



Study on the Construction of Zhanjiang-Haikou Railway under the Background of Hainan Free Trade Port

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Abstract: As Hainan Free Trade Port is about to launch the customs closure operation, the role of railway construction in building a high-level open economic system has become increasingly prominent. Based on a systematic analysis of the significance and value of the Zhanjiang-Haikou Railway construction, this study, through literature retrieval and field research, identifies the practical difficulties in the project construction as follows: complex geographical environment leading to significant engineering and technical challenges; cross-regional policy coordination and benefit distribution issues; and the balance between ecological protection and project construction. The feasible solutions proposed include: integrating multi-source data to construct a 3D geological-geophysical model; strengthening top-level design and providing legislative guarantees; and prioritizing ecological protection while promoting coordinated ecological restoration. This study is expected to provide theoretical and practical support for relevant work.

Keywords: Hainan Free Trade Port; economic integration; transportation bottleneck; regional coordination

1. Introduction

As a frontier for the country's comprehensive deepening of reform and opening up, Hainan Free Trade Port undertakes the important task of building a high-level open economic system. With the accelerated construction of Hainan Free Trade Port, the exchange of personnel and materials between Hainan and the inland regions has become increasingly frequent. The existing Yuehai Railway can hardly meet the medium- and long-term passenger transport demand for travel to and from the island. Moreover, the existing ferry terminal facilities are aging, posing potential safety hazards. Therefore, it is urgent to carry out relevant research work[1].

2. Significance and Value of the Study

2.1 Demand for Economic Integration

The customs closure operation of Hainan Free Trade Port requires the establishment of a seamlessly connected supply chain system with the inland areas. The Zhanjiang-Haikou Railway can shorten the land-sea transshipment time, reduce cross-border logistics costs, strengthen industrial linkage between Hainan and the Pearl River Delta as well as the southwest inland regions, accelerate industrial cooperation and resource complementarity between Hainan and the Guangdong-Hong Kong-Macao Greater Bay Area and the southwest regions, promote resource integration between the two sides, reduce logistics costs, facilitate the transportation of Hainan's agricultural products and characteristic products to other regions and the import of industrial raw materials, and inject new impetus into Hainan's economic development[2].

2.2 Breaking Through Transportation Bottlenecks

The existing ferry transportation across the Qiongzhou Strait is significantly restricted by weather conditions, and the capacity ceiling limits the efficiency of cross-strait transportation of bulk cargo and passengers[3]. The completion of the Zhanjiang-Haikou High-Speed Railway will, together with the existing Yuehai Railway and the highways along the route, form a comprehensive transportation corridor in the Leizhou Peninsula and for travel to and from Hainan Island, effectively alleviating the transportation pressure on the Qiongzhou Strait and improving regional transportation efficiency.

2.3 Considerations for Strategic Security

As a core base for the development of the South China Sea, Hainan Island needs to strengthen its capacity for emergency material transportation through land transportation corridors and improve the level of regional strategic security guarantees[4]. The construction of the Zhanjiang-Haikou High-Speed Railway will enable Hainan to better integrate into the national development pattern, enhance the radiation capacity of Hainan Free Trade Port in opening up to the outside world,

and elevate Hainan's position in the national economic structure.

3. Implementation Difficulties

3.1 Complex Geographical Environment and Significant Engineering and Technical Challenges

The Qiongzhou Strait is located in the core area of the Leiqiong Fault Depression Zone, and its geological structure exhibits significant differential subsidence characteristics. Tectonic activities since the Cenozoic Era have led to the fragmentation of the strait's basement rock formations, with the development of multiple concealed active fault zones. Some of these fault zones are active in the Quaternary Period, which have triggered the 1605 Qiongsan Ms 7.5 earthquake and many other strong earthquake events in history. The differential crustal uplift and subsidence movement as well as horizontal dislocation effect of such fault zones not only result in abrupt changes in the seabed terrain and poor rock mass stability, but also expose the cross-sea corridor project to the risks of uneven foundation settlement and seismic liquefaction[5].

3.2 Cross-Regional Policy Coordination and Benefit Distribution

As a large-scale infrastructure project spanning Guangdong and Hainan provinces, the Zhanjiang-Haikou Railway is affected by institutional frictions caused by administrative division barriers. For example, Guangdong Province focuses on the provincial-level unified land expropriation standards, while Hainan Province, due to the special policies of the free trade port, grants greater autonomy to cities and counties. This easily leads to conflicts between the two regions in terms of the scope of land expropriation compensation and resettlement models.

3.3 Balance Between Ecological Protection and Project Construction

The two sides of the Qiongzhou Strait are home to globally rare mangrove wetlands, coral reef ecosystems, and habitats for rare migratory birds. Their ecological sensitivity imposes rigid constraints on the construction of the Zhanjiang-Haikou Railway. For instance, the cross-sea corridor project may divide the continuous intertidal zone space, block the migration corridors of benthic organisms, leading to a decline in the connectivity of mangrove communities and a sharp reduction in biodiversity; the excavation of undersea tunnels or the construction of bridge pile foundations will change the local hydrodynamic conditions, and the diffusion of suspended solids may trigger coral bleaching; in addition, the stacking of dredged spoil is likely to cause tidal ditch silting, damaging the spawning grounds of fish and the habitat environment of shellfish.

4. Suggestions on Implementation Paths

4.1 Integrating Multi-Source Data to Construct a 3D Geological-Geophysical Model

To address the complex geological conditions, the combination of seismic wave tomography and borehole core sampling can be used to accurately identify the spatial distribution pattern of fault zones. During the route selection stage of the cross-sea corridor, the strategy of "prioritizing avoidance and conducting local reinforcement when necessary" should be adopted, and BIM (Building Information Modeling) technology should be used to simulate the geological risks of different route schemes, so as to avoid the impact of active faults to the greatest extent. For the construction of deep-water foundations, technologies such as large-diameter composite pile foundations and self-balancing caissons should be developed, and high-performance marine engineering concrete materials should be used to improve the bearing capacity of the foundation structure under the combined action of soft soil foundations and earthquakes. In response to the challenges of extreme climates, a multi-hazard coupling analysis model should be introduced into the structural design, and fluid-structure interaction numerical simulation should be used to evaluate the typhoon load and wave impact effect, so as to optimize the aerodynamic shape of bridge towers and reduce the risk of wind-induced vibration.

4.2 Strengthening Top-Level Design and Providing Legislative Guarantees

4.2.1 Establishing a Dynamic Long-Term Mechanism for Ecological Compensation

Based on the ecological service value evaluation model, indicators such as the increase in carbon sequestration and biodiversity conservation in the ecological protection areas on both sides of the Qiongzhou Strait should be quantified, and a composite compensation mechanism of "horizontal transfer payment + market-oriented transaction" should be designed. Specifically, it includes: Guangdong and Hainan provinces jointly contributing to the establishment of an ecological restoration fund, with the right to use the fund allocated according to the contribution degree of ecological benefits; and exploring the development of carbon emission trading.

4.2.2 Improving the Data-Driven Collaborative Supervision Network

The territorial spatial planning databases and ecological monitoring platforms of the two provinces should be integrated

to build a cross-regional "digital twin" management system, which can track the progress of land expropriation, ecological disturbances, and economic linkage effects in real time. Blockchain technology should be used to ensure the transparency of the flow of compensation funds, and third-party evaluation institutions should be introduced to release the coordinated development index regularly, forming a dynamic governance closed loop of "monitoring - feedback - optimization".

4.3 Prioritizing Ecological Protection and Promoting Coordinated Ecological Restoration

4.3.1 Establishing a Full-Cycle Ecological Impact Prevention and Control System

In the design stage, an "ecology-first" route comparison mechanism should be implemented, using the MaxEnt (Maximum Entropy) species distribution model and landscape ecology principles; in the construction stage, integrated micro-disturbance construction technologies should be applied: for underwater construction areas, multi-aperture pipe jacking technology combined with a mud closed-loop circulation system should be adopted to reduce the disturbance of seabed sediments; for the land section, prefabricated viaduct technology should be used to achieve "zero ground hardening" construction.

4.3.2 Innovating the Coordinated Mechanism for Ecological Restoration

A cross-regional special fund for ecological restoration should be established, with funding sources including central financial transfer payments, deductions from railway operation income, and targeted financing from the International Green Climate Fund. The fund will focus on supporting the artificial breeding of mangroves, the transplantation and restoration of coral reefs, and the construction of intelligent monitoring platforms. The coastal zone ecological network reconstruction project should be implemented: based on circuit theory, an ecological corridor optimization model should be constructed, and measures such as returning aquaculture areas to tidal flats and placing oyster reefs should be taken to rebuild biological migration stepping stones, connecting fragmented habitats to form a continuous ecological matrix. In addition, drone seeding and robot planting technologies should be introduced to improve the efficiency of vegetation restoration.

5. Conclusion

The construction of the Zhanjiang-Haikou Railway is a key pivot for Hainan Free Trade Port to leap from a "policy highland" to a "functional highland", and its significance goes far beyond that of a single transportation project. By breaking through the bottleneck of the cross-sea corridor, it can not only reshape the regional economic and geographical pattern, but also provide a practical sample for the country to explore the integrated development of land and sea. In the future, it is necessary to focus on institutional innovation, comprehensively coordinate technological breakthroughs, ecological protection, and benefit-sharing mechanisms, and promote the project from planning and demonstration to implementation.

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