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Email: gaspublishers@gmail.com

A Study on Comprehensive Evaluation of Port Logistics Capacity: The Case of the Chengdu-Chongqing Economic Circle

Shaohai Xie[1]

[1]*College of Economics and Management, Southwest Petroleum University, Chengdu 610500, China*

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***Corresponding Author:** Shaohai Xie[1]

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Abstract **Original Research Article**

In the new development pattern where domestic circulation is the mainstay and domestic and international circulations reinforce each other, accelerating the construction of the Chengdu-Chongqing Economic Circle and deeply integrating into the Yangtze River Economic Belt have become inevitable trends. Located in the upper reaches of the Yangtze River, the Chengdu-Chongqing Economic Circle serves as a vital hub connecting the east and west, with its ports becoming a key strategic resource for regional economic development. Despite recent progress in port development, many shortcomings remain in the face of new situations and requirements. This paper establishes an evaluation index system and employs the Entropy Weight-TOPSIS method to evaluate the comprehensive logistics capacity of major ports in the Chengdu-Chongqing Economic Circle. The evaluation reveals imbalanced development and shortcomings in cargo collection and distribution levels among the ports. Corresponding countermeasures are proposed to provide references for the future development and construction of inland ports.

Keywords: Chengdu-Chongqing Economic Circle, Port Logistics Capacity, Entropy Weight-TOPSIS Method.

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1. INTRODUCTION

Ports are crucial windows for inland areas to open to the outside world. They are not only comprehensive transportation hubs and logistics centers but also key parts of the regional logistics supply chain. Centered on cities, port logistics coordinates transportation to support industrial logistics activities, strengthen regional cooperation, and boost overall economic growth.

The Chengdu-Chongqing region, in southwestern China and the upper Yangtze River, is the nation's western region with the strongest comprehensive strength and highest openness. The Chengyu Region Double-City Economic Circle is set to become China's "fourth growth pole" after the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Guangdong-Hong Kong-Macao Greater Bay Area, making significant contributions to the country's coordinated regional development. The development of the Chengdu-Chongqing Economic Circle is closely tied to port logistics. Promoting the high-quality development of port logistics in this region is of great and far-reaching importance for the Belt and Road Initiative and the new round of large-scale western development.

Domestic research on port logistics mainly focuses on three aspects: the relationship between port logistics and the economy, port logistics capacity evaluation, and port logistics development level. In contrast, international research explores port logistics policies, forecasting, and border areas. While China has seen many research on large coastal ports, inland ports have received little attention. Hence, this study focuses on major ports in the Chengdu-Chongqing Economic Circle. Using the Entropy Weight-TOPSIS method, it evaluates their comprehensive logistics capacity, analyzes their development, advantages, and disadvantages, and aims to offer references for port development in the Chengyu Economic Circle.

The Belt and Road Initiative and the new round of large-scale western development are significant national strategies in China. The Belt and Road Initiative, proposed by the Chinese government in 2013, aims to build a trade and infrastructure network connecting Asia, Europe, and Africa to enhance regional cooperation and promote economic growth. The new round of large-scale western development, launched in 2020, seeks to further develop China's western regions, improve infrastructure, and boost economic growth in these areas. The

Chengdu-Chongqing Economic Circle, as a key region in western China, plays a crucial role in these national strategies. By promoting the high-quality development of port logistics in this region, it can better serve the Belt and Road Initiative and the new round of large-scale western development, providing strong support for China's overall economic development.

2. INDICATOR SYSTEM CONSTRUCTION

2.1 Indicator Setting Principles

The objectivity and rationality of evaluating port logistics comprehensive capacity depend on the selection of evaluation indicators. When constructing an evaluation indicator system, the following aspects must be considered. First, port logistics capacity should be studied as a systemic whole. Indicators must correlate highly with the aspect they represent and reflect its general development level. Second, the purpose of constructing the indicator system must be clear. Indicator selection should truly mirror the development level of port logistics capacity. Finally, the accessibility and objectivity of indicator data must be ensured.

In setting the evaluation indicators, this paper adheres to the following principles:

1) Scientificity Principle

The scientificity of indicators is measured by their ability to objectively and scientifically reflect the operational status and activity patterns of the aspect in question. A large amount of real data should serve as the foundation, and scientific statistical methods should be employed for evaluation. This ensures comprehensive and reasonable results.

2) Representativeness Principle

Numerous factors influence port logistics capacity. Detailed analysis of each factor would be highly labor-intensive and might obscure key issues. Therefore, when selecting and setting indicators, representative factors should be chosen based on the main characteristics of port logistics. This ensures the indicator system is appropriately detailed while maintaining the reliability of the evaluation results.

3) Hierarchical Principle

The indicator system should have a logical hierarchy, clearly demonstrating the relationships between the goal layer, criterion layer, and indicator layer. This ensures clarity among indicators and facilitates specific analysis of key indicators at each level.

4) Practicality Principle

When selecting indicators, the accessibility and accuracy of indicator data must be considered. The accuracy of data directly affects the reference value of the evaluation results. Ideally, data should be sourced from official channels such as statistical yearbooks. Combined with practical conditions, authoritative data should be used for further analysis.

2.2 Indicator Selection

Drawing on domestic and international research, this paper identifies three second - level indicators for evaluating port logistics capacity: port scale capacity, port city support capacity, and port cargo collection and distribution capacity. Considering the characteristics and realities of inland ports, 13 specific indicators - including cargo throughput, port city GDP, total imports and exports, and waterway freight volume - are selected to construct the evaluation system. The details are presented in the table below.

Table 1: Port Logistics Comprehensive Capacity Evaluation Indicator System

Level	Criteria Layer	Indicators Layer	Variable Name
Primary Indicator	Secondary Indicator	Tertiary Indicator	
Port Logistics Comprehensive Capacity	Port Scale Capacity	Cargo Throughput (10,000 tons)	X_1
		Container Throughput	X_2
		Cargo Throughput Growth Rate	X_3
		Container Throughput Growth Rate	X_4
	Port City Support Capacity	City GDP	X_5
		Primary Industry Value Added	X_6
		Secondary Industry Value Added	X_7
		Total Imports and Exports	X_8

		Total Retail Sales of Consumer Goods	X_9
		Number of Fresh Graduates	X_{10}
	Port Cargo Collection and Distribution Capacity	Road Freight Volume	X_{11}
		Railway Freight Volume	X_{12}
		Waterway Freight Volume	X_{13}

3. INTRODUCTION TO THE ENTROPY WEIGHT-TOPSIS METHOD

The entropy weight method, derived from the concept of "entropy" in thermodynamics, evaluates the discrete degree of indicator information entropy. A lower entropy value indicates a more stable system with richer information. The TOPSIS method, based on Euclidean distance calculations, assesses the proximity of evaluation objects to an ideal target. The entropy weight-TOPSIS method combines these two approaches. First, it uses the entropy weight method for objective indicator weighting. Then, it applies the TOPSIS method to select optimal and suboptimal solutions from the weighted data matrix, calculate scores, and rank the projects for comparison.

The basic steps of the entropy weight-TOPSIS evaluation model are as follows:

①Assume that there are m ports to be evaluated and n evaluation indicators. Then, the decision matrix M_{ij} is formed as follows:

$$(M_{\mathrm{ij}})_{\mathrm{m\times n}} = \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{12} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{1m} & A_{2m} & \cdots & A_{mn} \end{pmatrix} \tag{1}$$

②Data Standardization and Normalization. In a multi-indicator evaluation system, differences in the magnitude and dimension of indicators can lead to biases if calculations are performed directly on the original data. To address this issue, the original data must be standardized and normalized. This process eliminates the impact of dimensions and simplifies calculations. The result is a standardized matrix R_{ij}. The specific steps for standardization and normalization are as follows:

$$r_{ij} = \frac{x_j - x_{\min}}{x_{\max} - x_{\min}} \tag{2}$$

$$r_{ij} = \frac{x_{\max} - x_j}{x_{\max} - x_{\min}} \tag{3}$$

③Following the normalization step, the next step is to construct the probability matrix p_{ij}.

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} (0 \le r_{ij} \le 1) \tag{4}$$

$$P = \left\{ p_{ij} \right\}_{m\times n} \tag{5}$$

④Calculate the Entropy of Each Indicator.

$$e_j = -k \sum_{i=1}^{m} p_{ij} \cdot \ln p_{ij} \tag{6}$$

⑤Determine the weight of each indicator.

$$w_j = \frac{(1-e_j)}{\sum_{j=1}^{n}(1-e_j)} = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (7)$$

⑥Construct a weighted normalization matrix.

$$B_{ij} = (W_j \cdot R_{ij})_{m\times n} \quad (8)$$

⑦Determine positive and negative ideal solutions.

$$Z^+ = (Z_1^+, Z_2^+, \cdots, Z_m^+) = \left\{\max B_{ij} \mid i = 1, 2, \cdots, m\right\} \quad (9)$$

$$Z^- = (Z_1^-, Z_2^-, \cdots, Z_m^-) = \left\{\min B_{ij} \mid i = 1, 2, \cdots, m\right\} \quad (10)$$

⑧The distance between the evaluation object and the ideal solution is calculated.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(B_{ij} - Z^+)}(i = 1, 2, \cdots, m) \quad (11)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(B_{ij} - Z^-)}(i = 1, 2, \cdots, m) \quad (12)$$

⑨The relative proximity of the evaluation object is calculated.

$$S_i = \frac{d_i^+}{d_i^+ + d_i^-}(i = 1, 2, \cdots, m) \quad (13)$$

4. EMPIRICAL ANALYSIS

This study collects and integrates data on the seven major ports in the Chengdu-Chongqing Economic Circle for 2022 from the Sichuan Statistical Yearbook, China Port Yearbook, Sichuan Transportation Yearbook, and various city statistical bulletins.

4.1 Data Standardization

Due to the different dimensions of the collected data, standardization is required. As all indicators are positive (i.e., a larger value is better), the standardization is performed using equation (2), and the results are shown in the following table.

Table 2 Standardized results of port logistics indicators

	①	②	③	④	⑤	⑥	⑦
X1	1.0000	0.0623	0.0435	0.0000	0.0701	0.0142	0.0122
X2	0.0000	0.4002	0.3859	0.0181	1.0000	0.3826	0.4970
X3	1.0000	0.1681	0.0885	0.0000	0.0000	0.0000	0.0000
X4	0.0000	1.0000	0.9756	0.5611	0.5611	0.5611	0.5611
X5	1.0000	0.0522	0.0817	0.0418	0.0552	0.0102	0.0000
X6	1.0000	0.0351	0.1012	0.0484	0.1602	0.0185	0.0000
X7	1.0000	0.0788	0.1137	0.0487	0.0506	0.0000	0.0001
X8	1.0000	0.0572	0.0547	0.0319	0.0751	0.0106	0.0000
X9	1.0000	0.0218	0.0371	0.0117	0.0063	0.0029	0.0000
X10	1.0000	0.0597	0.0202	0.0183	0.0572	0.0000	0.0112
X11	1.0000	0.0510	0.0723	0.0630	0.0809	0.0000	0.0025
X12	1.0000	0.1711	0.3351	0.0119	0.1482	0.0000	0.0100
X13	1.0000	0.0838	0.0168	0.0000	0.0024	0.0005	0.0162

4.2 Entropy and weight of evaluation indicators

The entropy value of the normalized matrix was calculated and the index weight was determined, and the results are as follows.

Table 3: Entropy Values and Weights of Port Logistics Indicators

Indicator		Entropy *e*	Weight *w*
Cargo Throughput (10,000 tons)	X1	0.3553	0.0897
Cargo Throughput Growth Rate (%)	X2	0.7987	0.0280
Container Throughput (10,000 TEU)	X3	0.3277	0.0936
Container Throughput Growth Rate (%)	X4	0.9008	0.0138
City GDP (billion yuan)	X5	0.4001	0.0835
Primary Industry Value Added (billion yuan)	X6	0.4845	0.0717
Secondary Industry Value Added (billion yuan)	X7	0.4282	0.0796
Total Retail Sales of Consumer Goods (billion yuan)	X8	0.3884	0.0851
Total Imports and Exports (billion yuan)	X9	0.1853	0.1134
Number of Fresh Graduates (10,000 people)	X10	0.3147	0.0954
Road Freight Volume (10,000 tons)	X11	0.4199	0.0807
Railway Freight Volume (10,000 tons)	X12	0.5873	0.0574
Waterway Freight Volume (10,000 tons)	X13	0.2239	0.1080

4.3 Relative Closeness and Ranking of Evaluation Objects

①Standardized Weighted Matrix Calculation. The entropy weights of the indicators are incorporated into the original data matrix to perform weighted calculations, resulting in the standardized weighted matrix B_{ij}

Table 4 Weighted results of port logistics indicators

	①	②	③	④	⑤	⑥	⑦
X1	0.0897	0.0056	0.0039	0.0000	0.0063	0.0013	0.0011
X2	0.0000	0.0112	0.0108	0.0005	0.0280	0.0107	0.0139
X3	0.0936	0.0157	0.0083	0.0000	0.0000	0.0000	0.0000
X4	0.0000	0.0138	0.0135	0.0077	0.0077	0.0077	0.0077
X5	0.0835	0.0044	0.0068	0.0035	0.0046	0.0009	0.0000
X6	0.0717	0.0025	0.0073	0.0035	0.0115	0.0013	0.0000
X7	0.0796	0.0063	0.0090	0.0039	0.0040	0.0000	0.0000
X8	0.0851	0.0049	0.0047	0.0027	0.0064	0.0009	0.0000
X9	0.1134	0.0025	0.0042	0.0013	0.0007	0.0003	0.0000
X10	0.0954	0.0057	0.0019	0.0017	0.0055	0.0000	0.0011
X11	0.0807	0.0041	0.0058	0.0051	0.0065	0.0000	0.0002
X12	0.0574	0.0098	0.0192	0.0007	0.0085	0.0000	0.0006
X13	0.1080	0.0091	0.0018	0.0000	0.0003	0.0001	0.0017

②Calculate the positive and negative ideal solutions of each indicator.

Table 5: Positive and Negative Ideal Solutions of Port Logistics Indicators

Indicator		Ideal Solution *Z*+	Negative Ideal Solution *Z*−
Cargo Throughput (10,000 tons)	X1	0.0897	0
Cargo Throughput Growth Rate (%)	X2	0.028	0
Container Throughput (10,000 TEU)	X3	0.0936	0
Container Throughput Growth Rate (%)	X4	0.0138	0
City GDP (billion yuan)	X5	0.0835	0
Primary Industry Value Added (billion yuan)	X6	0.0717	0
Secondary Industry Value Added (billion yuan)	X7	0.0796	0
Total Retail Sales of Consumer Goods (billion yuan)	X8	0.0851	0
Total Imports and Exports (billion yuan)	X9	0.1134	0

Number of Fresh Graduates (10,000 people)	X10	0.0954	0
Road Freight Volume (10,000 tons)	X11	0.0807	0
Railway Freight Volume (10,000 tons)	X12	0.0574	0
Waterway Freight Volume (10,000 tons)	X13	0.108	0

③ Evaluation Objects' Relative Closeness and Scoring

Table 6 A table of Euclidean distances between the evaluation object and the positive and negative ideal solutions

Evaluate the object	D+	D-	Score
①	0.0312	0.2932	0.9038
②	0.2731	0.0303	0.0999
③	0.2746	0.0318	0.1039
④	0.2883	0.0117	0.0392
⑤	0.2789	0.0352	0.1121
⑥	0.2924	0.0134	0.0439
⑦	0.2921	0.0161	0.0523

④ Relative Closeness and Scoring of Each Port

Table 7 Ranking table of relative proximity and score of each port

Port	Port Scale Capacity		Port City Support Capacity		Port Cargo Collection and Distribution Capacity		Comprehensive Logistics Capacity		Rank
	S	U	S	U	S	U	S	U	
①	0.8059	10.0000	0.9998	10.0000	0.9997	10.0000	0.9038	10.0000	1
②	0.1739	2.1582	0.0514	0.5143	0.0946	0.9462	0.0999	1.1050	4
③	0.1379	1.7106	0.0680	0.6800	0.1298	1.2985	0.1039	1.1498	3
④	0.0553	0.6859	0.0327	0.3274	0.0345	0.3452	0.0392	0.4333	7
⑤	0.1915	2.3766	0.0699	0.6996	0.0714	0.7138	0.1121	1.2404	2
⑥	0.0927	1.1499	0.0084	0.0843	0.0003	0.0035	0.0439	0.4854	6
⑦	0.1096	1.3593	0.0049	0.0490	0.0126	0.1262	0.0523	0.5786	5

4.4 Conclusion

In summary, the ranking of port logistics comprehensive capacity is as follows: Chongqing Port, Nanchong Port, Yibin Port, Luzhou Port, Guangyuan Port, Guangan Port, and Leshan Port.

In recent years, Sichuan has advanced the "Four Rivers and Six Ports" infrastructure initiative, aiming to become a major inland port and shipping powerhouse in the upper Yangtze River region and western China. Despite progress, gaps with Chongqing Port persist. Apart from the economic development of port cities, Sichuan's inland ports suffer from underdevelopment and imbalanced functional structures, generally characterized as "dispersed, small, and weak." Port facilities are often outdated, with low levels of mechanization and informatization. Additionally, the cargo collection and distribution channels of Sichuan's ports are significantly less efficient than those of Chongqing Port.

The Yangtze River corridor is a core east-west axis in China's territorial development strategy. For regional development, leveraging the Golden Waterway to boost the Chengdu-Chongqing Economic Circle and stimulate rapid economic growth in the hinterland is crucial. Chongqing Port plays a pivotal role in the Yangtze River shipping system. A well-coordinated waterway port system should be established within the Chengdu-Chongqing Economic Circle, with Chongqing Port taking the lead, supported by Yibin and Luzhou Ports as the core, and supplemented by Nanchong, Guangyuan, Guangan, and Leshan Ports.

5. COUNTERMEASURE SUGGESTIONS

5.1 Strategy – Oriented

On the one hand, formulate port development strategies based on actual conditions, leveraging port location and resources to prevent overlapping business scope and homogeneous logistics services, and to create unique services for competitive differentiation. On the other hand, enhance multimodal transport, promote port linkage, establish a comprehensive transport system, coordinate and plan ports within the region, bolster the overall logistics capacity, and boost regional port coordination.

5.2 Policy – Supported

In line with the "Comprehensive Transportation Development Plan for the Chengdu - Chongqing Economic Circle" issued by the National Development and Reform Commission and the Ministry of Transport, Sichuan and Chongqing will give full play to their waterway advantages to jointly build the Yangtze River上游shipping center in Chongqing. They will strengthen port collaboration, form a rational and functional port cluster, and establish a general layout where the upstream shipping center in Chongqing serves as the core, and ports like Luzhou and Yibin act as the backbone, with other ports developing共同. Efforts will focus on enhancing the cargo handling and distribution capacity of upstream ports, constructing rail spurs and facilities, promoting river - sea transport and water - water transshipment, and forming a port alliance to boost cooperation among port enterprises and with the Shanghai International Shipping Center. The goal is to improve the inland shipping transaction, information, talent, finance, insurance, and vessel certification functions of the upstream shipping center, creating a comprehensive port - shipping service system.

The Chengdu-Chongqing Economic Circle, as a link for the "Belt and Road" in western China, has a significant impact on deepening land - sea openness and improving the level of opening up. Located in the Yangtze River Economic Belt, Chongqing and Sichuan have jointly issued the "Implementation Plan for Building the Yangtze River Upstream Shipping Center," aiming to create a collaborative, rational, and functional port cluster and to jointly develop the Yangtze River Upstream Shipping Center.

5.3 Talent – Centered

Talent is a vital resource for port logistics development. Establish cooperation with universities in the port's hinterland, set up training bases for students to combine theory with practice, and cultivate professionals in logistics supply chain operations, management, and technology. At the same time, provide in - service training in major knowledge foreign languages to improvement employee quality. Support large port logistics companies in creating logistics engineering research centers to strengthen the study, promotion, and application of port - related information technology and automation.

5.4 Technology – Driven

Ports are hubs for cargo and logistics information. With the rapid growth of the logistics industry and increasing dock operations, information flows have surged exponentially. Integrating modern technology with port management to create intelligent cloud - based ports is crucial. Apply digital tools like cloud computing, the Internet of Things, and big data to establish a port digital management platform, enhancing management efficiency and information processing. Additionally, use technology to optimize energy and equipment, supporting sustainable development, balancing port growth with environmental protection, and advancing low - carbon logistics to build efficient, eco - friendly, and smart ports.

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