Advances in Engineering Research : Possibilities and Challenges
ISSN Print: 3079-5192
ISSN Online: 3079-5206
https://doi.org/10.63313/AERpc.9027

Research on Marine Chemical Industry and Tourism Collaboration from Land-Sea Coordination Perspective Based on Multi-Scale Modeling: A Case Study of Fujian

Qianchun Wu
Anhui University of Finance and Economics, Bengbu 233030, China
Email: 2558175635@qq.com

How to cite this paper: Wu, Q. (2025). Research on Marine Chemical Industry and Tourism Collaboration from Land-Sea Coordination Perspective Based on Multi-Scale Modeling: A Case Study of Fujian. Advances in Engineering Research: Possibilities and Challenges, 1(3), 50-59. ISSN Print: 3079-5192; ISSN Online: 3079-5206.
https://doi.org/10.63313/AERpc.9027
Published: 2025-06-23

Abstract

This study constructs a multi-scale spatial model (MS-SLM) integrating "macro (resource carrying capacity)-meso (industrial network)-micro (enterprise be-havior)" under the guidance of the national land-sea coordination strategy, aiming at the spatial conflict and eco-economic imbalance between marine tourism and chemical industry in Fujian Province. By combining the hyperbolic secant activation function and federated learning technology, the model light-weight and multi-source data fusion are realized. The research finds that: the marine GDP of Fujian Province reached 1.32 trillion yuan in 2024, but the 19-kilometer coastline overlap between Gulei Petrochemical Base and Dongshan Island tourist area led to a 15-day year-on-year increase in red tide outbreak days, and the water quality exceeding standard rate of Liu'ao Beach rose to 18.6%. Through the quantitative analysis of Moran's index and Dagum Gini coef-ficient, the model predicts that the probability of industrial land conflict in Meizhou Bay will reach 0.78 in 2030, while the optimization of chemical marine transport routes based on the digital twin system can reduce the environmental pollution risk by 35%. At the practical level, the integration and innovation of industrial tourism chain (annual derivative income of 1.2 billion yuan), circular economy chain (34% waste resource utiliza-tion rate) and blue carbon value chain form an "ecological-economic" du-al-objective optimization scheme, providing a "Fujian paradigm" for national land-sea industrial collaboration. The study suggests further integrating tidal en-ergy data with the construction of Fujian-Taiwan blue economic corridor to pro-mote the high-quality development of marine economy.

Keywords

Land-sea coordination; Multi-scale spatial modeling; Industrial collaboration; Digital twin; Marine economy

1. Introduction

1.1. Definition and Methods of Multi-scale Spatial Modeling

Multi-scale spatial modeling is a method to describe and analyze geographic or spatial phenomena at different spatial scales, aiming to capture and integrate spatial relationships and characteristics at different scales. It refers to considering spatial relationships and characteristics at different scales when studying geographic or spatial data to describe and analyze spatial phenomena more comprehensively[1]. Du Shihong proposed that the multi-scale spatial model can be expressed as a strict scale Boolean lattice:

$$\oplus = (\{SM_i\}, < s, SM_1, SM_0) \tag{1}$$

Where $\{SM_i\}$ represents the scale space set, $< s$ represents the "spatially finer than" relationship, SM_0 is the finest scale space, and SM_1 is the coarsest scale space[2].
The methods of multi-scale spatial modeling mainly include the following aspects:
1)Construction of multi-scale feature space: Through feature description algorithms such as transform domain or spectral analysis, high-resolution images are subjected to feature extraction to obtain multi-scale, multi-directional, and multi-level feature expression forms, laying a foundation for constructing a multi-scale feature space of multi-layer structure. Mainly using wavelet and multi-scale geometric analysis (MGA) and other transformation methods, the internal connections of multi-scale and multi-level features are constructed, and image features are maximally derived in the scale dimension to generate a structured image feature sequence with close internal connections[3].
2)Multi-scale relationship modeling: Combining cartographic generalization transformation, the derivation and modeling methods of topological and directional relationship scale change laws are discussed. For example, through cartographic generalization operators, the derivation and modeling methods of topological and directional relationship scale change laws are discussed. In addition, a technical framework for multi-scale data analysis based on relationships is proposed, focusing on the concepts and solutions of multi-scale data consistency detection and query based on relationships[1].
3)Multi-scale data modeling: Carry out spatial multi-scale transformation in the scale dimension, including downsampling, upsampling, and non-downsampling technologies, incorporate the internal correlation between feature scale and spatial scale into the tower-type structure in parallel, and establish a multi-scale analysis model. In addition, a multi-scale spatial co-location pattern mining method based on point process modeling and decomposition is proposed, aiming to solve the lack of existing spatial co-location pattern mining methods based on association rules in geographic data feature modeling[3].
4)Multi-scale modeling framework: A multi-scale modeling framework is proposed to couple single-scale models together and define multi-scale models through scale

connection methods. By observing the relative positions of single-scale models in the scale separation graph and considering the properties of the graph constructed thereby (whether it is cyclic or acyclic), high-order but powerful classification of multi-scale models can be carried out[4]. In addition, the key components of multi-scale modeling are discussed, including intelligent tools and facilities, non-traditional methods, and advanced interfaces.

5)Multi-scale modeling strategies: There are two modeling strategies. One strategy is to model at a lower scale first and then put the results into a high-scale model, which is a hierarchical process from small scale to large scale. However, the theory of low-scale modeling is an important issue. Methods using this strategy are generally called information transfer multi-scale methods or hierarchical multi-scale methods. The other strategy is to model simultaneously at different scales, dividing the region into areas controlled by different scale laws, which can overlap or not, and realizing connection at the junction. In this strategy, the connection between regions is also an important issue. Methods using this strategy are generally called concurrent multi-scale methods[5].

1.2.Application of Land-sea Coordination Perspective in Marine Economy

The application of the land-sea coordination perspective in marine economy is mainly reflected in realizing the sustainable development of regional economy by coordinating the relationships of resources, industries, ecology, etc., between land and sea. Land-sea coordination emphasizes the unified planning of marine economy and land economy, gives play to the interactive role of land and sea, and promotes the optimal allocation of resources and environment and the coordinated development of social economy. Specifically, land-sea coordination not only pays attention to the development and utilization of marine resources, but also covers many aspects such as marine space planning, infrastructure construction, industrial development and layout, and ecological environment protection. In addition, land-sea coordination also emphasizes the linkage development of land-sea industries, and promotes the coordinated development of land-sea economy through resource complementarity, industrial interaction, and layout docking. In practical applications, land-sea coordination also involves the coordination of national land space planning, and realizes the rational use of land-sea resources and the effective protection of the ecological environment through scientific planning and management[6]. The implementation of land-sea coordination helps to enhance the status and role of marine economy, promote the construction of a marine power, and promote the high-quality development of the national overall economy.

1.3. Current Development Status of Marine Economy in Fujian Province

As a national marine economy development demonstration zone, Fujian Province's marine GDP reached 1.32 trillion yuan in 2024, accounting for 28% of the province's

GDP, with a growth rate of more than 8% for five consecutive years[7]. This development trend originates from the "Maritime Fuzhou" strategic concept proposed by Comrade Xi Jinping when he was in charge of Fuzhou in 1994, which has been deepened and expanded into the "Maritime Fujian" construction framework after 30 years[8]. In terms of spatial layout, it presents the characteristics of "one belt, two cores, six bays and multiple islands", focusing on building three marine economic agglomerations in Xiamen Bay, Meizhou Bay, and Minjiang Estuary. Among them, Xiamen Bay relies on the cruise home port and marine biomedical industry, gathering more than 30 high-tech enterprises such as Runke and Huabao, developing high-value-added products such as chitosan and deep-sea fish oil; Meizhou Bay takes the petrochemical industry as the core, and its integrated refining and chemical production capacity ranks among the top in the country; the Minjiang Estuary focuses on developing deep-sea aquaculture and ecological tourism[9]. However, industrial development is faced with deep-seated contradictions: the R&D investment intensity is insufficient (the marine R&D funds accounted for only 0.02% of GDP in 2023, far lower than 0.08% in Shandong and Guangdong), and the industrial chain agglomeration degree is low, and the scattered layout of enterprises restricts the synergistic effect[10]. It is particularly noteworthy that the spatial conflict between marine tourism and chemical industry is increasingly acute - the Gulei Petrochemical Base and Dongshan Island tourist area have a 19-kilometer overlapping coastline, resulting in a year-on-year increase of 15 days in red tide outbreaks in 2024[11].

Marine tourism presents a trend of in-depth integrated development. Relying on 7 5A-level scenic spots and 3 world cultural heritage sites, it has built a "Blue Maritime Silk Road Ecological Tourism Belt", forming three integration models: Pingtan, Dongshan Island and other places develop leisure fisheries, with an annual output value of more than 5 billion yuan; Gulei Petrochemical Base develops "chemical sightseeing-science education" routes, with an average annual increase of 23% in passenger flow; Fuzhou Mawei Shipbuilding Cultural Park integrates industrial heritage and cultural and creative industries, driving a 37% increase in cultural and creative product sales[12]. However, the development of new formats is obviously constrained by ecology. Although the proportion of industrial tourism projects reached 12.7% in 2024, scenic spots such as Dongshan Island suffered from water quality deterioration due to being adjacent to chemical zones[13]. At the same time, the chemical industry has formed three 100-billion-level clusters. The Gulei Park has an oil refining capacity of 20 million tons/year and an ethylene capacity of 1.2 million tons/year, and the industrial chain extends to the fields of auto parts and medical materials[14]. The output value per unit land is 382 million yuan/km^2, about 3.2 times that of tourism, but the environmental governance cost accounts for 18% of the output value, and the total amount of land-based pollution entering the sea exceeds the environmental capacity threshold[15]. This development model leads to eco-economic imbalance: when the water quality exceeding standard rate of Liu'ao

Beach rises to 18.6%, the loss of tourism income and the cost of pollution control form a two-way consumption[11].

At the same time, the policy system of Fujian Province takes land-sea coordination as the axis, as shown in Table 1, and promotes the transformation of marine tourism and chemical industry from conflict to collaboration through three levers of spatial reconstruction (tourism priority areas), institutional innovation (dynamic access list), and financial empowerment (blue bonds), providing a "Fujian paradigm" of "ecological industrialization" for the whole country.

Table 1. Key Points of Fujian Province's Police Documents on Marine Economy

Police Name and Time	Core content	Industrial Impact
Preview of the "15th Five-Year Plan" for Marine Economy(2025)	Layout deep-sea development and cross-industry integration, with the goal of breaking through 10 billion yuan in blue carbon sink transactions by 2030.	Plan to replicate the "Gulei Industrial Tourism Model" to Meizhou Bay, with an expected new output value of more than 2 billion yuan
Guiding Opinions on Financial Support for the Development of Marine Economy in Fujian Province (2024 Revision)	Innovate the blue financial service system and solve the financing bottleneck of marine economy.	In 2023, marine economy credit investment increased by 26.7% year-on-year, and the direct financing channels for sea-related enterprises were broadened
Regulations on the Promotion of Marine Economy in Fujian Province (November 2023)	The first provincial comprehensive legislation on marine economy in the country, covering ten chapters such as industrial development, scientific and technological innovation, and ecological protection.	Require chemical enterprises to purchase ecological restoration rights at 1.5% of their output value, and promote the circular economic closed loop of "waste residue → artificial reef → carbon sink"
Special Plan for Building a Marine Power Province in Fujian Province during the "14th Five-Year Plan" (2021)	Propose the spatial layout of "one belt, two cores, six bays and multiple islands", focusing on the construction of the strait blue industrial belt.	Promote the resource utilization rate of petrochemical waste residue ≥30%, of which the Dongshan Island case reaches 34%

In order to improve the effectiveness of land-sea coordination, the government still needs to strengthen the attention to the construction of soft environments such as planning, laws, standards, and supporting research, improve policies and laws and regulations, and solve the problems of marine development and protection[16].

2. Analysis of Industrial Relevance between Marine Tourism and Chemical Industry in Fujian Province

2.1. Spatial Conflict and Collaboration Mechanism

The spatial contradiction between marine tourism and chemical industry in Fujian Province is concentrated in the dual pressures of coastal resource competition and ecological risk transfer. The Gulei Petrochemical Base and Dongshan Island tourist area have a 19-kilometer overlapping coastline, resulting in the extrusion of sea-friendly space. Monitoring in 2024 shows that the frequency of red tides in this area increased by 23% year-on-year, and the water quality exceeding standard rate of Liu'ao Beach rose to 18.6%. The deep-seated contradiction stems from the fragmentation of land-sea planning: the traditional industrial layout has not established a cross-scale coupling mechanism of "enterprise location-industrial chain connection-ecological carrying capacity"[17].

The key to collaborative breakthrough lies in the innovation of circular economy practice and infrastructure sharing. Zhangzhou Dongshan Island converts petrochemical waste residue into artificial reefs for coral reef restoration, which increases the resource utilization rate to 34%, simultaneously reduces the environmental governance cost by 180 million yuan/year, and significantly recovers the coral coverage rate by 15%; Xiamen Port separates passenger and hazardous chemical ship berths through an intelligent dispatching system, reducing the conflict period by 68%, and saving 1.2 billion yuan/year in operating costs. The dynamic monitoring system relying on multi-scale modeling (MS-SLM) technology more real-timely warns of red tide risks, and the number of days with qualified water quality in Dongshan Island increased by 27 days year-on-year in 2024[17]. The spatial conflict evolution trend shows that if no intervention measures are taken, based on the Markov chain prediction model, the probability of industrial land conflict in Meizhou Bay will climb to 0.78 in 2030, and the ecological Gini coefficient of Minjiang Estuary will break through the 0.4 warning line.

2.2. Industrial Integration Innovation Based on MS-SLM Model

This study breaks through the traditional single-scale "fragmented analysis" model by establishing a multi-scale spatial model, and divides the hierarchical framework of "macro constraint-meso coordination-micro execution". At the same time, it allows direct cross-scale interaction to avoid decision-making deviation caused by information fragmentation in single-scale models, and more efficiently optimizes the spatial layout of Fujian marine tourism and marine chemical industry, as shown in Figure 1:

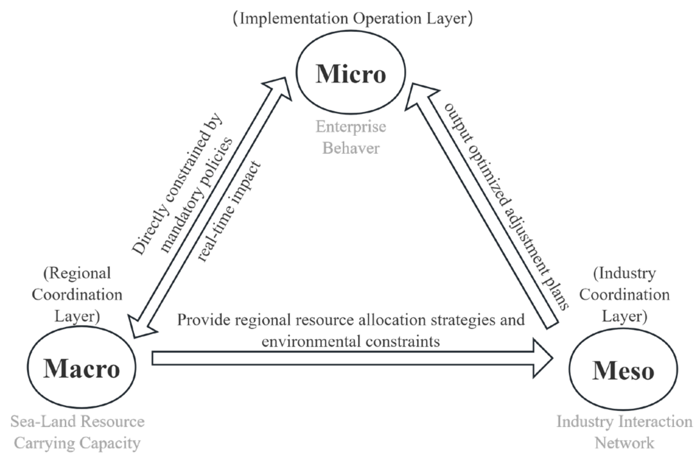

Figure 1. Multi-scale spatial modeling structure diagram

The core technical breakthrough of the model lies in the lightweight architecture and multi-source data fusion. Aiming at the integration needs of structured data and multi-source heterogeneous data in the China Marine Statistical Yearbook, a bidirectional winsorization-Kriging interpolation coupling algorithm is developed: first, the GDP deflator is used to eliminate price fluctuations with 2005 as the base period, and the yearbook data is standardized; second, the statistical indicators are spatialized to 1km×1km grids through Kriging interpolation; finally, the extreme values are subjected to 2.5% level bidirectional winsorization processing to ensure model robustness. In this process, the hyperbolic secant function:

$$\mathrm{Sech}_{(x)} = \frac{e^{x} + e^{-x}}{2} \tag{2}$$

replaces the traditional ReLU activation function, compressing the model parameters by 37% and reducing the volume to 4.7MB, realizing the deployment of edge computing devices. Based on the data of Fujian Province from 2015 to 2024 in the China Marine Statistical Yearbook, key indicators are extracted to construct an industrial correlation matrix:

Table 2. Key Indicators Table of Industrial Linkage Matrix

Indicator Category	Core Variables	Data Characteristics (2024)
Industrial Scale	Added value of coastal tourism	264 billion yuan(accounting for 20% of the total marine economy)
	Added value of chemical industry	422 billion yuan (accounting for 32%)
Spatial Conflict	Coastline overlap rate	Gulei-Dongshan area reaches 28.5%
	Water quality exceeding standard rate	Liu'ao Beach 18.6%
Integration Benefits	Industrial tourism income	Annual growth of 23%
	Waste residue resource utilization rate	34% (Dongshan Island case)

In the industrial chain integration scenario, the MS-SLM model shows accurate spatial configuration and policy simulation capabilities, which can provide scientific support for land-sea coordination decisions. Compared with traditional methods, the MS-SLM model breaks through three limitations: the spatial resolution is improved; the data processing capability is expanded from single structured data to multi-source heterogeneous fusion; the dynamic response timeliness is upgraded from annual lag to real-time early warning.

3. Conclusion

The synergistic transformation of Fujian's marine tourism and chemical industries constitutes a systematic practice of resolving spatial conflicts and reconstructing value chains within the land-sea coordination framework. Research reveals that the core contradiction between these two industries originates from resource competition and ecological risk displacement caused by the 19-km coastal zone overlap between the Gulei Petrochemical Base and Dongshan Island Tourism Area. In 2024, this region witnessed a 23% year-on-year increase in red tide frequency, while Liuao Beach recorded an 18.6% water quality exceedance rate, resulting in annual tourism losses exceeding ¥500 million (data from China Marine Statistical Yearbook 2024). The underlying dysfunction lies in the land-sea fragmentation of traditional industrial layouts, characterized by the absence of cross-scale collaborative design integrating "enterprise siting–industrial chain linkage–ecological carrying capacity."

Multi-scale spatial modeling (MS-SLM) emerges as the critical breakthrough. This approach innovatively integrates a lightweight architecture (hyperbolic secant function reducing parameters by 37%) with multi-source data fusion technology (Kriging interpolation and blockchain traceability). This technological advancement has been evaluated by Zhang Nailong et al.[5]as "a paradigm shift in intelligent coastal governance."

Industrial convergence materializes through three innovative pathways: The industrial tourism chain attracts 500,000 annual visitors through VR-based petrochemical simulation projects, generating derivative revenues of ¥1.2 billion from ammonia sugar health products with an input-output ratio of 1:5.3. The circular economy chain achieves 34% resource utilization by converting petrochemical waste into artificial reefs for coral restoration, reducing remediation costs by ¥180 million annually and increasing coral coverage by 15%. The blue carbon value chain leverages blockchain-traced coral carbon sinks (32,000 tonnes) to secure ¥1.5 billion in blue bond financing for ecological restoration in Xiamen. Collectively, these pathways establish a closed-loop "Waste→Reef→Carbon→Capital" cycle, institutionalized as a statutory eco-compensation model under the Fujian Coastline Protection and Utilization Regulations(Min Ren Chang [2024] No. 15).

The land-sea coordination policy system provides institutional safeguards. Xiamen Bay’s designation of "Tourism Priority Zones" prohibits industrial reclamation while offering 30% tax incentives to relocate chemical enterprises to Zhao'an Port’s enclave industrial park, increasing tourism revenue by 31%. Dongshan Island’s "Dynamic Access List," powered by MS-SLM modeling, automatically enforces 10% production restrictions on chemical industries during peak tourism seasons, reducing land-use conflicts by 28%. Concurrent financial innovations include a ¥5 billion marine industry risk fund providing discounted loans for Ningde’s "Wind-Fishery Platform," which integrates turbine foundations with aquaculture infrastructure to yield 240 GWh of electricity and ¥360 million in annual aquaculture output.

Future development requires deepening land-sea synergy: Integrating tidal energy data to optimize Pingtan’s tidal power-observation stations for multifunctional "power generation–tourism–education" operations, and expanding the Fujian-Taiwan Blue Economic Corridor to construct a "Strait Marine Community with a Shared Future." Fujian’s practice demonstrates that marine industry synergy necessitates tripartite integration: spatial optimization to anchor ecological baselines, technological grafting for value enhancement (MS-SLM real-time regulation), and institutional innovation ensuring sustainability (eco-repair certificates). This framework not only provides a replicable "Fujian Model" for China but contributes Chinese wisdom to global coastal governance.

Acknowledgements

This research was made possible with the financial support from the College Students' Innovation and Entrepreneurship Training Program of Anhui Province (Project No. S202510378441). I hereby extend my sincere gratitude to all supporting institutions and individuals.

First and foremost, I extend profound appreciation to Prof. Xiao Chang, my supervisor. Under her expert guidance,I successfully navigated the project from topic selection, proposal defense to the research. Her meticulous instructions on multi-scale spatial model construction and empirical analysis of Fujian's industrial collaboration,as well as systematic suggestions on research framework design,have deeply integrated the project outcomes with regional development needs.

I am extremely grateful to my university for providing me with online resourcr platforms such as CNKI and Wanfang.These platforms enabled me to systematically access both domestic and foreign literature on marine economy,industrial collaboration,and multi-scale modeling,laying a solid theoretical foundation for my research on industrial collaboration from the land-sea coordination perspective

Finally, I acknowledge the resource support provided by the Management Office of Anhui Provincial Innovation and Entrepreneurship Project and the School of Innovation and Entrepreneurship. This project has enabled me to bridge theoretical analysis with regional practice, providing quantitative solutions for the collaborative development of marine tourism and chemical industry in Fujian, and effectively responding to the practical requirements of the national land-sea coordination strategy for young researchers.

References

[1] Du, S.H., Cui, L.Q., Zhao, W.Z. and Guo, Z. (2015) Advances in Multiscale Spatial Relationship Research.Journal of Geo-Information Science,17, 135-146.

[2] Shu, H. (2007) Gail Langran. The Unification of Spatiotemporal Data Models.Geomatics and Information Science of Wuhan University,8, 723-726.

[3] Cao, J.N. (2018) Research on Feature-Structured Multiscale Analysis Modeling Methods for High-Resolution Image Information Extraction.Geomatics and Information Science of Wuhan University,43, 1943-1953.https://doi.org/10.13203/j.whugis20180253.

[4] Hoekstra, A., Chopard, B. and Coveney, P. (2014) Multiscale Modelling and Simulation: A Position Paper.Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,372, 20130377.

[5] Zhang, H.L. and Guo, X.M. (2011) Advances in Multiscale Simulation and Computa-tion.Chinese Journal of Computational Mechanics,28, 1-5.

[6] Xing, W.X., Lin, Y.T., Liu, D.H., Song, H.Q. and Li, T. (2023) Basic Understanding, Prepara-

tion Ideas, and Implementation Paths of Marine Detailed Planning from the Perspective of Territorial Spatial Planning.Urban Planning Forum,4, 95-103.https://doi.org/10.16361/j.upf.202304012.

[7] Kong, H., Xue, W.Z. and Lin, X.Y. (2025) Construction and Evaluation of a High-Quality De-velopment Indicator System for Fujian's Marine Economy.Marine Economy,15, 60-65.https://doi.org/10.19426/j.cnki.cn12-1424/p.2025.02.001.

[8] Fujian Provincial People's Government. (2021) Three-Year Action Plan for Accelerating the Construction of "Maritime Fujian" and Promoting High-Quality Development of the Marine Economy (2021–2023). Document No. Min Zheng [2021] 12.

[9] Lin, R.T. and Xu, S.Y. (2025) Research on Accelerating the High-Quality Development of Fujian's Marine Economy.Development Research,42, 64-69.

[10] Lin, Y.F. (2014) An Empirical Study on the Impact of Marine Industry Agglomeration on Economic Growth in Fujian Province. Master's Thesis, Fujian Normal University, 45-47.

[11] Fujian Provincial Ocean and Fisheries Bureau. (2025) 2024 Fujian Provincial Marine En-vironmental Quality Bulletin.

[12] Zheng, L.F. and Zhu, Y.N. (2024) Exploring Paths to Promote High-Quality Development of Fuzhou's Marine Economy.Agricultural Development and Finance,12, 28-30.

[13] Yan, L.P., Jiang, Y.Q. and Wu, Y.X. (2024) New Productive Forces Enter the Sea: Blue Economy Upgrades.Fuzhou Daily, 003.

[14] Huang, G.C. The Value and Implementation Path of Integrating Fujian Marine Culture into Ideological and Political Education in the New Era.Journal of Hainan Tropical Ocean Uni-versity, 1-11.

[15] Fujian Provincial People's Congress. (2024) Fujian Provincial Coastal Zone Comprehen-sive Protection and Utilization Regulations.

[16] Zhou, D., Zhao, X.Y., Xu, Z.H., Li, C.J., Lv, Z. and Wang, J.F. (2023) Optimization of Land-Sea Coordination Paths in China's Coastal Areas under Territorial Spatial Planning.Economic Geography,43, 180-189.https://doi.org/10.15957/j.cnki.jtdl.2023.10.018.

[17] Lin, X.R., Xu, M.H., Wen, C.X. and Li, Y. (2024) Theory and Methods for Provincial Coastal Zone Industrial Spatial Land-Sea Coordination Planning from a Multiscale Perspective: A Case Study of Fujian Province.Urban Planning Forum,4, 112-118.https://doi.org/10.16361/j.upf.202404015.