Research on the Development of Urban Industrialization and Ecological Environment: A Case Study of Tangshan and Detroit

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Abstract. Taking Tangshan and Detroit as examples, this paper explores the strategies for the coordinated development of industrialization and ecological environment in Tangshan. The relationship between industrialization and ecological environment in Tangshan is investigated by studying the industrialization process and urbanization indicators. The Environmental Kuznets Curve is employed to analyze the correlation with wastes in Tangshan and Detroit. The results indicate that the traditional inverted "U" curve cannot adequately capture the relationship between industrialization and ecological environment in Tangshan. Tangshan and Detroit exhibit different trends in air emissions, waste water discharge and solid particulate matter emissions, with variations in goodness of fit and F-value tests. These differences may be influenced by various factors such as the characteristics of the cities. In conclusion, studying the coordinated development of industrialization and ecological environment in Tangshan contributes to a deeper understanding of environmental issues in the industrialization process and explores the challenges and opportunities in urban economic transformation. By comparing the experiences of Tangshan and Detroit, Tangshan can identify effective pathways to address issues such as industrial upgrading and promote sustainable urban development and economic growth.

Keywords: Urban Industrialization, Ecological Environment, Environmental Kuznets Curve, Tangshan and Detroit.

1. Introduction

Tangshan, located in Hebei Province, China, has been a center of industrialization and one of the most prosperous regions in the country. However, during the process of market-oriented reforms in China, Tangshan faced serious environmental pollution and lead to issues such as scarcity of natural resources and severe pollution. The challenges faced by Tangshan are similar to those of cities like Detroit in the United States.Detroit is the largest city in the U.S. state of Michigan and the second-largest automotive manufacturing center in the United States known as the "Motor City." The city was once the center of American industry in the first half of the 20th century. However, in the past few decades Detroit has faced challenges of population decline and urban decay. In recent years Detroit has begun to show signs of revitalization including urban redevelopment projects and improvements in city infrastructure and public services. Detroit's economy was historically reliant on the automotive manufacturing industry. The relationship between development and industrialization is inseparable and has brought about a series of challenges and problems. The experience of Detroit also reflects the complex impact of industrialization on urban development and the challenges faced by cities in the face of economic transformation. Therefore, certain areas of Tangshan have been likened to the "Rust Belt" of the United States, both being industrial centers facing a dilemma in terms of development momentum and causing environmental and natural resource pollution.

Tangshan, as a former industrial center, faces serious environmental pollution and reflects the negative impact of the industrialization process on the ecological environment. Besides, the experiences of Tangshan and Detroit can provide valuable lessons for other industrialized cities. By conducting in-depth research on the historical development of cities, lessons can be summarized on how to better coordinate economic development with environmental protection during the process of industrialization, providing sustainable development paths and models for other similar cities.

Grossman and Krueger conducted statistical analysis on environmental issues and proposed the Environmental Kuznets Curve (EKC) [1]. It suggests that pollution increases with economic development at lower levels of economic development, but decreases as the economy reaches a certain level of development. However, there are differing views within the academic community regarding this theory. Opponents, through repeated empirical studies in various regions, have found that the Kuznets Curve is not always a simple inverted "U" shape; it can also take the form of an "N," exhibit monotonic increase, or show monotonic decrease. Numerous environmental economists have extensively researched the existence of the EKC using cross-sectional, time-series, or panel data from various countries. Donald Kuznets focused on the relationship between economic growth and inequality in his research and introduced the concept of the EKC [2]. Nicholas Stern et al. used the EKC to explore the balance between economic growth and environmental protection and offered important insights into environmental policies. John Gowdy et al. have explored the impact of economic growth on natural resource consumption and proposed strategies for sustainable development through their research on the EKC [3]. EKC is also used to examine the relationship between economic growth and environmental quality and provides in-depth analysis of environmental management policies [4]. Alfred Greiner et al. have explored the relationship between economic growth and sustainable development and propose a theoretical framework for sustainable development [5]. John Hartwick eta al. have used the EKC to examine the balance between economic growth and natural resource consumption, offering policy recommendations for resource management [6]. Zhang Xiao conducted a study on EKC and showed the relationship between the emissions of wasted and per capita emissions [7]. Du Kai verified the EKC using Nanjing as an example. The research results indicate that there is indeed a typical inverted "U-shaped" EKC characteristic between industrial wastewater emissions and per capita emissions; there is no apparent relationship between industrial waste gas emissions and per capita emissions; and there is no obvious EKC characteristic between industrial solid waste generation and per capita emissions [8]. Industrial solid waste generation accelerates with economic growth. Zhang Jie et al. studied the Kuznets environmental curve of a factory in Guangdong Province and its determinants and found a typical relationship of the EKC between industrial wastewater emissions, waste gas emissions, and per capita GDP [9].

These scholars have extensively applied the EKC in their research, providing important theoretical support for understanding the relationship between industrialization and economic growth, and offering valuable insights into environmental policies and sustainable development strategies. It is evident that domestic research on the relationship between industrial waste emissions and per capita emissions is mainly focused on the relatively developed regions in China's eastern and central areas, with limited research on the environmentally fragile city of Tangshan. As industrialization is the cause of environmental problems, this paper conducts a comparative study of Tangshan and Rust Belt cities such as Detroit in Europe and the United States, aiming to combine quantitative analysis with sustainability and provide rational recommendations for ecological civilization construction.

2. Dataset

Industrialization and ecological environment are both complex integrated systems. When selecting indicators, systematicness, scientificity, feasibility, and conciseness should be followed. The frequently mentioned indicators in recent years were identified by analyzing existing literature on urbanization and industrialization characteristics. urbanization and industrialization indicators were selected as shown in Figure 1 when considering the availability of data of Tangshan and Detroit. To verify the existence of the EKC in cities, it is necessary to select indicators for industrialization and ecological environment measurement. This study considers the actual situation of Tangshan and Detroit as resource-based industrial cities and chooses per capita GDP as one of the indicators, representing the development trend of industrialization using per capita GDP. The emission of industrial wastes is chosen as the indicator for the selection of ecological environment indicators [10].

In recent years, the industrial economy of Tangshan has shown a significant increase in growth rate. The total GDP has risen from 14.379 billion yuan in 2001 to 11.5571 trillion yuan in 2022, indicating a substantial increase. This study selects environmental indicators including air emissions, waste water, and solid particulate matter. The emission of exhaust gas has remained relatively stable over the years, while the growth rate of solid particulate matter has been the fastest, and the emission of wastewater has also increased. In contrast, Detroit is in the post-industrial era with little growth in per capita GDP, but the production of the wastes has increased year by year.

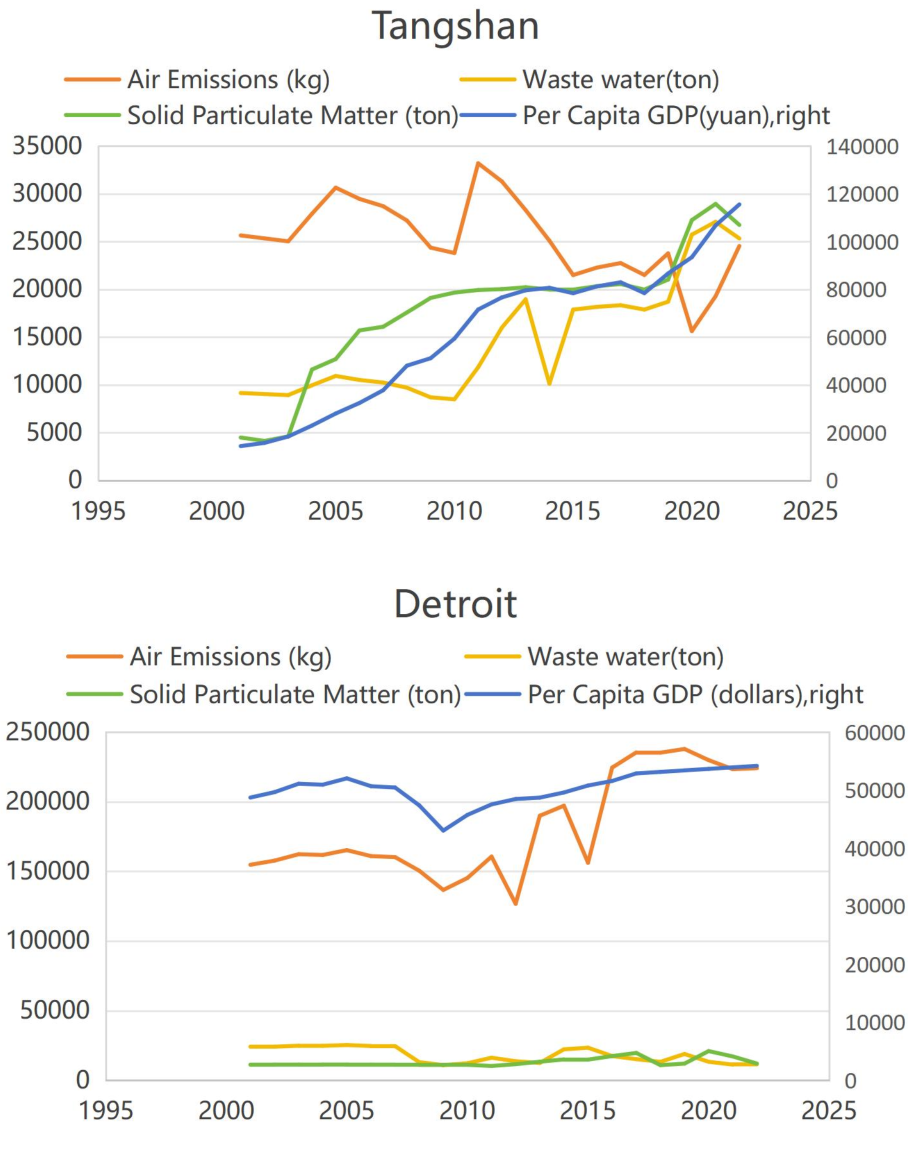

Fig. 1 Urbanization and Industrialization Indicators for Tangshan and Detroit

3. Models

There may be multiple relationships between industrial economic growth and ecological environment in the process of industrialization. Combining the speed of industrial growth and the level of ecological environment pollution, there are four models: high growth, low pollution model; high growth, high pollution model; low growth, high pollution model; low growth, low pollution model. Our goal is to achieve the first model, the "high growth, low pollution" model. To accurately understand the current situation of Tangshan and Detroit in terms of these models, it is necessary to validate the EKC in these cities. By using industrialization and ecological environment data for Tangshan and Detroit in year x, we can verify the EKC. We establish a simple regression model using per capita GDP as the independent variable x and wastes as the dependent variables y, as follows:

$$y = ax + b,$$

In addition, we can also establish quadratic simulation curves for the measurement model of urban industrialization and ecological environment. The mathematical formula is as follows:

$$y = ax^2 + bx + c.$$

Furthermore, the cubic simulation curve is as follows:

$$y = ax^3 + bx^2 + cx + d.$$

The logarithmic curve simulation formula is as follows:

$$y = a\log(bx) + c.$$

The exponential curve simulation formula is as follows:

$$y = ae^{bx} + c.$$

a, b, and c are constant terms in previous equations.

4. Results

Table 1: Comparison of the Goodness of Fit (R2) for curve models of Tangshan

	Linear model	Quadratic curve	Cubic curve	Logarithmic model	Exponential model
Air Emissions	0.2017	0.253	0.3331	0.13	0.2215
Waste Water	0.7129	0.8269	0.838	0.5452	0.7263
Solid Particulate Matter	0.5559	0.5756	0.6397	0.6092	0.7263

It is found that the above models can accurately describe the patterns of urbanization and industrialization development in Tangshan according to the regression simulation results in Table 1. Although the curve of Tangshan's industrialization and ecological environment quality does not perfectly match the inverted U-shaped EKC, it generally exhibits a trend of monotonic increase or decrease. We applied selected indicators to establish measurement models to further validate the relationship between industrialization and urbanization .

Curve fitting analysis was conducted and showed that the cubic curve had a higher goodness of fit for the relationship between air emissions and per capita GDP, indicating a better fit. Similarly, for waste water we established a cubic equation for the relationship between industrial waste water emissions and GDP. Additionally, for other industrialization indicators such as solid particulate matter, we used an exponential function for modeling. The estimated fitting results for each model are detailed in Figure 2.

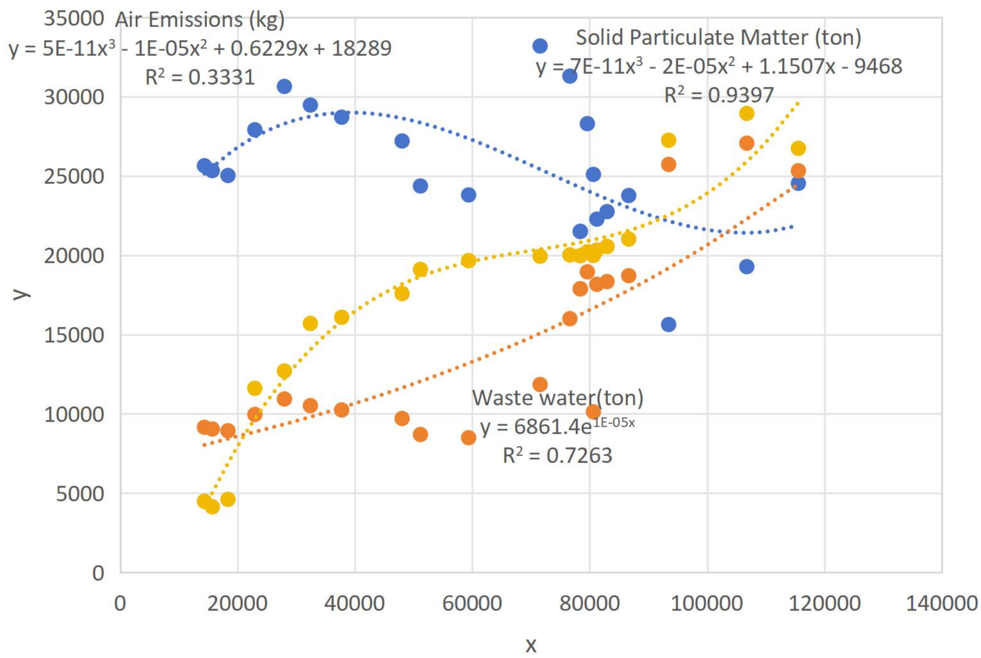

Fig. 2 Simulated Curves of Per Capita GDP and Wastes in Tangshan

Table 2. Results of Measurement Models for Urbanization and Industrialization in Tangshan

	Goodness of fit	F-test	Note
Air Emissions	0.3331	13.47	Decreasing trend
Waste Water	0.9397	53.22	Increasing trend
Solid Particulate Matter	0.7263	37.85	Increasing trend

Table 2 showed the goodness of fit is 0.3331 for air emissions, and the F-value test is 13.47 with a decreasing trend. For wastewater emissions, the goodness of fit is as high and the F-value test is 53.22. The characteristics of the EKC are closer to an upward-sloping straight line, indicating an increasing trend between industrial wastewater emissions and per capita emissions. For solid particulate matter emissions, the goodness of fit is 0.7263, and the F-value test showed an upward trend. In summary, we can observe that air emissions in Tangshan are decreasing based on the results of these measurement models, while wastewater and solid particulate matter emissions are showing a clear upward trend. These findings have important reference value for formulating relevant environmental protection policies and planning urban development.

Table 3. Results of Measurement Models for Urbanization and Industrialization in Detroit.

	Linear model	Quadratic curve	Cubic curve	Logarithmic model	Exponential model
Air Emissions	0.5945	0.5958	0.6053	0.5757	0.6059
Waste Water	0.0161	0.4015	0.6962	0.0223	0.0198
Solid Particulate Matter	0.2208	0.2529	0.2536	0.2142	0.2248

A curve fitting analysis was conducted to examine the relationship between industrial wastewater emissions and GDP in Detroit. The results indicate that an exponential function provides a good fit for the relationship between Air Emissions and per capita GDP, suggesting a satisfactory fit. Similarly, for Waste water, we established a cubic equation to model the relationship between industrial wastewater emissions and per capita GDP. Additionally, for the remaining variables of industrialization and Solid Particulate Matter, we employed a cubic curve modeling approach. These models were used to illustrate the relationship between industrialization and ecological environmental pollution in Tangshan. The estimated fitting results for each model are detailed in Table 3 and Figure 3.

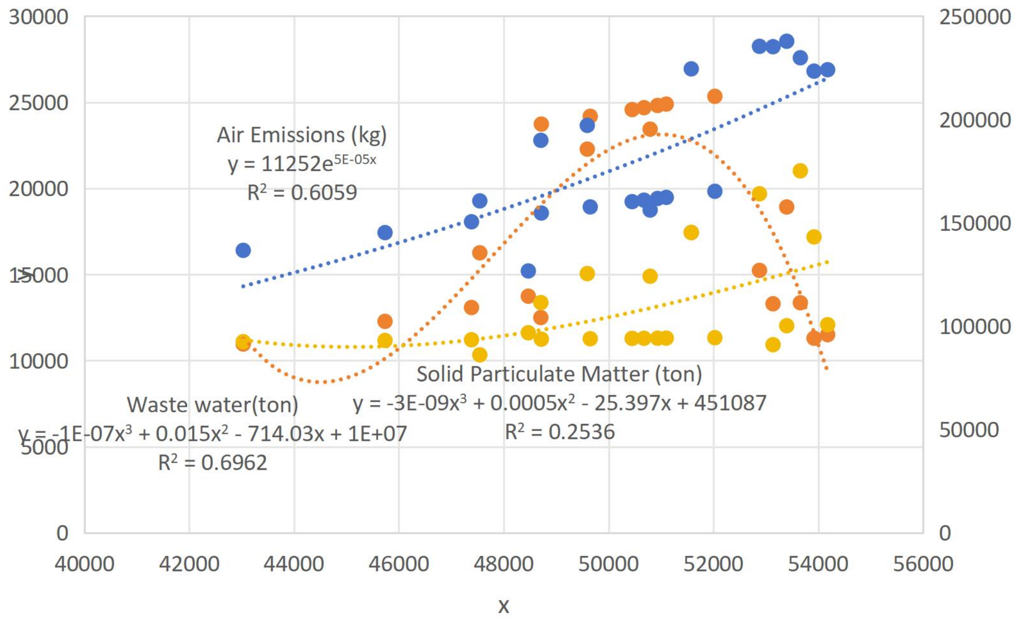

Fig. 3 Fitted Curve Graph of Per Capita GDP and Wastes in Detroit

Table 4. Econometric Model Results of Urbanization and Industrialization in Detroit

	Goodness of fit	F-test	Note
Air Emissions	0.6059	22.36	Increasing trend
Waste Water	0.6962	29.58	Decreasing trend
Solid Particulate Matter	0.2536	55.36	Increasing trend

Table 4 shows the air emissions in Detroit, with a goodness of fit of 0.6059 and an F-value test of 22.36 with an upward trend. For wastewater emissions in Detroit, the goodness of fit is 0.6962, with an F-value test of 29.58. In the case of solid particulate matter emissions, the goodness of fit is 0.2536, with an F-value test of 55.36 and an upward trend. In summary, these results indicate that air emissions and solid particulate matter emissions in Detroit are on the rise, while wastewater emissions are declining. These data provide important insights into the impact of urbanization and industrialization.

5. Discussion

5.1 Comparison of two cites

The industrial wastewater emissions in Tangshan show an increasing trend with the increase in per capita GDP. This trend is primarily influenced by the annual increase in industrial value-added, resulting in a sharp increase in industrial wastewater emissions that exceeds the capacity for treatment, leading to an upward regression curve. The industrial solid waste emissions in Tangshan are positively correlated with per capita GDP. This is due to Tangshan being a resource-based industrial city with most industrial enterprises belonging to high-energy-consuming and highly polluting industries. The governance speed is unable to keep up with the emission rate and lead to an exacerbation of ecological environmental pollution. The industrial gas emissions in Tangshan are positively correlated with per capita GDP, but over time, the emissions of industrial solid waste decrease year by year. This is because Tangshan has formed multiple industrial circular chains based on the concept of a circular economy, achieving efficient utilization of resources and wastes [11-12].

Detroit was once the hub of the American automobile manufacturing industry and went through a period of economic decline with changes in its economic structure,. Detroit's industrial wastewater emissions did not show a clear correlation with the per capita GDP growth in contrast to Tangshan. The economic decline of Detroit can be attributed to several factors. These include the decline of the American automobile industry that was a significant economic driver for the city. This decline was partly due to increased competition from foreign car manufacturers and the impact of economic recessions [13]. Additionally, factors such as population loss and racial tensions also contributed to the city's economic downturn. Instead, over the past few decades, Detroit has been actively working to improve its industrial wastewater emissions and has invested in enhancing its wastewater treatment capacity to address the environmental impact brought about by industrial development.

By analyzing the Kuznets curves of Tangshan and Detroit, we can observe some similarities and differences in the results of the quantification models for urbanization and industrialization. In both Tangshan and Detroit, different models were used to fit and analyze the relationship between industrial wastewater emissions and GDP. The fitting models for both cities provide insights into the impact of urbanization and industrialization on the environment, and these data are of great reference value for formulating relevant environmental protection policies and planning urban development. In the quantification model results for Tangshan, air emissions show a downward trend, while wastewater emissions and solid particulate matter emissions exhibit a clear upward trend. In Detroit, air emissions and solid particulate matter emissions show an upward trend, while wastewater emissions exhibit a downward trend. There are differences in the goodness of fit and F-value tests between Tangshan and Detroit. For example, the goodness of fit for wastewater emissions in Detroit is 0.6962, with an F-value test of 29.58, while in Tangshan, the goodness of fit for wastewater emissions is as high as 0.9397, with an F-value test of 53.22. Tangshan conducted a cubic curve fitting analysis for the relationship between industrial wastewater emissions and GDP, while Detroit also used a cubic curve fitting, but with different modeling results. In conclusion, there are similarities and differences in the study of industrialization and ecological environmental pollution between Tangshan and Detroit, and these differences may be influenced by factors such as the characteristics of the cities themselves and policy implementation.

5.2 Insights and directions

By comparing the industrial and economic characteristics of Tangshan and Detroit, valuable insights and directions can be provided for Tangshan. As an important industrial city in northern China, Tangshan can learn a lot from Detroit's experience:

Industrial upgrading and transformation are among the key issues that Tangshan needs to focus on. Detroit has faced the challenges of industrial transformation. Tangshan can draw from its experience and reduce reliance on traditional industries.Urban planning and regeneration are also crucial topics. Detroit has faced urban decline and population outflow issues. Detroit is reshaping its urban image and enhancing the quality of life for its residents through urban planning and regeneration projects. Tangshan can adopt similar practices to reshape its urban landscape and improve the living environment for its residents. Environmental governance and sustainable development are challenges that cannot be ignored. Industrialization often brings environmental pollution issues that Detroit has also faced in the past. Tangshan can learn from Detroit's experience in environmental governance and sustainable development and achieve a balance between economic growth and environmental protection. Talent cultivation and innovation development are essential drivers for urban development. Detroit possesses abundant talent resources and an innovative ecosystem and provides strong support for the city's development. Tangshan can learn from Detroit's experience in talent cultivation and innovation development, enhance talent attraction and cultivation, promote technological innovation, and drive economic transformation and upgrading.

By comparing the experiences of Tangshan and Detroit, Tangshan can identify effective pathways to address issues such as industrial upgrading and promote sustainable urban development and economic growth. When we compare the two cities of Tangshan and Detroit, we find significant differences in environmental protection and economic development. This kind of comparison helps guide people's attention to urban development and inspires them to be aware and take action to contribute to the communities within cities. We can help people better understand the complexity of industrial development and stimulate their sense of social responsibility and innovation. It helps in addressing community and green smart ecological solutions by providing insights into effective strategies for sustainable development and fosters innovation. Besides, it promotes active engagement in community building and drives intelligent ecological development.

6. Conclusions

This study collected economic and industrial-related data from two cities and established EKCs to analyze the mutual influence between the economy and industry. By analyzing the EKCs of Tangshan and Detroit, it was found that there are similarities and differences in the results of the quantification models for urbanization and industrialization. The fitting models for both cities provide insights into the impact of urbanization and industrialization on the environment, and are of great reference value for formulating relevant environmental protection policies and planning urban development. Tangshan and Detroit exhibit different trends in air , waste water and solid particulate matter emissions. These differences may be influenced by factors such as the characteristics of the cities themselves, industrial structure, and policy implementation. In conclusion, the research findings contribute to exploring how cities can effectively address environmental issues and achieve sustainable development during the process of economic structural transformation. Nowadays, Detroit is making efforts to attract new industries and innovative companies to promote economic diversification and sustainable development in the city. We believe that Tangshan City is also striving to improve urban infrastructure, enhance education and healthcare resources, and is committed to enhancing urban sustainability and environmental quality.

This study only quantitatively analyzed some indicators related to industrial development and urbanization. There was no rigorous demonstration of whether the establishment of the indicator system is in line with the actual situation of industrialization and ecological environment in the study area. There are still many shortcomings in this paper due to the broad and complex nature of the research on industrialization and ecological environment quality,. It requires continuous research and improvement of the indicator system and quantitative method models. Efforts will be made in the future to explore and address these issues.

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