Analysis of Logistics Network Spatial Layout from the Perspective of full connectivity: A Case Study of China and Some ASEAN Countries

Tong Jian[1, a], Wenwen Jiao[2*], Yifei Wang[3]

[1]Road Transport Development Center of Guangxi Zhuang Autonomous Region, Nanning, 530025, China
[2]Research Institute of Highway Ministry of Transport, Beijing, 100088, China
[3]School of Traffic and Transportation, Beijing Jiaotong University, Beijing, 100044, China

[a]124658184@qq.com
[*]ww.jiao@rioh.cn

Abstract. In order to explore the impact of factors such as economy, foreign trade, transportation infrastructure, social development and network connectivity on the logistics connection and spatial layout between China and ASEAN countries, this paper selects six representative ASEAN countries as examples. This study analyzes the characteristics of logistics network between China and ASEAN countries from the perspective of total connectivity, which differed from the views of transportation modes. By using logistics gravity model and logistics connectivity to analyze the spatial distribution characteristics and network conditions of logistics between China and ASEAN countries. The following conclusions can be drawn from the logistics network with the maximum logistics attraction line and 25% logistics connectivity: In the evaluation scores for logistics development, China ranked first with a score of 0.9535. China plays a vital role in logistics cooperation with ASEAN. Malaysia and Singapore have the maximum gravitational values at 4.1843. And Singapore is an important logistics hub for ASEAN and Southeast Asia. There are obvious differences in logistics networks within ASEAN.

Keywords: Gravity model, Logistics connectivity, Network analysis

1 Introduction

With the proposal of *"Belt and Road" Initiative*, China's position in the global logistics system has become increasingly significant, and ASEAN, as one of the core regions of the initiative, plays a crucial role in logistics cooperation between China and ASEAN countries. In the field of logistics networks, scholars have conducted extensive research. Lam C.Y [1] has proposed a resilience analysis framework for analyzing and designing logistics networks to help them cope with disruptions and complexity. Wu Y[2] has applied complex network theory to analyze logistics networks, concluding that logistics networks exhibit small-world properties, and discussed key nodes based on

S. M. Ghadiri et al. (eds.), *Proceedings of the 2025 4th International Conference on Engineering Management and Information Science (EMIS 2025)*, Advances in Computer Science Research 121,
https://doi.org/10.2991/978-94-6463-736-6_11

statistical indicators. Yan L et al[3]. have built a regional logistics model from a macro perspective, using social network analysis to examine its structure and offering specific recommendations for building logistics networks. Jia[4] has introduced a new method that uses social network analysis and complex network technology to simulate the co-evolution of logistics organizations. This model combined static structural analysis with dynamic network reorganization, providing a practical path for the evolution of logistics organizational networks. In terms of ASEAN logistics networks, Timperio et al.[5] have proposed a beneficiary-centric logistics resource coordination decision support framework for emergency logistics resource distribution. Jomthanachai[6] has developed a machine learning application to predict logistics performance indicators based on economic attributes, testing it with the six ASEAN countries. Kutin N[7] analyzed the relative efficiency of 50 container ports and terminals in ASEAN, providing support for port managers in the region when deciding whether to increase container throughput. Katayama[8] has developed a mathematical programming model for the design of a minimal-cost production logistics network between China and ASEAN, which can be used to execute the model and recommend an optimal global production logistics system.

Table 1. Basic data of ten ASEAN countries in 2023

Nation	GDP (billion dollars)	Population
Brunei	16.68	449,002
Cambodia	29.5	16,767,842
Indonesia	1320	275,501,339
Laos	15.47	7,529,475
Malaysia	407.03	33,958,221
Burma	62.25	54,179,306
Philippines	404.35	115,559,009
Singapore	498.47	5,637,022
Thailand	495.65	71,697,030
Vietnam	410.32	98,186,856

The relevant basic data of ASEAN countries are shown in Table 1. It can be seen from Table 1 that the GDP and population of Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam rank top in ASEAN. Therefore, this paper selects China and six representative ASEAN countries as research objects to study the spatial layout and feature analysis of logistics network between China and ASEAN countries from the perspective of full connectivity.

2 Models

2.1 Construction of Logistics Quality Evaluation Index System

Based on the research of Ahn and Wang[9], this paper constructs an evaluation index system consisting of economic development, transportation infrastructure, logistics supply and demand level, social development, and informatization level. Among these, economic development reflects the logistics development level of each country, using GDP as an indicator for each country.

Transportation infrastructure represents the transportation conditions of the logistics network. This paper considers four modes of logistics transportation: road, rail, air, and sea, with indicators such as Roadway mileage, Railway mileage, Freight transported by air, and Container port traffic; Merchandise imports and exports measure the logistics supply and demand level of each country, Population is an important factor influencing social development in each country, and the informatization level indirectly affects the logistics connectivity of each country, with individuals using the Internet as the indicator.

Table 2. Logistics Quality Evaluation Index

Primary index	Secondary index
Economic development	GDP
Transportation infrastructure	Roadway mileage
	Railway mileage Freight transported by air Container port traffic
Logistics supply and demand level	Merchandise imports and exports
Social development	Population
Informatization level	Individuals using the Internet

The logistics quality evaluation indexes are shown in Table 2. Due to the differences in the measurement units of different evaluation indicators, normalization is performed in this study, as shown in Formula 1:

$$X = \frac{X - X_{\min}}{\mathrm{X}_{\max} - X_{\min}} \tag{1}$$

Based on the Analytic Hierarchy Process (AHP), weights are assigned to different evaluation indicators, and the logistics quality score is calculated using the following formula (Formula 2):

$$S_r = \sum_{\mathrm{r}=1}^{\alpha} \mathrm{k}_{ir} X_r \tag{2}$$

Where Sr is the development score of the country with serial number r; r=1,2,3...α is the total number of countries; kir is the value of the indicator r for each country; and X_r is the weight of the indicator r.

The study of networks originated in topology, an important branch of mathematics that deals with the properties of space that remain unchanged under continuous deformation, regardless of geometric features such as distance and Angle. Topology is widely used, including in data analysis, physics, computer science and other fields[10]. For example, in data science, topological data analysis (TDA) can help discover potential patterns in data, while in physics, topology is used to study the properties of space and the structure of matter.

Network Analysis is the study of the relationships and interactions between nodes (or points) and connections (or edges) in complex systems, as shown in Table 3 and Figure 1. Network analysis is widely used in many fields, such as social networks, computer networks, transportation networks, biological networks, etc.

Table 3. Description of network node features

Node	An individual or entity in a network (e.g. a computer, a user in a social network, etc.).
Edge	The connection or interaction between nodes, representing the relationship or transmission path between them.

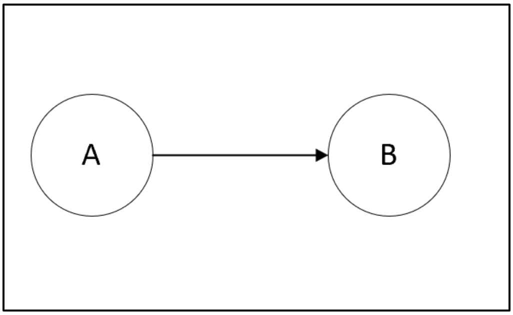

Fig. 1. Network node diagram

2.2 Logistics gravity model

The Logistics Gravity Model is a mathematical model developed based on the Gravitational Theory, which aims to explain and predict the intensity of logistics flow (such as goods transportation, trade exchange, etc.) between two or more regions. In the Logistics Gravity Model[11], the level of logistics flow linkage between two regions (or countries) can be represented by the following formula:

$$F_{ij} = G\frac{S_i S_j}{d_{ij}^2} \tag{3}$$

Where F_{ij} is the spatial strength of logistics linkages between countries; G is the gravitational coefficient, which usually takes the value of 1; and S is the score of each country's logistics development evaluation indicator.

2.3 Logistics Connectivity

To further study the logistics flow direction between China and the six ASEAN countries from a fully connected perspective, the concept of logistics connectivity Cij is introduced. In the Logistics Gravity Model, the maximum gravity value Fmax for each country is selected, and the maximum gravity line diagram of the logistics network between China and the six ASEAN countries is plotted. The calculation formula for logistics connectivity C_{ij} and the maximum gravity value for each country is as follows[12]:

$$C_{ij} = \frac{F_{ij}}{\sum_{j=1}^{\alpha} F_{ij}} \tag{4}$$

$$F_{\max} = MAX(F_1 F_2, \ldots) \tag{5}$$

3 Logistics Network Analysis

3.1 Data Source

The study selects GDP data and population data of six ASEAN countries for reference to the World Bank. The data of the logistics quality evaluation system in Table 4 are from the China-ASEAN Statistical Yearbook 2024. The geographical distance between countries, d_{ij}, is calculated from the straight-line distance between the capitals of the two countries on Google Maps (Jakarta is selected as the representative node of Indonesia).

3.2 Logistics Connectivity

Using the obtained data, the logistics quality scores are processed according to Formula 1[13]. The resulting logistics quality score table is shown in Table 4.

Table 4. Logistics Quality Scores

Evaluation index	Maximum value	Minimum value	Mean value
Level of economic development	0.4601	0.301	0.4143
Transportation infrastructure	0.3566	0.9	0.4575
Logistics supply and demand level	0.3306	0.3523	0.3482
Social development	0.3121	0.416	0.3487

Informatization level	0.4241	0.8172	0.5897

Based on the data processed from Table 4, the relevant values are substituted into Formula 2 to obtain the logistics quality scores for each country, as shown in Table 5.

Table 5. Evaluation scores for logistics development between China and six ASEAN countries by each country

Nation	Scores
Indonesia	0.4477
Malaysia	0.6029
Philippines	0.4758
Singapore	0.7854
Thailand	0.5746
Vietnam	0.6169
China	0.9535

Based on the data in Table 5, the following conclusions can be drawn.

China occupies a key position in the logistics network.

Initially, according to the scores, China stands out as the leader in the logistics network, with a score of 0.9535, far ahead of other countries. China's logistics network not only covers vast domestic regions but also deeply connects with global supply chains. Its efficient transportation and distribution systems have made China an irreplaceable player in global trade. The logistics capabilities in China provide strong support for its international economic and trade development, especially in facilitating trade flows between Southeast Asia.

Singapore holds a dominant position in ASEAN logistics networks.

Secondly, with a logistics score of 0.7854, Singapore ranks top 1 in Southeast Asia, demonstrating its leadership in the regional logistics network. In particular, Singapore's ports and airports lead globally in handling capacity, significantly boosting logistics flows within the region and beyond. As one of the world's most important transshipment hubs, Singapore's logistics network not only serves the ASEAN region but also connects major global economies, playing a crucial role in trade with China.

Logistics networks in Thailand, Indonesia, and the Philippines need improvement.

Thirdly, compared to China and Singapore, Thailand, Indonesia, and Philippines have relatively low logistics scores of 0.5746, 0.4477, and 0.4758, respectively. This indicates that these countries face challenges in constructing and optimizing their logistics networks.

Table 6. Maximum gravitational values between each country

Trading nation i	Trading nation j	Scores
Indonesia	Singapore	0.45
	Malaysia	0.335
	China	0.249
	Philippines	0.212
Malaysia	Vietnam	0.334
	Singapore	0.512
	Thailand	0.451
Philippines	Vietnam	0.452
	Singapore	0.366
	Malaysia	0.327
Thailand	Vietnam	0.493
	Philippines	0.325
	Singapore	0.429
	Malaysia	0.373
	Indonesia	0.248
China	Vietnam	0.345
	Indonesia	0.274
	Philippines	0.314
	Thailand	0.323
	Malaysia	0.269
	Singapore	0.281

Based on the data in Table 6, Figure 2 and Figure 3, the following conclusions can be drawn:

China is an important trading partner of ASEAN.

Initially, according to the data, China plays a key role in trade relations with ASEAN countries. Although its trade score with Singapore is relatively low (0.249), its trade connections with other ASEAN countries such as Thailand, Vietnam, and Philippines remain strong. For example, the trade score between China and Thailand is 0.323, and with Vietnam, it is 0.345. These data suggest that China not only plays a critical role in the global economy but also maintains strong economic interactions within the ASEAN trade network.

Singapore and Malaysia are the closest trade partners.

Secondly, the trade connections between Singapore and Malaysia are extremely close, with scores of 0.512 and 0.451, respectively. This indicates tight cooperation between the two countries in logistics and supply chain coordination.

There are disparities in logistics connections within ASEAN.

Thirdly, the data reveals clear disparities in logistics connections between ASEAN countries. For instance, the high trade score between Singapore and Malaysia indicates that the logistics connection between these two countries is very tight. In contrast, Indonesia's trade links with other ASEAN countries are relatively weak. These differences are closely related to factors such as the countries' economic scale, infrastructure development, trade policies, and their level of participation in the global economy.

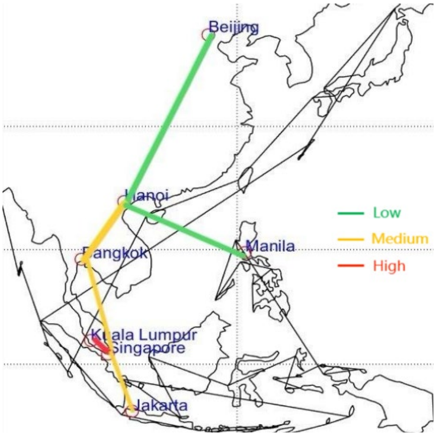

Fig. 2. China and ASEAN Six Countries Logistics Maximum Gravity Line Diagram

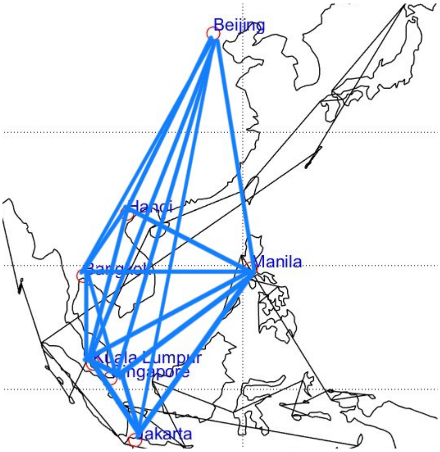

Fig. 3. China and ASEAN Six Countries Logistics Membership Degree

4 Conclusions

This study investigates the logistics network and spatial layout of the China-ASEAN region from a fully connected perspective, using China and six representative ASEAN countries as case studies. The results show that China ranked first with a score of 0.9535 in the evaluation scores for logistics development. China plays a significant role in logistics cooperation with ASEAN and is an indispensable partner for ASEAN countries. Within ASEAN, Singapore plays a crucial role in the logistics network, serving as Southeast Asia's logistics hub and promoting regional logistics development. Within ASEAN, Malaysia has maximum gravitational values of 4.1843, but its gravitational values with China need to be improved. Malaysia can strengthen its transportation cooperation with China in the future logistics and transportation. There are noticeable differences in the internal logistics network of ASEAN, with close connections between Singapore and Malaysia, while Indonesia, the Philippines, and Thailand still need to strengthen their logistics ties.

Acknowledgments

This paper is funded by the APEC project Promoting Asia Pacific Regional Supply Chain and Interconnection Cooperation.

References

1. Lam C Y. Resilience of logistics network: analysis and design (2016) World Congress on Industrial Control Systems Security (WCICSS). London 2016. 1-5.
2. Wu Y, Ma H. Logistics network nodes importance analysis based on the complex network theory (2013) Applied Mechanics and Materials, 336: 2410-2414.
3. Yan L, Wen Y, Teo K L, et al. Construction of regional logistics weighted network model and its robust optimization: Evidence from China (2020) Complexity, 2020(1): 2109423.
4. Jia Z X, Shi X L, Sun M Q. A CO-EVOLUTIONARY BASED SIMULATION MODEL FOR LOGISTIC ORGANIZATION (2024) International Journal of Simulation Modelling (IJSIMM), 23(1).
5. Timperio G, Kundu T, Klumpp M, et al. Beneficiary-centric decision support framework for enhanced resource coordination in humanitarian logistics: A case study from ASEAN (2022) Transportation Research Part E: Logistics and Transportation Review, 167: 102909.
6. Jomthanachai S, Wong W P, Khaw K W. An application of machine learning to logistics performance prediction: an economics attribute-based of collective instance (2024) Computational Economics, 63(2): 741-792.
7. Kutin N, Nguyen T T, Vallée T. Relative efficiencies of ASEAN container ports based on data envelopment analysis (2017) The Asian Journal of Shipping and Logistics, 33(2): 67-77.
8. Katayama H. Design of a global car production-logistics system for a future ASEAN-China region (1999) International Journal of Operations & Production Management, 19(5/6): 582-603.
9. Ahn T K. A Study on the Effect of Logistics Performance on the Trade of Goods in the Korea-ASEAN FTA (2021) Journal of Korea Port Economic Association, 37(4): 145-160.
10. Beer G, Lucchetti R. Weak topologies for the closed subsets of a metrizable space (1993) Transactions of the American Mathematical Society, 1993, 335(2): 805-822

11. Primorac D, Kozina G. Applying gravity model to analyse trade direction (2020) Tehnički vjesnik, 27(5): 1670-1677.
12. Rezitis A N, Zangelidis L, Karytsas S. Investigating factors affecting trade flows in pork and poultry global markets using gravity models (2024) Agrekon, 2024: 1-16.
13. Deshmukh A, Song D W. Probing into hinterland connectivity with a web of transport modes and logistics nodes: A case of Indian container ports[J]. Transportation Research Part A: Policy and Practice (2024) ,189: 104200.