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# Research on the Impact of Environmental and Geological Conditions on Urban Economic Development and Countermeasures: A Case Study of Shenzhen City

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**Abstract:** As the core engine of the Guangdong-Hong Kong-Macao Greater Bay Area, Shenzhen's rapid economic development is closely intertwined with its unique environmental and geological conditions. This paper systematically analyzes how multiple geological factors in Shenzhen, such as geological hazards, coastal zone geological environment problems, groundwater resources, and engineering geological conditions, profoundly affect urban land development value, major project site selection safety, infrastructure operation costs, and specific industrial development potential through direct and indirect paths. Research shows that the complex geological environment constitutes the "natural background" and rigid constraint for Shenzhen's economic development. On this basis, the paper puts forward a series of countermeasures and suggestions to promote the coordinated, safe, and sustainable development of urban economy and geological environment from four aspects: territorial spatial planning, geological hazard prevention and control, sustainable utilization of groundwater resources, and integrated coastal zone management.

**Keywords:** CGE model; Economic loss assessment; Land subsidence; Shenzhen city; Soft soil area

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## 1. Introduction

In the course of more than 40 years of development, Shenzhen has leaped from a border agricultural county to an internationally influential innovative city, creating a miracle in the history of global urbanization, industrialization, and modernization. However, its rapid economic development, high population concentration, and rapid urban spatial expansion have always been based on a specific geological environment "base". The city's natural geographical background, a terrain that is high in the southeast and low in the northwest, complex fault structures, diverse rock and soil types, a long coastline, and abundant precipitation, has not only provided space and resources for its development but also hidden many environmental and geological risks [1–3].

As Shenzhen enters a new development stage centered on "high-quality development", urban development has put forward higher requirements for territorial spatial quality, engineering safety standards, and an ecologically livable environment. Geological environment issues are increasingly becoming key factors affecting urban safety, restricting the efficiency of spatial resource allocation, and determining long-term comprehensive competitiveness. Therefore, systematically sorting out the multi-dimensional impacts of environmental and geological conditions on economic development and exploring collaborative development paths are of crucial strategic significance for Shenzhen to move towards the future and build a more resilient global benchmark city [4].

## 2. Analysis of Shenzhen's core environmental and geological conditions and their economic impacts

### 2.1. Constraints of geological hazards on urban development and operation costs

Shenzhen's landform is dominated by low mountains and hills, which are important ecological barriers and rich in tourism resources, but also high-risk areas for geological hazards [5,6]. Slope hazards have increased the engineering construction and later maintenance costs in these areas.

Karst ground subsidence is mainly concealed in karst-developed areas such as Longgang and Pingshan Districts. A large number of foundation pit excavations, tunnel constructions, and changes in groundwater dynamic conditions in urban development are likely to induce sudden ground subsidence. Such hazards are characterized by concealment, suddenness, and strong destructiveness, posing a serious threat to ground buildings, urban roads, and underground pipelines [7,8].

Although large-scale land subsidence in Shenzhen is not significant, local land subsidence exists in the western coastal soft soil areas and some reclaimed land areas due to the consolidation of soft soil layers and human engineering activities (such as large-area filling and loading) [9,10]. This uneven subsidence will damage the stability and service life of major infrastructure such as roads, bridges, ports and terminals, and underground pipe corridors, increasing financial expenditures on maintenance and restoration.

### 2.2. Dual effects of coastal zone geological environment changes on marine economy

Shenzhen has a 260 kilometer coastline, and the marine economy is an important pole of its economic growth. However, the dynamic changes of the coastal zone geological environment have had a profound impact on the development of the marine economy.

Under the combined effect of natural processes and human activities (such as sand mining and coastline modification), some sandy coasts are facing the risk of erosion and retreat, directly threatening coastal tourism resources. Meanwhile, some port waterways may face silting problems, increasing dredging costs and affecting shipping efficiency. At the same time, large-scale historical reclamation has inevitably changed the marine hydrodynamic environment, which may aggravate erosion or silting in adjacent areas and bring long-term hidden economic costs such as loss of ecological service functions [11].

Surveys show that seawater intrusion exists in some coastal areas such as Bao'an. Although the problem has been effectively controlled through strict measures of prohibiting and restricting mining, it serves as a warning, highlighting the importance of maintaining the balance between fresh water and seawater interfaces in the development of coastal cities [12].

### 2.3. Coordination and conflict between groundwater resource endowment and urban development

The total groundwater storage capacity in Shenzhen is approximately 561.631 million cubic meters. Historically, groundwater has been an important supplementary water supply source. Currently, the strategic economic value of groundwater resources is reflected in two aspects: first, in the event of extreme droughts or sudden water pollution incidents, it can be used as an emergency water source to ensure the operation of core urban functions and reduce systemic economic risks; second, groundwater demonstration projects being explored in areas such as Dapeng New District provide new possibilities for high-quality drinking water and the development of specific industries. Therefore, the protection of groundwater resources is essentially an investment in the resilience of the urban economic system and future development potential [13].

### 2.4. Engineering geological conditions and reconstruction of urban spatial value

There are significant differences in engineering geological conditions among different regions of Shenzhen. This spatial differentiation of engineering geological conditions profoundly affects the cost of converting “raw land” into “developed land” in different plots, thereby reshaping the economic value and development sequence of land at the micro level [14]. Urban planning and construction must fully respect this geological law to achieve the optimization of input and output.

## 3. Countermeasures and suggestions for promoting the coordination between geological environment and economic development

To achieve the long-term balance between geological safety and urban prosperity in Shenzhen, a long-term mechanism should be constructed from the following four dimensions.

### 3.1. Strategic guidance: Deeply integrate geological safety into the entire process of territorial spatial planning and decision-making

The important position of geological surveys and risk assessments should be established in the stages of territorial spatial master planning, detailed planning, and feasibility studies of major engineering projects. An intelligent decision support system of “Shenzhen Geological Safety Map” which serves as one of the core bases for delineating urban development boundaries and optimizing the “three zones and three lines” should be built.

For high-risk areas of geological hazards, they should be designated as ecological protection red lines or restricted construction areas in principle to control development activities; for medium-risk areas, implement “positive list + negative list” management, restrict high-density and high-sensitivity land use types, and compulsorily require the supporting implementation of high-standard engineering governance and monitoring measures; for low-risk areas, encourage intensive and efficient development to reduce the potential safety costs of economic development from the source.

For special geological areas with insufficient current understanding or immature governance technologies, draw on the “reservation” concept in ecological protection to delineate “geological safety strategic reservation areas”. In these areas, large-scale and high-intensity development should be suspended to reserve space and flexibility for future technological progress and more accurate risk assessments.

### 3.2. Intelligent empowerment: Build a comprehensive perception and real-time early warning geological risk prevention and control system

Multi-source data such as geological, geographical, meteorological, engineering, and social-economic data should be deeply integrated, and BIM+CIM+GIS technologies should be used to build a fully transparent, dynamically visible, and virtual-real interactive Shenzhen geological information model, thereby providing a “sand table deduction” style scientific decision support for urban planning, disaster early warning, and emergency command.

An “air-space-ground-well” integrated intelligent monitoring network should be deployed by comprehensively using satellite remote sensing (InSAR), UAV aerial photography, ground sensor arrays, and underground monitoring equipment, and using artificial intelligence and big data technologies to conduct intelligent analysis and in-depth mining of massive monitoring data, realizing the full-process precise control of geological hazards from “hidden danger identification” to “pre-disaster early warning”, and transforming passive disaster relief into active disaster prevention [15].

A technical system of “adaptive design and resilient infrastructure” should be developed through using Shenzhen’s specific geological environment problems, vigorously research and promote resilient engineering technologies. Through technological innovation, make infrastructure itself adaptable and resilient to changes in the geological environment.

### 3.3. Mechanism innovation: Build a multi-governance pattern led by the government and coordinated by the market and society

To enhance urban geological resilience, it is essential to innovate the "geology-finance" linkage mechanism. Collaboration with financial institutions should focus on developing green financial instruments, such as urban resilience bonds and special loans for geological hazard prevention and control. Preferential loan interest rates and guarantee fee subsidies may be provided to enterprises and projects that proactively adopt high-standard resilient designs and implement measures for geological environment protection and restoration.

In addition, a "geological ecological compensation and development rights transfer" mechanism should be established. For regions or rights holders whose development potential is restricted due to geological protection responsibilities, such as those located in high-risk geological hazard zones or key water conservation areas, a scientific ecological compensation framework is necessary. This mechanism promotes both fairness and efficiency, realizing the principle that "protectors benefit while developers compensate" within the urban system.

Moreover, it is important to cultivate a new geological safety industry. Leveraging Shenzhen's industrial strengths in electronic information, high-end equipment manufacturing, and new materials, the city can strategically develop emerging industries related to geological safety. By transforming geological challenges into opportunities for innovation, Shenzhen can foster new economic growth drivers and establish a globally competitive "resilient technology" industrial cluster.

### 3.4. Social co-governance: Improve the geological risk literacy and participation of the whole society

Strengthening urban geological resilience requires geological safety science popularization and transparent information disclosure. This includes regular publication of an accessible Shenzhen Urban Geological Environment Status White Paper and a public version of the city's geological risk map, disseminated widely through converged media platforms. Ongoing public science outreach activities further enhance the risk awareness and self-rescue capabilities of citizens, enterprises, and grassroots personnel.

The development of "community-park" micro-resilient units represents another critical measure. By integrating geological risk prevention with the construction of smart communities and safe parks, communities and industrial parks can conduct self-inspections of potential geological hazards, formulate emergency response plans, and maintain essential emergency supplies. The adoption of the community planner system embeds resilience concepts into micro-renovations and incremental upgrades, establishing a grassroots defense line for urban resilience.

Establishment of a cross-disciplinary knowledge sharing and public participation platform strengthens collaboration and public engagement. Regular communication among geologists, economists, urban planners, engineers, sociologists, and decision-makers fosters integrated solutions. Digital technologies enable citizens to report geological hazards through simple methods such as mobile-phone photography, combining professional monitoring with community-based surveillance and prevention and promoting a social environment where everyone is aware of geological risks and actively participates in resilience-building.

Through the coordinated efforts of the above four dimensions of strategy, technology, mechanism, and society, Shenzhen will be able to build a "geological-economic" collaborative governance system that runs through the entire process of urban planning, construction, management, and operation.

## 4. Conclusion

Shenzhen's economic development achievements have attracted worldwide attention, but its future sustainable development capacity largely depends on how we perceive, adapt to, and intelligently manage its complex environmental and geological conditions. The geological environment is no longer a static backdrop for economic development, but a key active factor that dynamically participates in and profoundly affects urban economic safety, costs, and models. By elevating geological safety to a city-wide strategic height and fully integrating it into planning, construction, and management practices, Shenzhen is fully capable of transforming the “constraints” of geological conditions into an “opportunity” to shape a safer, more intensive, and more resilient development model, thereby consolidating and enhancing its core position in the fierce competition of the Guangdong-Hong Kong-Macao Greater Bay Area, and laying a solid geological foundation for achieving high-quality and sustainable long-term prosperity.

## Disclosure statement

The author declares no conflict of interest.

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