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Exploring the Pathways for Green Transformation and Development in Resource-Based Cities

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Abstract: This paper explores the pathways for green transformation and sustainable development in resource-based cities in China, which have historically relied heavily on natural resources for economic growth. With a focus on three Chinese cities - Ordos, Handan, and Hegang - each representing different stages of resource dependency and transformation progress, the study assesses their transition strategies from traditional resource exploitation to a more diversified, green economy. It evaluates the economic, environmental, and social challenges that these cities face in shifting away from resource-intensive industries. The paper also analyzes the impacts of existing policies and offers strategic recommendations to facilitate effective green transitions. By incorporating case studies, the research highlights the unique approaches each city has adopted, including investments in new technologies, shifts in industrial structures, and enhancements in social policies, to achieve sustainable development. The findings emphasize the importance of comprehensive planning, technological innovation, and community engagement in driving the successful transformation of resource-based cities towards eco-friendly and economically diverse futures.

Keywords: Green transformation, resource-based cities, sustainable development, economic diversification, policy evaluation.

1. Introduction

Resource-based cities refer to those whose economies primarily depend on the development of local natural resources. They are characterized by an economy dominated by natural resources and significant environmental pressure. China has 262 resource-based cities, which have played a vital role in supporting China's rapid economic development [1]. The "National Sustainable Development Plan for Resource-based Cities (2013-2020)" issued by China's State Council classifies these cities into four categories: growing cities, mature cities, declining cities, and regenerating cities, with 31, 141, 67, and 23 cities in each category, respectively. These categories are based on a combination of the degree of resource security and the accumulation of urban development issues. Cities with high resource security and few development issues are in the growth stage, referred to as growing cities; cities with slightly declining resource security and some accumulated development issues are known as mature cities; cities with nearly depleted resources and many development issues are declining cities; and cities with almost exhausted resources but successful transformation and resolution of

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various issues are regenerating cities [2]. Additionally, resource-based cities can also be categorized by function into coal, oil, metal, non-metal, and forest types, or by their formation into either "mine-first, city-second" or "city-first, mine-second" types.

Achieving breakthroughs in high-quality economic development is a major goal and task for China's future development, and promoting the greening and low-carbon transition of economic and social development is key to achieving high-quality development. Resource-based cities in China are numerous and widely distributed, with significant historical contributions and a prominent current status. However, many such cities, especially those in decline, face issues such as industrial structural imbalances and the "resource curse," leading to situations of "mined-out city decline" or even "mined-out city demise [3]." Resource-based cities face tightening resource constraints and significant environmental pollution, presenting substantial challenges in terms of resource and environmental carrying capacity. The green transformation and high-quality development of resource-based cities are both a realistic need and a critical focus in China's new stage of economic and social development, involving adjustments to industrial structures, changes in resource utilization methods, enhancement of industrial efficiency, and improved ecological environment governance.

This paper aims to study the green transformation of typical large cities among the four types of Chinese resource-based cities and discuss how Chinese resource-based cities can transition from traditional resource dependence to a green and sustainable development model. It analyzes major economic and environmental challenges, explores effective transformation strategies, evaluates policy impacts, and offers specific policy recommendations. The structure of the paper includes an introduction, case studies, conclusions and recommendations, and references, aiming to systematically analyze and provide practical guidance to support the sustainable development of China's resource-based cities.

2. Literature Review

Currently, the academic community is making strides in both theoretical understanding and empirical experiences regarding the transformation of resource-based cities.

Chinese scholars have highlighted a series of unique challenges facing resource-based cities in China. These challenges include depletion of natural resources, environmental pollution, and significant pressure on resource-based cities with abundant reserves and concentration of energy-intensive industries under China's carbon emission reduction targets.

Moreover, the heavy economic reliance of Chinese resource-based cities on single-resource industries has hindered economic diversification and kept them on a path of development dependent on resources. While efforts to develop alternative industries and projects are still in the nurturing or developing stages, achieving new momentum for development and creating emerging leading industries for cities requires long-term accumulation and consolidation. Newly developed substitute industries and high-energy-consuming, high-emission industries face the risk of secondary transformation and elimination pressure [4]. Excessive reliance on resource industries not only impedes economic diversification but also makes these cities vulnerable to economic volatility caused by global commodity price fluctuations and environmental degradation. Additionally, during the early stages of transformation, the improvement in the level of green transformation development in Chinese resource-based cities has to some extent sacrificed economic development. The effectiveness of urban green transformation performance mainly depends on the effects of economic and social transformation, with the contribution to environmental transformation performance not being significant [5]. Resource-based cities also face urban planning issues such as industrial spatial problems, low-quality public spaces, land and housing vacancies, inefficient land use, abandoned buildings, and abandoned infrastructure.

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The advancement of resource-based cities towards green transformation benefits from several core theoretical foundations. These include sustainable development, green economy, and circular economy theories. These theories advocate for a shift from traditional growth patterns, which often exacerbate environmental and social issues, towards more sustainable and environmentally friendly approaches. Specifically, this requires exploring "new resources" and constructing a pathway from "old resources" to "new resources". Before pursuing international opportunities, government should adopt a development model that focuses on internal growth. It is also necessary to optimize resource flow processes, rebuild value flows, redistribute ecological and social benefits, and bring about profound changes to the urban governance system. Customized and long-term research should be conducted based on climatic conditions, geographical environments, social cultures, and the role of cities within the regional urban system. This will facilitate the formation of a more direct and effective "policy science" mechanism. These transformations are guided by policies aimed at balancing economic growth with environmental protection to ensure long-term sustainability.

Over the years, successful cases of green transformation in resource-based cities have been observed both domestically and internationally. For example, the economic transformation experience of the Ruhr Area in Germany provides important development insights for other regions globally. Effective transformation strategies require comprehensive planning and coordination by the government across energy, environmental protection, social welfare, and economic development to ensure policy synergy. Technological innovation is crucial in driving economic structural transformation, with support for emerging industries and high-tech enterprises promoting economic renewal and reducing reliance on traditional industries. Additionally, social participation and stakeholder coordination during the transformation process are essential for balancing the interests of different groups and ensuring broad policy acceptance. Furthermore, economic and social transformations should be gradual, with governments flexibly adjusting strategies to address new challenges. The synergistic growth of the environment and economy demonstrates that they are not mutually exclusive but can achieve win-win outcomes. Finally, investments in education and vocational training are crucial to support emerging industries and improve the adaptability and living standards of the workforce. These insights indicate that economic transformation is a complex and systematic process requiring diverse strategies and sustained efforts [6]. In successful cases of green transformation in resource-based cities in Western countries, early planning and construction mainly focused on internal development, seeking industrial upgrades and land redevelopment, before gradually integrating into the globalization process and forming an outward-oriented development model. Therefore, to some extent, the success of the transformation of Western resource-based cities also benefited from seizing the trend of globalization in this open era and reflecting a high degree of integration of internal and external development dynamics.

The successful transformation of Tangshan, a regenerative city in Hebei Province, China, highlights the importance of industrial upgrading, green low-carbon development, policy support, and market-oriented reforms. By eliminating backward production capacity and promoting ultra-low emission transformations in heavily polluting industries, Tangshan has achieved a green transformation of its industrial structure, particularly in steel and high-end manufacturing. Furthermore, the active development of new energy and clean energy, such as new energy-heavy trucks and photovoltaic power generation, has not only improved energy efficiency but also significantly reduced environmental pollution. Through a series of specific policy guarantees and market-oriented measures, such as carbon market trading and carbon emission verification, Tangshan has strengthened dual control of the environment and climate change. Simultaneously, enhanced technological and infrastructure support has promoted standardization of carbon monitoring and high-end equipment manufacturing, enhancing environmental governance and climate adaptation capabilities. Strengthening market-oriented operations and financial support has also ensured

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sustained investment and implementation of relevant projects, demonstrating that the path of combining technological support, policy guidance, and market incentives can effectively promote economic transformation and sustainable development in old industrial cities [7].

Case studies extracted from domestic and international backgrounds show that efforts to achieve green transformation in resource-based cities have yielded varying results. Successful cases typically share some common features, such as strong government support, sound policy frameworks, and substantial investments in technology and infrastructure to reduce carbon footprints and promote sustainable industrial practices.

Conversely, struggling cities often exhibit insufficient policy support, lack of investment in sustainable practices, and continued reliance on traditional resource extraction and processing industries. These cities face ongoing economic challenges, compounded by environmental degradation and social issues such as unemployment and resulting changes in population structure.

The literature indicates that transitioning resource-based cities to a green economy requires adopting multifaceted approaches. This includes not only adopting relevant theoretical frameworks but also implementing comprehensive strategies to address the economic, environmental, and social challenges faced by these cities. Successful transformation cases emphasize the importance of integrated planning and the roles of governments and international cooperation in promoting and sustaining these changes.

3. Case Studies

In this paper, this paper select three well-known prefecture-level cities in China, which are also resource-based, namely Ordos City, Handan City, and Hegang City, for a cross-sectional and longitudinal case study.

Ordos City is located in the western part of the Inner Mongolia Autonomous Region. In 2013, among the four types of resource-based cities in China, it was categorized as a growing city and follows the "mining first, city later" development model. It has vast grasslands and abundant coal resources. The region has a dry climate, classified as a temperate continental climate. Its dominant industries include coal mining and electricity production. In recent years, it has also been developing new energy and modern manufacturing industries, attempting economic diversification. The transition from a single-resource-based city to a diversified economic entity emphasizes the development of clean energy and high-tech industries.

Handan City is situated in Hebei Province on the North China Plain. In 2013, among the four types of resource-based cities in China, it was categorized as a mature city and follows the rare "city first, mining later" development model. The climate is characterized by a temperate monsoon climate with distinct four seasons. Handan is a well-known national production area for coal and high-grade iron ore, with a strong foundation in the steel and building materials industries. Traditionally focused on steel and building materials industries, in recent years, it has been striving to transition to high-tech and service sectors to alleviate the environmental and economic pressures brought by heavy industries. Facing the problem of over-reliance on heavy industries, it is attempting economic transformation and upgrading by developing new industries such as new materials and electronic information.

Hegang City is also located in the eastern part of Heilongjiang Province. In 2013, among the four types of resource-based cities in China, it was categorized as a declining city and follows the "mining first, city later" development model. Hegang is a typical cold region city with abundant forest and coal resources. The climate is cold, with long and severe winters. Historically reliant on coal mining as its economic pillar, the city is now facing the challenge of economic transformation due to resource depletion and the decline of the coal industry. Faced with economic decline and population loss, it is striving to find new economic growth points such as tourism and light industry.

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Selecting the cities of Ordos, Handan, and Hegang as research subjects allows for a comprehensive analysis of the green transformation and development strategies of Chinese resource-based cities at different stages of development. Ordos represents a growing city that initially relied heavily on resource extraction, and in recent years, it has been diversifying its economy through the development of new energy and modern manufacturing. Handan, as a mature city, was once dependent on the steel and building materials industries and is now striving to shift towards high-tech and service sectors. Hegang, a declining city, faces the challenges of resource depletion and population loss, and is exploring new economic growth opportunities through its forest resources and tourism potential. These three cities not only demonstrate the challenges of green development under different climatic and geographical conditions but also provide diverse pathways for economic transformation, offering valuable case studies and insights into how resource-based cities can achieve sustainable development through innovation and policy adjustments.

4. Cross-sectional Comparison

4.1. Ordos City

4.1.1. Industrial Structure Adjustment and Development of Emerging Industries in Ordos City

Ordos is undergoing a transformation from an over-reliance on coal-based industries to a more diversified industrial base. Efforts include extending the coal chemical industry chain and promoting clean energy projects such as solar and wind power. Through initiatives like constructing the world's first zero-carbon industrial park and developing new energy sources like wind power, photovoltaics, and energy storage systems, Ordos is vigorously promoting the greening transformation of its industrial structure. The city is also dedicated to building an industrial system centered on new energy and high technology industries, particularly through the development of a "wind-solar-hydrogen energy storage vehicle" industry cluster, fostering industry integration and innovation. Additionally, Ordos has established carbon neutrality research institutes and other research and development institutions, which not only promote technological innovation and industrialization but also strengthen cooperation with universities and enterprises, accelerating the transformation of scientific and technological achievements and industrial upgrading. Ordos is committed to building a dual carbon research institution integrating research and development, incubation, and industrialization, aiming to support high-quality green development, demonstrating a clear direction in industrial restructuring and the development of emerging industries. With the introduction of new technologies and the transformation of old industries, such as the introduction of 5G and digital technology in the Madiangliang coal mine, Ordos is modernizing traditional industries to drive high-quality economic development. The city is promoting the development of new materials such as carbon-based materials and high-end wax, and combining big data and artificial intelligence technologies with traditional industries to drive innovation.

From 2021 to 2022, the value added of non-coal industries, high-tech industries, and equipment manufacturing in Ordos City all showed significant growth, indicating that green and high-tech industries are becoming new drivers of economic growth. The carbon emission intensity of Ordos City decreased by 3.9% in 2022, demonstrating that its efforts in environmental protection and carbon reduction have yielded results [8].

Through initiatives like promoting the construction of smart mines and implementing new energy projects, Ordos has not only improved its energy structure but also enhanced the region's economic potential. Particularly, the development of new energy industries such as wind power, photovoltaics,

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and hydrogen energy has provided new momentum for regional sustainable development and contributed to achieving carbon neutrality goals [9].

4.1.2. Strategies and Practices of Environmental Policy in Ordos City

The overall policy direction of Ordos is to prioritize ecological protection and sustainable development, which means focusing on maintaining social stability and security during the transition [10].

Ordos is dedicated to comprehensive pollution control, including volatile organic compounds and wastewater treatment, aiming to achieve "near-zero emissions." It also emphasizes the comprehensive treatment of solid waste and the ecological protection of the Yellow River Basin. The city improves energy efficiency through technological upgrades in coal mines and coal-fired power plants, promoting the utilization of waste heat and by-products.

By renovating and upgrading traditional energy infrastructure, such as the desulfurization system at Yongtai Thermal Power Co., Ordos effectively reduces pollution emissions and resource consumption while enhancing energy efficiency. Photovoltaic projects not only increase the clean utilization of energy but also integrate with ecological restoration agriculture and animal husbandry, achieving comprehensive resource utilization and improving environmental quality.

Implementing environmental tax policies incentivizes enterprises to adopt environmental technologies and practices voluntarily, thus reducing their environmental tax burden and promoting technological innovation and environmental investment. Through optimizing the business environment and implementing policy support, Ordos encourages enterprises to adopt energy-saving and emission-reduction measures, such as electrolytic hydrogen production, to promote the widespread application of green technologies. It advocates for the establishment of a green manufacturing system, the adoption of low-carbon technologies in industries, and the establishment of a green energy consumption certification system.

4.1.3. Acceptance of Green Transformation and Social Security among Urban Residents in Ordos City

Residents generally accept and support the green transformation, such as the photovoltaic power generation projects, which not only bring benefits to enterprises but also provide income and employment opportunities for local residents.

The green transformation policies in Ordos City include tax incentives, technical support, and investment in funds for enterprises, indirectly providing employment opportunities and social stability for residents.

While promoting green transformation, Ordos City emphasizes social security measures, such as enhancing the well-being of miners and local residents by improving working conditions and raising living standards.

4.1.4. Challenges Encountered in the Green Transformation of Ordos City

The economy of Ordos heavily relies on coal and chemical industries, resulting in a single industrial structure dominated by sectors that are both highly polluting and energy-intensive. As a city known for its substantial involvement in energy-intensive and heavy chemical industries, Ordos exhibits levels of carbon emissions and energy consumption that are significantly above the national average, placing it under considerable pressure to reduce these emissions. Additionally, despite some investments in new energy and materials sectors, the overall technological innovation capability in Ordos remains inadequate. This insufficiency hampers the necessary support for industrial upgrading and the green transformation of the city.

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4.2. Handan City

4.2.1. Industrial Structure Adjustment and Development of Emerging Industries in Handan City

The economic transformation of Handan City is mainly reflected in the transition from heavy industry to high-tech and service industries, particularly in promoting the development of ecological agriculture and ecotourism. During the "13th Five-Year Plan" period, Handan City successfully reduced a significant amount of traditional production capacity, such as iron smelting, steelmaking, and coal, and implemented the "Three-Year Thousand Projects" plan for the technological transformation of traditional industries, promoting the transformation of traditional industries towards higher efficiency and environmental friendliness.

For example, areas like Feixiang District and Fengfeng Mining District have demonstrated the strategic implementation of green economy through the development of holistic tourism and ecological agriculture [11]. Furthermore, Handan Iron and Steel Company, by implementing energy-saving and emission reduction measures and adopting a circular economy approach while optimizing its product structure, has also shifted towards ecotourism, becoming a demonstration enterprise for industrial tourism, showcasing typical characteristics of green development. Additionally, the resurgence district has accelerated the transformation from an industrial pollution zone to a green ecological zone through large-scale greening activities and the removal of polluting enterprises, reflecting high-standard environmental governance and ecological restoration. During the "13th Five-Year Plan" period, emerging industries such as new materials, new energy, and biotechnology have developed rapidly, with the added value of high-tech industries growing at a rate of about 22% [12].

4.2.2. Implementation and Practices of Environmental Policies in Handan City

Handan City, in terms of environmental governance, promotes the green transformation of heavy industries, strengthens energy-saving and emission-reduction measures, and implements circular economy and low-carbon technologies to improve resource utilization efficiency. For example, Handan Iron and Steel Company continuously optimizes and adjusts its product structure, actively promotes comprehensive environmental governance, and has become one of the first batches of industrial tourism demonstration enterprises in Hebei Province.

4.2.3. Acceptance of Green Transformation and Social Security Measures among Urban Residents in Handan City

Handan City actively promotes a green and low-carbon concept throughout society. This includes encouraging green and low-carbon travel, purchasing environmentally friendly and recyclable products, advocating for green consumption, and supporting green production. Such extensive educational activities are crucial for increasing public participation and acceptance of green transformation. Green upgrades and renovations of urban domestic waste and sewage treatment facilities are being promoted, as well as the development of green transportation systems. These measures not only improve residents' quality of life but also promote greater acceptance of sustainable practices through direct improvements in their daily lives [13].

Simultaneously, Handan City has implemented a series of measures to deepen ecological governance, including improving air, water, and soil quality, increasing forest coverage, and promoting the creation of green mines.

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4.2.4. Challenges Encountered in the Green Transformation of Handan City

In traditional industrial and mining areas, severe industrial emissions and dust are prominent issues that significantly challenge environmental governance and air quality. To address the extensive damage caused by industrial activities, there is a pressing need for greening and ecological restoration efforts, including large-scale afforestation. Despite efforts to promote non-coal industries like biomedicine, the transformation of industrial sectors has been slow, putting considerable pressure on economic structural transformation.

4.3. Hegang City

4.3.1. Industrial Structure Adjustment and Development of Emerging Industries in Hegang City

Hegang City actively adjusts its industrial structure, shifting from the traditional "coal-dominated" model to diversified development. From 2015 to 2021, the proportions of the primary, secondary, and tertiary industries in Hegang City have changed, with an increase in the proportion of the tertiary industry, reflecting a trend towards a more balanced industrial structure [14].

In recent years, Hegang has accelerated the elimination of backward production capacity by closing several backward coal mines, thereby reducing the number of coal mines and promoting their upgrading and transformation. Hegang City has actively adjusted its industrial structure. With the overall improvement of the coal industry, the proportion of the mining industry in GDP has dropped to 22.1%, reducing dependence on a single coal resource.

Furthermore, Hegang has strengthened the deep processing of coal resources, extended the industrial chain, and enhanced the value-added and environmental performance of the coal industry, such as "coal-to-fertilizer," "coal-to-gas," and "coal-to-electricity" projects.

Hegang City vigorously develops emerging industries such as graphite, utilizing its abundant graphite resources to establish a complete industrial chain from resource reserves to high-purity negative electrode materials. The graphite industrialization project invested in and constructed by China Minmetals Corporation in Hegang is expected to greatly increase the output value and tax revenue of the local graphite industry. Additionally, Hegang is actively developing new energy industries such as wind power and photovoltaics, expecting to significantly increase installed capacity.

4.3.2. Implementation and Practices of Environmental Policies in Hegang City

Hegang City has taken a series of measures to improve environmental quality, such as rectifying black and odorous water bodies and restoring the geological environment of mines after savage exploitation. These measures have been recognized and rewarded by the state, and Hegang has been named a national demonstration city for the treatment of black and odorous water bodies.

By promoting the intelligent and capacity-enhancing transformation of the coal industry, Hegang has improved the comprehensive utilization efficiency of resources. For example, the annual production of 300,000 tons of green value-added compound fertilizer project of CNOOC Huabei Company achieves efficient utilization of resources by increasing the added value of coal.

Hegang City widely applies green technologies in the deep processing of coal and the development of new energy industries. This not only enhances the environmental level of industries but also provides technical support for the city's green transformation.

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4.3.3. Acceptance of Green Transformation and Social Security Measures among Urban Residents in Hegang City

Urban residents in Hegang City show a high acceptance of green transformation, which can be seen from their positive responses to environmental improvement. Citizens actively participate in urban greening and environmental protection activities, such as frequent walking and leisure activities in renovated parks. Residents express a high level of satisfaction and support for the improvement of their living environment.

While promoting green transformation, Hegang City also pays attention to improving the social security system. The municipal government has provided new employment opportunities for residents by introducing and supporting emerging industries. At the same time, by vigorously developing and expanding green industries, such as agricultural industrialization, the city has increased employment opportunities and improved residents' living standards. These measures not only promote economic transformation but also ensure social stability and improve residents' lives during the transformation process.

4.3.4. Challenges Encountered in the Green Transformation of Hegang City

Overreliance on coal resources has long been the norm, leading to a mono-industrial economic structure that now pressures structural adjustments. Compounding this issue, extensive coal mining and usage have precipitated severe environmental pollution, particularly affecting air and water quality, necessitating considerable time and investment for ecological restoration. Furthermore, despite efforts to promote emerging industries like graphite, their growth rate and scale have not sufficiently supplanted the traditional coal industry, continuing the pressure for economic transformation.

4.4. Analysis

Table 1: Comparison of Transformation: Ordos City, Handan City, and Hegang City

Comparison Dimension	Ordos City	Handan City	Hegang City
Economic Transition	- Transition from reliance on coal industry to diversified industries - Development of new energy, high-tech industries, and carbon-based materials - Significant growth in emerging industries	- Transition from heavy industry to high-tech and service industries - Development of ecological agriculture and tourism - Promotion of technological upgrades in traditional industries	- Transition from a coal-centric to a diversified industrial structure - Development of graphite and new energy industries - Phasing out outdated capacities, enhancing the added value of the coal industry
Environmental Policy	- World’s first zero-carbon industrial park - Smart mines and clean energy projects - Implementation of environmental tax incentives and technology upgrades	- Green transformation of heavy industries, optimizing resource utilization - Implementation of circular economy and low-carbon technologies - Environmental governance model enterprises	- Remediation of black and odorous water bodies - Coal industry's intelligentization to improve resource utilization - Application of green technologies to enhance environmental standards

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Table 1: (continued).

Social Adaptation	- High acceptance and support for green transformation - Provision of tax incentives and technical suppor - Improving residents' work and living conditions	- Emphasis on green and low-carbon lifestyle - Improvement of waste and sewage treatment facilities - Development of a green transportation system	- High resident acceptance and participation - Provision of employment opportunities through new industries - Enhancement of social security and living standards
Transformation Challenges	- Single industry structure - High carbon emissions and energy consumption - Insufficient capacity for technological innovation	- Severe industrial pollution - Pressure on ecological restoration - Slow pace of industrial transformation	- Over-reliance on coal resources - Environmental pollution issues - Insufficient development of new momentum

As shown in table 1, the cities of Ordos, Handan, and Hegang all face their challenges in promoting green transformation. Ordos's challenges are primarily concentrated in its single-industry structure, high carbon emissions, and insufficient technological innovation capabilities, which limit the speed of its industrial upgrading and green transformation. Handan faces severe industrial pollution issues and tremendous pressure for ecological restoration, and the slow pace of industrial transformation is also a major problem. Hegang has long relied on coal resources, leading to pressure on economic structural adjustment. Additionally, due to long-term coal mining, environmental pollution is severe, and the growth rate and scale of new industries have not yet been able to fully replace traditional industries, still facing transformation pressures.

5. Longitudinal Comparison

As shown in figure 1,by analyzing the trends in GDP and per capita GDP of Ordos, Handan, and Hegang, several key points can be observed. Firstly, Ordos has a higher GDP and per capita GDP than Handan and Hegang, and it shows a stable growth trend. Although Handan has a good performance in terms of total GDP, the growth in per capita GDP is relatively slow. In contrast, Hegang's GDP and per capita GDP are weaker and more volatile, reflecting significant economic challenges.

Regarding the annual changes in GDP growth rate, Ordos and Handan have relatively stable GDP growth rates, with fluctuations but no sharp declines. Hegang's GDP growth rate is significantly more volatile, which may be related to changes in the local economic structure and external economic environment.

The proportion of the tertiary sector in GDP has been rising annually in all three cities, indicating a shift towards the service sector. This is particularly evident in Ordos and Handan, where the continuous rise in the proportion of the tertiary sector reflects strong industrial diversification and successful economic transformation. Although Hegang's proportion is rising more slowly, it still shows a trend towards transitioning to the tertiary sector.

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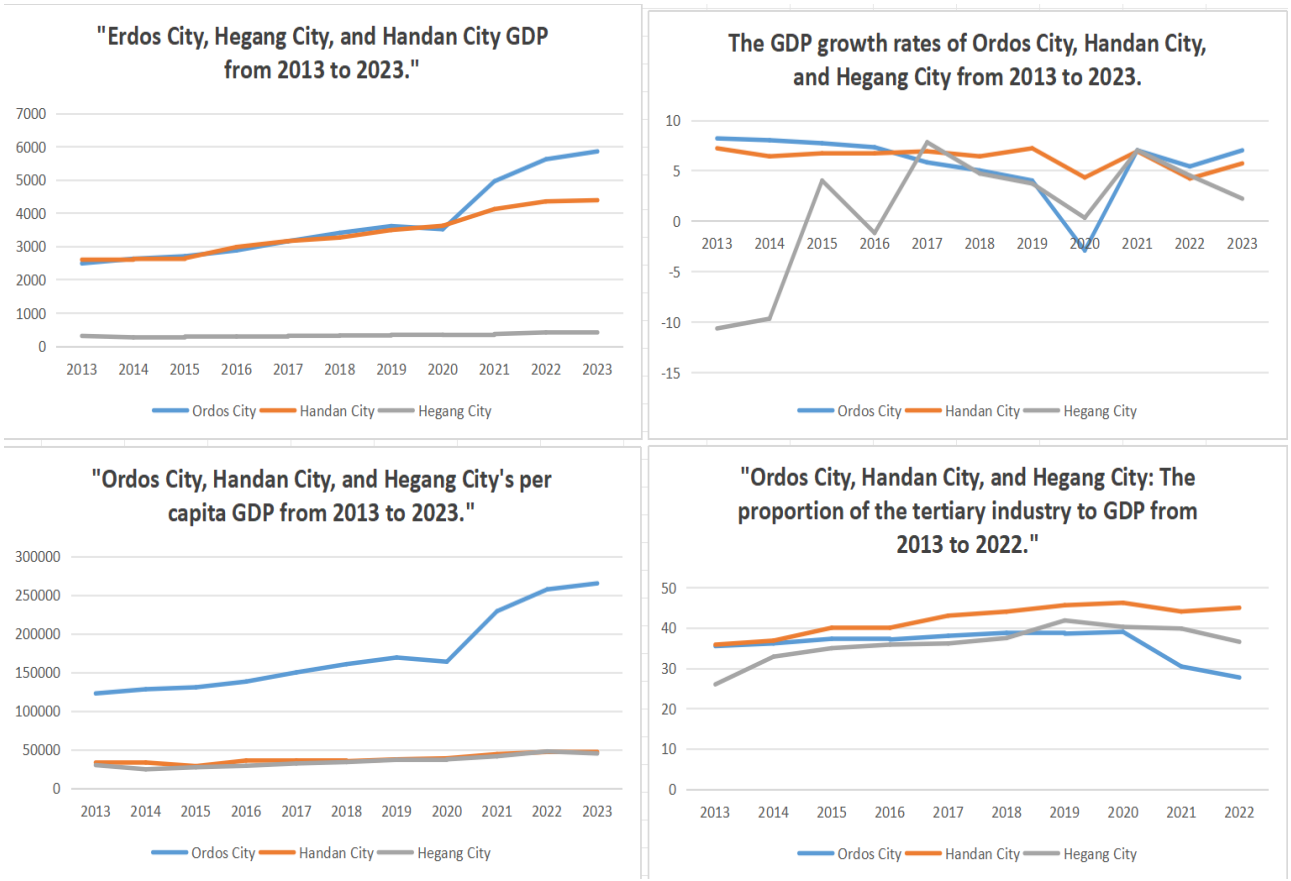

Figure 1: Economic and Industrial Transition of Ordos City, Handan City, and Hegang City

6. Conclusion

The key to successful green transformation and challenges first lies in economic diversification. Handan has significantly increased the proportion of the tertiary sector by developing high technology and services, reducing dependence on heavy industry, while Ordos needs to accelerate economic diversification as the proportion of the tertiary sector has declined despite progress in new energy and high-tech industries.

Secondly, technology and innovation are crucial. Ordos has promoted industrial upgrading and environmental improvement by introducing new technologies and building zero-carbon industrial parks. In contrast, Hegang, despite attempts to develop emerging industries, has not fully replaced the traditional coal industry in terms of the growth rate and scale of new industries.

Thirdly, social participation and policy support are vital, as seen in Handan, which has improved residents' acceptance of green transformation through widespread promotion of green concepts and ecological governance measures.

Comparing the transformation strategies and outcomes of the three cities, Ordos shows how to use local resources (such as wind and solar energy) to promote the greening of industries but needs to further strengthen the development of the service sector and tertiary industries for more comprehensive economic diversification. Handan's transformation strategy is the most successful among the three cities, particularly in promoting high technology and services, effectively reducing environmental pressure and promoting economic growth. Hegang faces severe challenges from resource depletion and economic downturn, and despite efforts to promote emerging industries, the transformation has had limited effects, requiring more external support and policy incentives.

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From this, it can learn successful experiences and lessons from failures. For example, as a "city first, mine later" city, Handan uses mature resources to promote the service sector and high-tech industries, reducing dependence on traditional industries to achieve sustainable economic growth. Ordos leverages its large economic scale to build zero-carbon industrial parks and promote technological innovation, enhancing industrial added value and environmental performance.

However, there are also lessons to be learned, such as Ordos needing to avoid over-reliance on a single or few emerging industries and should more comprehensively develop the tertiary sector. Hegang's economic slowdown and population loss are due to its excessive reliance on traditional resource-based industries, failing to adjust and upgrade the economic structure in time.

The green transformation strategy of resource-based cities needs to consider the specific conditions of the local economy, society, and environment, and tailor transformation strategies accordingly. For example, enhancing urban economic vitality, promoting orderly population movement, and improving public services are important one.

To promote green transformation and sustainable development in resource-based cities, governments should implement comprehensive support policies and encourage investments in green technologies and infrastructure. Simultaneously, businesses need to prioritize investing in renewable energy, adopt sustainable practices, and establish partnerships with communities. Additionally, raising public awareness and education about green transformation is crucial; community participation should be encouraged, and support for workforce transition from traditional industries to emerging green sectors is essential. These measures not only foster economic diversification but also enhance societal adaptability and overall environmental sustainability.

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