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Logistics Measurement and Influencing Factors of Guangdong-Hong Kong-Macao Greater Bay Area Urban Agglomeration

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Abstract: This study examines 11 cities in the Guangdong-Hong Kong-Macao Greater Bay Area, focusing on regional logistics efficiency disparities and their driving mechanisms. Using 2023 statistical data, the DEA-BCC model was applied to measure logistics efficiency across three dimensions: technical efficiency, scale efficiency, and comprehensive efficiency. Empirical analysis through the Tobit regression model revealed the influence of key factors, including openness and economic development levels. These conclusions provide a scientific basis for optimizing logistics resource allocation and enhancing efficiency in the Greater Bay Area.

Keywords: Guangdong-Hong Kong-Macao Greater Bay Area; Logistics efficiency; DEA-BCC model; Tobit regression

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1. Introduction

The Guangdong-Hong Kong-Macao Greater Bay Area, as one of the most open and economically vibrant regions in China, is strategically positioned as “a globally influential international science and technology innovation center” and “a key support for the Belt and Road Initiative.” By 2024, the region’s GDP exceeded 14.79 trillion Chinese Yuan, surpassing the world-class bays of New York and San Francisco, and ranking alongside the Tokyo Bay Area in the top tier of global economic scale. Relying on major transportation projects such as the Hong Kong-Zhuhai-Macao Bridge and the Shenzhen-Zhongshan Channel, it has formed a “1-hour living circle” along with world-class port clusters and airport clusters. As the “lifeblood” of regional economic synergy, the efficiency of the logistics industry directly affects the speed of factor mobility and the quality of industrial collaboration.

The current imbalance in logistics development among cities within the Greater Bay Area has become increasingly evident. Core cities and peripheral cities exhibit disparities in infrastructure, technological application, and talent reserves, which may hinder the enhancement of regional competitiveness. Therefore, accurately measuring logistics efficiency across cities and identifying key influencing factors have become crucial issues for optimizing the Greater Bay Area's logistics system and promoting sustainable economic development. This paper employs a research framework of "efficiency measurement-impact analysis-countermeasure orientation" to provide theoretical support and practical references for the high-quality development of the Greater Bay Area's logistics industry.

2. Current research status

2.1. Status quo of domestic research

Domestic scholars have conducted multidimensional research on regional logistics efficiency, with the combination of DEA series models and Tobit regression being widely applied. Li used an improved entropy weighting method and fixed effects model to analyze the spatiotemporal evolution characteristics of the logistics industry in 30 provinces of China from 2011 to 2021, pointing out that economic vitality and technological innovation are the core driving forces for the high-quality development of the logistics industry [1]. Deng et al. studied the logistics efficiency of China's coastal ports based on the super-efficiency SBM-Tobit model, finding that distribution and transportation capacity and technological innovation levels have a positive impact on efficiency, while the role of openness to the outside world varies by context [2].

In regional scale studies, Ge applied the DEA model and Moran index to analyze the logistics efficiency of the Yangtze River Delta from three dimensions: static, dynamic, and spatial correlation, proposing that regional disparities should be narrowed through industrial collaboration [3]. Wang et al. used the DEA-BCC and DEA-Tobit models to measure the logistics efficiency of the Yangtze River Economic Belt from 2012 to 2021, emphasizing the constraining role of environmental factors on efficiency [4]. Additionally, Liu focused on Belt and Road coastal port cities, measuring green logistics efficiency using the SBM model with non-expected outputs, and pointed out that urban agglomeration collaboration is key to efficiency improvement [5]. Chen et al. concentrated on the resilience of the logistics industry, revealing inter-provincial resilience differences in China using the Theil index method, and proposed that policy interventions are needed to promote balanced development [6].

2.2. Current situation of overseas research

Foreign studies focus more on the analysis of sub-sectors and mechanisms of logistics efficiency. He et al. used three-stage DEA and Malmquist index to study the efficiency of cold chain logistics under carbon constraints in China's four major urban agglomerations, finding that the efficiency showed an upward trend from 2010 to 2020, but low scale efficiency was the main bottleneck, and the level of economic development had a positive impact on all regions [7]. Duan et al. calculated the substitution elasticity of China's logistics industry based on the VES production function from 1978 to 2017, pointing out that the substitution elasticity in the eastern region was higher than in the central and western regions, with capital deepening level and workers' higher education level being key influencing factors [8].

2.3. Research status summary

Current research has established a framework characterized by "diversified measurement methods and multi-level research scales". The DEA model demonstrates significant advantages in evaluating efficiency for multi-input/multi-output systems, while Tobit regression effectively addresses efficiency value limitations. However, two key shortcomings remain:

(1) There is a lack of specialized studies focusing on the Guangdong-Hong Kong-Macao Greater Bay Area, with existing research predominantly concentrating on regions like the Yangtze River Delta and the Yangtze River Economic Belt, failing to adequately incorporate the institutional uniqueness and factor mobility characteristics under the “one country, two systems” framework;

(2) Some studies exhibit overly simplistic factor selection, neglecting emerging drivers such as digitalization and talent quality.

This paper addresses these gaps by filling the research void in logistics efficiency studies within the Greater Bay Area.

3. Relevant theoretical basis

3.1. Basic characteristics of the Guangdong-Hong Kong-Macao Greater Bay Area urban agglomeration

The Guangdong-Hong Kong-Macao Greater Bay Area includes two special administrative regions, Hong Kong and Macao, as well as nine cities in Guangdong Province such as Guangzhou, Shenzhen, and Zhuhai, boasting three unique advantages:

(1) Significant industrial synergy-Hong Kong is an international financial center, Shenzhen is home to tech innovators like Tencent and Huawei, Guangzhou serves as a commercial hub and advanced manufacturing base, forming a “golden triangle,” while Macao complements the equipment manufacturing industry belt on the west bank of the Pearl River;

(2) Highly concentrated innovation resources-the Shenzhen-Hong Kong-Guangzhou technology cluster ranks second in the Global Innovation Index, with both R&D investment intensity and the number of high-tech enterprises among the top in China;

(3) Prominent transportation and institutional advantages-projects like the Hong Kong-Zhuhai-Macao Bridge and the Shenzhen-Zhongshan Channel have reshaped the geographical landscape, while cooperation zones such as Qianhai and Hengqin drive institutional innovations in cross-border finance and regulatory alignment, facilitating the flow of logistics elements.

3.2. Core concepts of logistics efficiency

Logistics efficiency refers to the capability of achieving “minimum cost-maximum output” in logistics activities through rational resource allocation, process optimization, and technology application. This is specifically reflected in the input-output ratios of transportation, warehousing, and distribution processes. Its core characteristics include: systematicness, requiring coordinated consideration of all operational links; dynamism, influenced by factors such as technology, policies, and market demand; regional characteristics, where regional economic foundations and infrastructure density significantly impact efficiency levels.

3.3. Research methodology

3.3.1. DEA-BCC model

Data Envelopment Analysis (DEA) is a non-parametric efficiency evaluation method for multi-input, multi-output systems. The Bounded Contracting Circle (BCC) model, a key branch of DEA, assumes variable returns to scale and decomposes total benefits into technical efficiency (reflecting technological application and management level) and scale efficiency (reflecting resource allocation rationality). When the total benefit index equals 1 and slack variables are zero, the decision unit (city) achieves optimal logistics efficiency.

3.3.3. Tobit regression model

The Tobit model is suitable for scenarios where dependent variables (such as logistics efficiency values) are censored ($0 \leq$ efficiency value ≤ 1), which can avoid the estimation bias of ordinary least squares. Through this model, the impact of various external factors on logistics efficiency can be quantified, providing a precise basis for policy formulation.

4. Application of the DEA-BCC model in measuring logistics efficiency in the Greater Bay Area

4.1. Indicator selection and data sources

4.1.1. Design of indicator system

Following the principle of "scientificity and operability", 3 input indicators and 3 output indicators were selected as outlined:

(1) Input indicators: workforce (in 10,000 people, reflecting human resources input), capital input (in 10,000 Chinese Yuan, reflecting facility and capital input), and road mileage (km, reflecting infrastructure density);

(2) Output indicators: freight volume (10,000 tons, reflecting the scale of logistics), goods turnover (10,000 tons kilometers, reflecting the radiation capacity of logistics), and gross domestic product of the logistics industry (100 million Chinese Yuan, reflecting the contribution of the logistics industry).

4.1.2. Data sources

The data are from the 2024 Guangdong Statistical Yearbook, the Hong Kong Census and Statistics Department, the Macao Census and Statistics Bureau, and the statistical bulletins of various prefecture-level cities. The statistical year is 2023, covering 11 cities in the Greater Bay Area (**Table 1**).

Table 1. Input-output data of cities in Guangdong-Hong Kong-Macao Greater Bay Area in 2023

City	Labor force (10,000)	Capital input (Wan Yuan)	Road mileage (km)	Quantity of shipments (10,000 tons)	Freight turnover (10,000 ton-km)	Industry gross product (100 million CNY)
Guangzhou	46	612	8421	92862	229075137	2750
Shenzhen	56	761	721	42751	24204200	3300
Zhuhai	7	97	1526	9482	4629301	260
Foshan	22	278	4806	28090	3461312	1150
Huizhou	10	118	13976	23931	4187022	410
Dongguan	24	252	3541	15045	4817621	800
Zhongshan	9	79	2853	9587	856713	280
Jiangmen	1	91	10020	17988	1553808	230
Zhaoqing	6	73	14378	10012	983203	120
Hong Kong	29	56	2100	209	650012	1400
Macau	2	17	60	4	3989	40

4.2. Measure results analysis

The DEA-BCC model was employed to evaluate the logistics efficiency of 11 cities, with the results presented in **Table 2**.

Table 2. Logistics metrics of urban agglomerations in the Guangdong-Hong Kong-Macao Greater Bay Area in 2023

Decision package	Technical feedback	Scale merit	Comprehensive benefits	Return of scale
Guangzhou	1.000	1.000	1.000	Fixed
Shenzhen	1.000	1.000	1.000	Fixed
Zhuhai	0.854	0.765	0.653	Increase progressively
Foshan	0.895	0.981	0.878	Increase progressively
Huizhou	1.000	1.000	1.000	Fixed
Dongguan	0.612	0.955	0.585	Increase progressively
Zhongshan	0.900	0.845	0.760	Increase progressively
Jiangmen	1.000	1.000	1.000	Fixed
Zhaoqing	0.800	0.847	0.677	Increase progressively
Hong Kong	1.000	1.000	1.000	Fixed
Macau	1.000	0.408	0.408	Increase progressively

The most efficient group (Guangzhou, Shenzhen, Huizhou, Jiangmen, and Hong Kong) demonstrates perfect alignment in technology, scale, and comprehensive efficiency coefficients (all 1.000), with fixed returns to scale. These cities stand out: Guangzhou leverages its commercial hub and infrastructure, Shenzhen capitalizes on innovation and management efficiency, while Hong Kong utilizes its global logistics network. Their optimal resource allocation makes them benchmarks for logistics development in the Greater Bay Area.

The economies of scale of efficiency improvement group (Zhuhai, Foshan, Dongguan, Zhongshan, Zhaoqing, Macao) all showed increasing trends, requiring efficiency enhancement through resource allocation optimization or increased input. Specifically, there is redundant technology in Zhuhai (comprehensive benefit 0.653) and Zhaoqing (0.677), and labor and highway mileage input cannot be effectively translated into freight output. Dongguan (0.585) has the lowest technical efficiency (0.612), reflecting its strong demand for manufacturing logistics but lagging management mode and technology application; Macau (0.408) has the lowest scale efficiency (0.408) due to its small geographical area and limited logistics demand, it is difficult to form scale economy.

5. Tobit regression analysis of factors affecting logistics efficiency in the Greater Bay Area

5.1. Variable selection and data description

The comprehensive benefit value calculated by the DEA-BCC model serves as the dependent variable (logistics efficiency), with five core independent variables selected. The indicator descriptions are shown in **Table 3**.

Table 3. Description of influencing factors

Type of variable	Name of index	Indicator description	Data sources
Dependent variable	Logistics efficiency value	The comprehensive benefit value calculated by the DEA-BCC model	Estimation of this article
Argument	Degree of openness	Import and export trade volume as a percentage of regional GDP (%)	Statistical bulletins of cities at all levels, Hong Kong Statistics Department
Argument	Economic development level	Per capita GDP (in 10,000 CNY)	Guangdong Statistical Yearbook 2024
Argument	Logistics professionals	Logistics workforce (people)	Local logistics industry association reports
Argument	Level of informatization	Logistics informatization input as a percentage of the added value of the logistics industry	Statistical bulletin of each prefecture-level city
Argument	Locational factor	Distance from the city to core ports (Hong Kong Port, Guangzhou Port) (km)	Geographic Information System (GIS) measurement

The data sample consists of panel data from 11 cities in the Guangdong-Hong Kong-Macao Greater Bay Area (2020-2023), comprising 44 observations. Missing data were supplemented using linear interpolation to ensure data integrity.

5.2. Regression results analysis

An empirical analysis of the influencing factors was conducted using the Tobit regression model, with the results presented in **Table 4**.

Table 4. Tobit regression results of factors affecting logistics efficiency

Influencing factor	Coefficient	Standard error	*t*	*P*
Degree of openness (%)	0.087	0.049	1.788	0.000***
Level of economic development (10,000 CNY)	0.158	0.317	4.94	0.004*
Logistics professionals (people)	0.002	0	6.938	0.000***
Informationization level (%)	5.478	0.63	8.701	0.000***
Distance to core port (km)	-0.048	0.026	1.809	0.012***
Constant term	0.215	0.103	2.087	0.038**

(*, **, *** represent the significance levels of 10%, 5%, 1% respectively)

The positive driving effect of openness is demonstrated by a coefficient of 0.087, statistically significant at the 1% level. This indicates that a 1% increase in the proportion of import and export trade volume results in an approximate 0.087-point rise in logistics efficiency. An open market environment stimulates cross-border logistics demand, prompting logistics companies to optimize service processes and enhance resource allocation efficiency. The positive correlation between economic development and logistics efficiency (coefficient 0.158, statistically significant at 1%) indicates that a 10,000 Chinese Yuan increase in per capita GDP corresponds to approximately 0.158 units of efficiency gain. Economic growth drives the development of logistics infrastructure (e.g., ports, highways) and stimulates high-end logistics demands (e.g., cold chain logistics, cross-border e-commerce logistics), thereby establishing a foundation for efficiency enhancement.

The positive driving force of logistics professionals: the coefficient is 0.002 and passes the 1% significance test, reflecting that the logistics efficiency value increases by about 0.002 for every 1 additional practitioner. Professional talents can optimize warehousing management, transportation scheduling and other links, reduce resource waste and improve operational efficiency. The informationization level demonstrates a positive driving effect, with a coefficient of 5.478 and 1% significance, making it the most influential variable among all positive factors. Logistics informationization investments (such as intelligent dispatching systems and IoT traceability technologies) enable real-time supply-demand matching, reduce empty load rates, and significantly enhance operational precision and efficiency.

The negative impact of location factors: The coefficient of -0.048, statistically significant at 5%, indicates that every additional kilometer from the core port reduces logistics efficiency by approximately 0.048. Greater distances from the core port result in higher transshipment costs and extended transportation times, thereby hindering efficiency gains.

6. Research conclusions and prospects

6.1. Research conclusion

The logistics efficiency shows significant regional disparities, where among the 11 cities in the Guangdong-Hong Kong-Macao Greater Bay Area, the pattern of ‘core cities leading with optimal efficiency and peripheral cities needing improvement’ is evident. Core cities like Guangzhou, Shenzhen, and Hong Kong achieve peak efficiency through their economic, technological, and geographical advantages, while cities such as Zhuhai, Dongguan, and Macao face substantial room for improvement due to technological redundancy and scale limitations. Multiple factors collectively drive efficiency improvements: openness to the outside world, economic development level, logistics professionals, and IT adoption form the core positive drivers of logistics efficiency, with IT adoption being the most influential. However, geographical factors (proximity to core ports) significantly constrain efficiency, which can be mitigated through infrastructure improvements.

6.2. Recommendations

Based on the research conclusions, the following targeted suggestions are put forward:

(1) Promote coordinated regional logistics development: Establish a cross-city logistics coordination mechanism with Guangzhou, Shenzhen, and Hong Kong as core hubs. For instance, Dongguan could leverage Shenzhen’s innovation resources to optimize logistics management technology, while Zhuhai could integrate with Hong Kong’s international logistics network to expand cross-border operations. Through resource complementarity, regional disparities can be narrowed;

(2) Increase investment in information technology and talents: Encourage logistics enterprises to introduce intelligent scheduling, Internet of Things and other technologies to improve the level of information technology; establish logistics professional training programs with universities, and carry out skills training for on-the-job personnel to solve the shortage of professional talents;

(3) Improve the transportation network of marginal cities: For cities such as Zhaoqing and Jiangmen that are far away from the core ports, plan and build fast logistics channels (such as freight lines) to connect the core ports and reduce the cost of transshipment; set up regional logistics distribution centers in cities such as Zhongshan and Zhuhai to improve the efficiency of goods distribution;

(4) Optimize Macao’s logistics development model: Leveraging its unique’ tourism + gambling ‘industry, de-

velop high-end cold chain logistics (for catering and fresh produce sectors) and cross-border e-commerce logistics (to meet tourist demands). By adopting a ‘small but specialized’ approach, overcome geographical constraints and enhance economies of scale.

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Disclosure statement

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