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The Relationship Between Urban Resilience Construction and Economic Development from the Perspective of Environmental Geology — A Case Study of Shenzhen

Qi Liao[1], Wenbo Li[2]*, Jiangbo Wang[1]

[1]School of Economics, Shenzhen Polytechnic University, Shenzhen 518055, China
[2]Shenzhen Development Research Center for Natural Resources and Real Estate Evaluation (Shenzhen Geological Environment Monitoring Center), Shenzhen 518034, China

**Author to whom correspondence should be addressed.*

Abstract: Urban resilience is a key capability for contemporary cities to maintain core functions, recover quickly, and adapt to development when facing natural and social disturbances. From the fundamental perspective of environmental geology, this paper explores the intrinsic logical relationship between urban resilience construction and economic development in Shenzhen when addressing natural challenges such as geological hazards, coastal zone changes, and groundwater system fluctuations. The study argues that effective management of geological risks constitutes the physical foundation of urban economic resilience, while sustained economic development provides necessary material and technical support for enhancing geological safety resilience. The two form an interdependent and mutually promoting coupled system. Finally, the paper proposes an implementation path for constructing a "geological-economic" coordinated resilience system, aiming to provide theoretical reference and practical insights for Shenzhen and other similar coastal cities with high-intensity development.

Keywords: Urban resilience; Environmental geology; Economic development; Geological hazard prevention and control; Sustainable development; Shenzhen

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1. Introduction: The geological dimension in the era of resilient cities

Against the global backdrop of intensifying climate change impacts and frequent extreme weather events, "resilient cities" have become a core issue in modern urban development and governance [1–2]. Urban resilience emphasizes not only the ability to resist shocks but also the capacity to learn, adapt, and transform. For a megacity like Shenzhen, which is located along the coast, has complex landforms, and a highly concentrated economy,

a significant portion of the shocks and pressures it faces originates from the geological environment system on which it depends. Typhoons and heavy rains may trigger landslides, sea-level rise exacerbates coastal erosion, and engineering construction may disturb concealed karst — all these geological processes can pose severe challenges to the normal operation of the urban economy and society [3–5].

Therefore, examining urban resilience construction from the perspective of environmental geology essentially returns to the most fundamental level of cities as complex adaptive systems exchanging materials and energy with the natural environment. A resilient economic system can provide sustained investment and innovative momentum for the monitoring, assessment, governance, and adaptation of the geological environment. This paper aims to deeply analyze this often-overlooked geological dimension in Shenzhen's urban resilience construction and explain its inseparable symbiotic relationship with economic development.

2. Literature review

The theory of urban resilience provides a core framework for understanding cities' ability to maintain core functions amid disturbances, with its connotation evolving from engineering-oriented "recovery" to eco-social "adaptation and development" [6]. Within this framework, the geological environment, as the physical foundation of urban systems, its stability is a prerequisite for economic and social resilience. Studies have shown that the ability to resist geological hazards is directly related to urban lifeline safety and the continuity of economic operations, while geological processes such as coastal zone dynamics are key constraining factors for the sustainable development of the blue economy [7–8].

There is a profound interactive relationship between economic development and urban resilience. Strong economic strength provides necessary financial and technological support for resilience construction, enabling high-standard risk monitoring and infrastructure investment [9]; conversely, a safe and resilient environment can reduce operational risks, enhance investment confidence, and thereby feed back into long-term economic prosperity [10]. Domestic research has integrated resilience concepts into territorial spatial planning exploration, but case studies on Shenzhen mostly focus on climate risks, often treating geological issues as isolated technical challenges [11].

Thus, existing research has not fully revealed how Shenzhen's complex geological conditions systematically shape its economic resilience. This paper aims to fill this gap by placing environmental geology, urban resilience, and economic development within a unified framework, deeply analyzing their intrinsic logic, and providing a new perspective for Shenzhen's high-quality development.

3. Geological safety: The physical foundation of urban economic resilience

The resilience of an urban economic system is first reflected in the integrity and functionality of its physical infrastructure and production factors when facing disturbances. Environmental geological conditions are the core component of this physical foundation.

3.1. Infrastructure resilience and geological hazard prevention

Shenzhen's transportation networks, energy facilities, communication hubs, and high-density built-up areas are widely distributed across different geological risk zones. If a key expressway or subway line is interrupted due to slope failure, the direct economic losses and indirect impacts of industrial chain disruptions will be enormous.

Therefore, high-standard surveys, regular monitoring, and efficient governance of slope-related geological hazards are prerequisite conditions for ensuring the smooth flow of urban "blood vessels" and maintaining economic vitality. A city with high resilience to geological hazards will have significantly reduced vulnerability of its economic system to external shocks such as extreme weather [12].

3.2. Spatial asset resilience and risks of karst and land subsidence

The risks of land subsidence and karst collapse faced by areas with soft soil and soluble rock directly threaten the safety of ground buildings and the long-term value of land assets. A sudden collapse incident not only causes direct property losses but also triggers regional credit impairment and undermines development confidence. Delimiting risk zones through high-precision geological surveys and conducting scientific planning and engineering avoidance based on this is the fundamental protection of social wealth and spatial assets. This proactive resilience construction is far more economically valuable than post-disaster reconstruction investment.

3.3. Water supply resilience and strategic groundwater reserves

Against the backdrop of Shenzhen relying mainly on the Dongjiang Water Diversion Project for its water supply, the economic role of groundwater resources has shifted from daily water supply to strategic emergency reserves. When surface water sources face supply crises due to sudden pollution or consecutive droughts, widely distributed and high-quality groundwater reservoirs can be quickly activated to provide guarantees for key industries and residents' basic lives, avoiding economic and social shutdowns. Protecting groundwater from pollution and over-extraction, and maintaining its strategic reserve function, is a key link in building urban water supply resilience, whose value cannot be measured by short-term economic interests [13].

4. Economic development: The core support for enhancing geological safety resilience

A city's resilience to geological risks does not arise out of thin air; it highly depends on sustained economic investment, technological innovation, and institutional construction — all of which are backed by solid economic development [14–15].

4.1. Financial support

The construction of advanced geological hazard monitoring networks, large-scale slope governance projects, coastal zone ecological restoration projects, groundwater resource surveys, and the delineation of protected areas all require substantial capital investment. Shenzhen's strong public financial capacity and active social capital make it possible to carry out these tasks that enhance the city's basic resilience.

4.2. Technological drive

Economic development promotes scientific and technological progress. Using InSAR satellite remote sensing technology for large-scale and high-precision surface deformation monitoring, adopting artificial intelligence algorithms to analyze massive geological data for collapse risk prediction, and developing new materials for ecological slope protection — these high-tech means have greatly enhanced cities' ability to perceive, warn, and respond to geological risks, embodying "smart resilience." Shenzhen's industrial advantages in the information technology field can well empower the improvement of geological safety resilience.

4.3. Institutional guarantee

At a higher stage of economic development, society's demands for safety, environmental quality, and sustainable development become increasingly strong, thereby promoting the formation of stricter land use controls, building codes, and environmental regulations. For example, Shenzhen took the lead in the country in formulating systematic geological hazard prevention and control plans and detailed survey and zoning — this itself is a reflection of the upgrading of social demand for public goods such as safety after economic development reaches a certain stage, and the construction of institutional resilience.

5. Path suggestions for constructing a "geological-economic" coordinated resilience system

To deeply embed geological safety into the core of urban economic development and realize a paradigm shift from passive prevention to active adaptation, and from cost burden to value creation, Shenzhen needs to strive to build a forward-looking and systematic "geological-economic" coordinated resilience system. The construction of this system should follow the following four strategic paths.

5.1. Conceptual innovation path: Strategic upgrade from "disaster prevention and reduction" to "resilience value addition"

Establish a new development concept of "geological resilience as core competitiveness": In urban top-level design, clearly regard geological safety resilience as a core urban competitiveness equal to the business environment and technological innovation. Advocate the concept that "investing in resilience is investing in future value increment", guiding the whole society to recognize that excellent geological risk management capacity is itself a "distinctive urban asset" for attracting high-end talents and ensuring long-term capital safety.

Promote the "mainstreaming" and "front-loading" of resilience thinking: Shift geological resilience considerations from "engineering remedial measures" in the later stages of projects to the source stage of territorial spatial planning, industrial policy formulation, land transfer, and feasibility studies of major projects. Set up a special "urban resilience" chapter in urban development strategies and national economic and social development plans to ensure that geological safety and economic development goals are planned and deployed simultaneously.

Define and promote "resilience value": Go beyond the traditional cost-benefit analysis framework and establish a "resilience value" evaluation system. This system should comprehensively consider the risk avoidance benefits, whole-life cycle cost savings, ecological system service value improvement brought by geological safety measures, as well as the resulting regional brand value increment and investment confidence enhancement, providing a more comprehensive demonstration of the economic rationality of resilience construction projects.

5.2. Institutional innovation path: Constructing a comprehensive and whole-chain resilience governance system

Establish an integrated "geological-planning-economic" decision-making platform: It is recommended to set up a high-level cross-domain "Urban Resilience Development Committee" at the municipal level, led by municipal leaders, to coordinate the powers and responsibilities of departments such as natural resources, development and reform, finance, housing and urban-rural development, water affairs, transportation, and emergency management. The committee is responsible for reviewing the city's overall resilience development strategy, coordinating the resolution of major contradictions involving geological safety and economic development, and ensuring policy

coordination.

Improve the "space-property-rights-finance" linked policy toolbox: Spatial control: On the basis of China's territorial spatial planning boundaries "three zones and three lines", further refine and issue the "Shenzhen Municipal Spatial Control Rules for Geological Hazard Prevention and Control and Geological Environment Protection", clarifying prohibited, restricted, and guided development requirements for areas with different geological risk levels.

Property right incentives: Explore the establishment of a "transfer and transaction mechanism for geological safety development rights." Allow land rights holders in high-geological-risk ecological sensitive areas to transfer their restricted development rights to concentrated construction areas with suitable geological conditions, realizing Pareto improvement in ecological protection and economic development.

Green finance: Cooperate with financial institutions to innovate and launch financial products such as "urban resilience bonds", "special loans for geological hazard prevention and control", and "resilient building insurance." Provide policy incentives such as green credit interest subsidies and floor area ratio rewards for real estate development and infrastructure projects adopting high-standard resilience design and technologies, guiding market capital to actively flow into the field of resilience construction.

5.3. Technology empowerment path: Building an intelligent and precise resilience support system

Construct an "urban geological digital twin platform": Integrate data from geological surveys, Internet of Things monitoring, InSAR remote sensing, BIM/CIM, etc., to build a comprehensive, full-element, and whole-process urban geological information model. This dynamically updated "digital foundation" can simulate and predict changes in the geological environment under different climate scenarios and engineering activities, providing "sand table deduction"-style decision support for urban planning, project site selection, and risk early warning.

Build an "intelligent risk perception and emergency dispatch" network: Based on the digital twin platform, establish an intelligent monitoring and early warning network covering key risk areas. Use artificial intelligence and big data models to achieve advanced prediction, precise judgment, and rapid early warning of risks such as geological hazards, land subsidence, and seawater intrusion. Once a danger occurs, the system can automatically match emergency resources, generate optimal disposal plans and evacuation routes, realizing a leap from "human prevention" to "intelligent prevention."

5.4. Market and social participation path: creating a co-construction and sharing resilience ecosystem

Cultivate new formats of the "resilience industry": Relying on Shenzhen's advantages in information technology, high-end equipment, and environmental protection industries, encourage and support enterprises to develop technologies, equipment, and services related to geological surveys, monitoring and early warning, ecological restoration, and emergency rescue. Transform the process of addressing geological challenges into an opportunity to cultivate new economic growth points and build a "resilience technology" industrial cluster.

Construct a market-oriented mechanism of "risk sharing and benefit sharing": Fully implement the PPP (Public-Private Partnership) model in the field of geological hazard prevention and control projects. Deepen the "geology-insurance" linkage, develop innovative products such as index insurance and catastrophe insurance, and use market-oriented means to smooth the fiscal impact caused by disasters, forming a positive economic cycle of

"disaster prevention and loss reduction — premium reduction."

Improve the geological risk literacy of the whole society: Regularly release an easy-to-understand "Shenzhen Urban Geological Safety White Paper" and risk maps, and open geological parks and monitoring stations as popular science education bases. Through community publicity, school education, media communication, and other methods, improve the cognitive level and independent response capabilities of citizens, enterprises, and grass-roots staff to geological risks, and build a grass-roots defense line for urban resilience construction.

Through the coordinated advancement of the above four paths, Shenzhen will be able to construct a "geological-economic" coordinated resilience system guided by conceptual innovation, guaranteed by institutional innovation, supported by technology empowerment, and driven by market and social participation. This can not only effectively resolve the threat of geological risks to economic development but also transform the "constraints" of geological safety into a unique advantage driving the city towards a higher-quality and more sustainable future, providing a "Shenzhen solution" for the sustainable development of high-intensity development megacities worldwide.

6. Conclusion

From the perspective of environmental geology, Shenzhen's urban resilience construction and economic development are not two parallel lines but an intertwined and mutually reinforcing spiral upward chain. Geological safety provides a stable spatial carrier and resource guarantee for economic activities, serving as the material prerequisite for economic resilience; while sustained and healthy economic development provides a steady stream of technical, financial, and institutional supply for understanding, managing, and adapting to geological environment risks, acting as the fundamental driving force for enhancing geological safety resilience. Facing the future, Shenzhen should more consciously identify and strengthen this coordinated relationship, deeply implant geological resilience thinking into the genes of urban development, thereby building a truly resilient global benchmark city that can calmly respond to natural disturbances and maintain economic innovation vitality in an uncertain world.

Disclosure statement

The authors declare no conflict of interest.

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