents an imbalanced state of "gradient distribution from north to south"

The Xinjiang Business Logistics Development Plan divides Xinjiang into the trade and logistics zone of Tianshan North Slope (the TNS), the trade and logistics zone of Tianshan South Slope (the TSS) and the trade and logistics zone of South Xinjiang (the SX). From the perspective of distribution of logistics hubs, the TNS has the strongest radiation capacity, including a core logistics hub, four important logistics hubs, only Turpan is a general logistics hub; the TSS is second, both regions are important logistics hubs; the SX has weak radiation capacity, including

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an important logistics hub, two General logistics hub. In general, the distribution of logistics hubs in the three regions presents the imbalance of "North Strong South Weak". The reasons include three aspects.

First, the industrial distribution is uneven.

Xinjiang's industry and commerce are mainly distributed on the TNS, accounting for 69% and 79% respectively. The SX is dominated by agriculture, the industry and commerce are relatively backward. It leads to a small total logistics demand and a general development level of the logistics industry.

Second, the traffic conditions are not balanced.

The TNS has formed a three-dimensional transportation network integrating highways, railways, aviation and pipelines. The high-grade roads and railways have short mileage and low grades in the TSS and the SX. The traffic trunk line is in the process of planning and construction, resulting in fewer options and high logistics costs in both areas.

Third, the advantage of the "Silk Road Economic Belt" has not yet fully emerged.

The SX is a key area for the China section of the China-Pakistan Economic Corridor. The construction and development of the corridor will bring huge development opportunities to the southern Xinjiang region. However, the most critical support line of the China-Pakistan Economic Corridor (China-Pakistan Railway) has not yet started construction, resulting in this advantage has not yet emerged.

4.2. Suggestions

Along with construction of the core area of the Silk Road Economic Belt, Ili, Bortala, and Kashi, which own border crossings, comprehensive bonded areas, and regional industrial clustering advantages, will play an important role as logistics hubs, thereby enhancing the influence of regional logistics.

In order to promote development of the logistics industry in Xinjiang and enhance the status and role of various logistics hubs, changing the current situation of uneven distribution, the following suggestions are proposed:

First, actors must seize the opportunity to construct the core area of the Silk Road Economic Belt, and promote restructuring and upgrading of the regional logistics industry.

Such construction of the core area of the Silk Road Economic Belt will optimize the industrial structure of Xinjiang, promote regional economic development, and enhance Xinjiang's position in the global supply chain, which will place greater demands on the regional logistics industry. All regions should actively introduce preferential policies, improve logistics infrastructure construction, improve the logistics development environment, focus on reducing local logistics costs, and accelerate logistics development. In particular, it is necessary to accelerate the construction of the expressways of the Ku-Ge Railway, the Zhong-Ji-Wu Railway (domestic section) and the highway of G3012, G0612, G0711, etc., optimize the traffic network of the southern slope of the TSS and the SX, realize interconnection and enhance the logistics radiation in the region.

Second, maximum advantage must be taken of port trade to enhance the driving force of logistics hubs.

Ili, Bozhou, and Kashi should make the best use of Horgos port, Alashankou Port, and Hongqi Lahu Port, and take advantage of the government policy on the comprehensive bonded zone and China–Kazakhstan cooperation zone to develop international logistics business and promote the development of an export-oriented economy. This would drive the enhancement of logistics service capacity throughout the region, and continuously improve the logistics hubs. In particular, it is necessary to guide large-scale commercial and trade logistics enterprises to conduct business in the SX and improve the logistics service capacity.

Third, cultivation of logistics enterprises should be enhanced, and regional logistics service capacity expanded.

Construction of the Silk Road Economic Belt Trade Logistics Center requires a large number of logistics enterprises with strong service capabilities. The district government should introduce preferential policies, such as financial subsidies and tax reductions, to actively support local logistics enterprises so that they can reduce costs and increase efficiency, expand the scope of their logistics business, and improve logistics service capabilities. To this end, the whole province should seek to enhance the radiation of the region's logistics industry.

Fourth, there should be greater emphasis on training logistics talent and providing intellectual support for the development of the logistics industry.

Talent is the cornerstone of developing the logistics industry, since one of the most important obstruction factors in the industry at present is its lack of talent with practical operation skills. Only by increasing the training of multi-level logistics talent, and the skill level of existing logistics personnel, we can solve this problem and provide intellectual support for the development of the logistics industry. In particular, it is necessary to increase logistics talents and improve the professional skills of existing logistics talents through various measures such as talent introduction, social training, orientation training, and addition of logistics management to provide talent support for the rapid development of logistics in SX.

Fifth, logistics park project and multimodal transport project should be vigorously promoted.

Combining the traffic conditions and logistics needs of major logistics nodes such as Urumqi, Changji, Turpan and Kashi, we should accelerate the construction of a number of integrated logistics parks with land use conservation, industrial agglomeration, functional integration and operational intensive. Relying on the basic conditions of international transportation channels such as roads, railways, aviation and pipelines, we should effectively link the various nodes on the channel, promote the transportation organization and optimize the upgrade, and comprehensively promote the construction of multimodal transport.

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