Research on Nanyang City's Industrial Development Based on Statistical Analysis and ARIMA Forecasting

Tianyu Lu

School of Computer and Software, Nanyang Institute of Technology, Nanyang, China, 473004

18258350621@163.com

Abstract. In recent years, Nanyang City has focused on balancing rapid industrial growth with sustainable development by integrating traditional industries with emerging high-tech sectors to enhance competitiveness and reduce environmental impacts. This study examines the industrial development of Nanyang City using statistical analysis and ARIMA forecasting. Key indicators such as GDP, number of enterprises, employees, and industrial pollution were sourced from the Nanyang Statistics Bureau, preprocessed for quality and consistency, and normalized. The ARIMA model, following stationarity tests and optimal parameter identification, predicts a slight GDP decline in 2023 and, a recovery in 2024, but slower growth by 2027. Environmental indicators were evaluated using Pearson correlation coefficients and the Analytic Hierarchy Process, revealing volatility in green development. The study suggests that Nanyang should strengthen industrial chain integration and technological innovation to enhance competitiveness and environmental performance.

Keywords: Industrial layout, Environmental impact, Statistical analysis, Spatial model.

1. Introduction

With the rapid development of China's economy, industrialization has played a crucial role in enhancing economic output and improving people's livelihoods [1, 2]. However, the swift advancement of industrialization has also brought significant environmental issues [3, 4], particularly highlighting the conflict between industrial layout and ecological protection. Nanyang City, an important industrial city in central China, boasts abundant resources and a favorable geographical location, yet it also faces the dual challenges of industrial restructuring and environmental pressure [5].

In recent years, with the continuous growth of Nanyang's economy, the scale of industrial production and energy consumption levels have significantly increased, accompanied by increasingly severe industrial pollution problems, which have become key factors restricting the high-quality development of the regional economy [6]. To achieve coordinated development of the economy and environment, Nanyang needs to scientifically plan its industrial layout through advanced analytical methods and technologies and formulate effective environmental protection policies [7].

Through the comparative analysis of Nanyang and Xiangyang, two cities with similar geographical and economic backgrounds, we reveal the impact of different policies, resource allocations, and industrial structures on urban development. This study not only aids in understanding the commonalities and differences in regional economic development but also offers targeted recommendations for regional economic growth. By conducting a comprehensive evaluation of the industrial layout and its environmental impact in Nanyang City using statistical analysis and spatial models, we preprocess and analyze historical industrial data with big data technologies to construct ARIMA forecasting models. These models help uncover the spatial distribution characteristics and development trends of Nanyang's industrial layout. Simultaneously, we assess the environmental impact of the industrialization process, providing data support and a theoretical basis for formulating scientific and reasonable industrial and environmental policies.

2. Data Source and Description

The data for this study is sourced from https://tj.nanyang.gov.cn/tjfw/tjnj/. Initially, we preprocessed the relevant industrial data. Using statistical methods, we spatially and structurally processed the data, covering key indicators such as output value, number of enterprises, number of employees, and industrial pollution. This step included data cleaning and differential processing to ensure data quality and consistency. Additionally, to meet the analytical needs of the ARIMA model, we imputed missing values, removed outliers, and standardized the data to eliminate dimensional effects, thereby enhancing the model's accuracy and generalization capability. Some of the key indicators for Nanyang City over recent years, post-preprocessing, are shown in Table 1.

Table 1. Key Indicators for Nanyang City in Recent Years

Indicator/Year	2023	2022	2021	2020	2019
GDP (billion yuan)	4572.20	4555.40	4342.22	3925.86	3815.00
GDP per capita (ten thousand yuan)	4.47	4.73	4.49	3.99	3.87
GDP growth rate (%)	4.80	4.91	11.67	2.40	7.00
Primary industry GDP share (%)	16.10	16.09	16.10	16.62	14.93
Secondary industry GDP share (%)	28.80	32.04	31.60	32.12	33.23
Tertiary industry GDP share (%)	55.10	51.87	51.56	51.27	51.84

Further, this study conducted normality tests on the relevant indicator data to analyze whether they follow a normal distribution for statistical analysis. The test results are shown in Table 2.

Table 2. Normality Test Results

Variable	Sample size	Median	Mean	Standard deviation	Skewness	Kurtosis
Development indicator	58	2	1.586	0.497	-0.359	-1.939

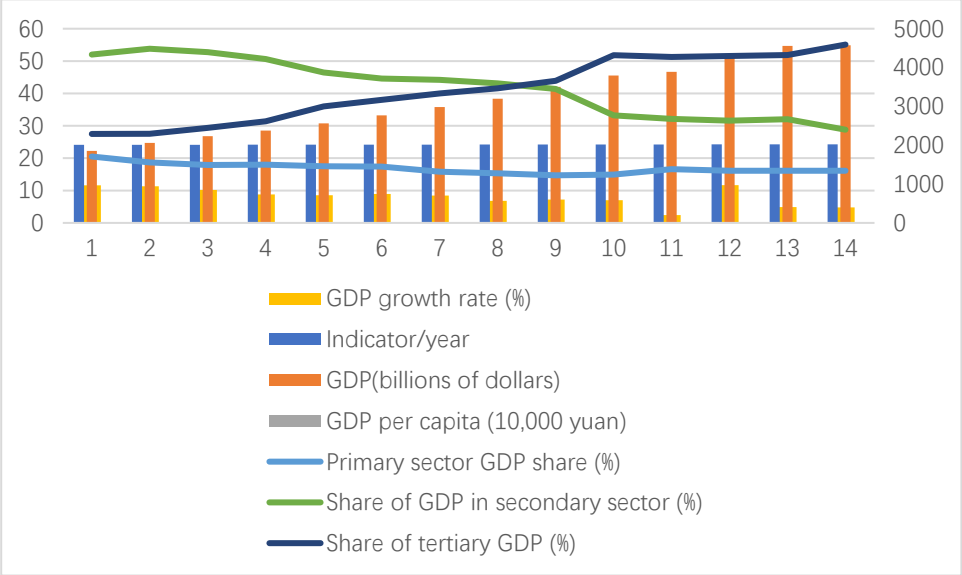

Figure 1. Summary of Development Indicators in Nanyang City over the Past Ten Years

The analysis shows that for the development indicator sample size N<5000, the Shapiro-Wilk test was used, and the significance PPP-value is 0.000***, indicating a significant level (P<0.05), meaning the data follows a normal distribution. Using the development indicator data for the past ten years obtained from the Nanyang City Statistics Bureau and the Xiangyang City Statistics Bureau, this study used descriptive statistics and time series analysis methods to create Figures 1 and 2. Nanyang and Xiangyang, both important cities located in central China, share similar geographical environments and economic backgrounds. By comparing the development of these two cities, we can gain a clearer understanding of the commonalities and differences in urban development within the

central region. Their similarities in transportation, resources, and industrial structure make comparative analysis highly feasible, allowing us to reveal the impact of different policies, resource allocations, and industrial structures on urban development. This in-depth exploration provides more targeted recommendations for regional economic development, identifies unique challenges and opportunities in Nanyang's development process, and offers a basis for formulating more precise development strategies.

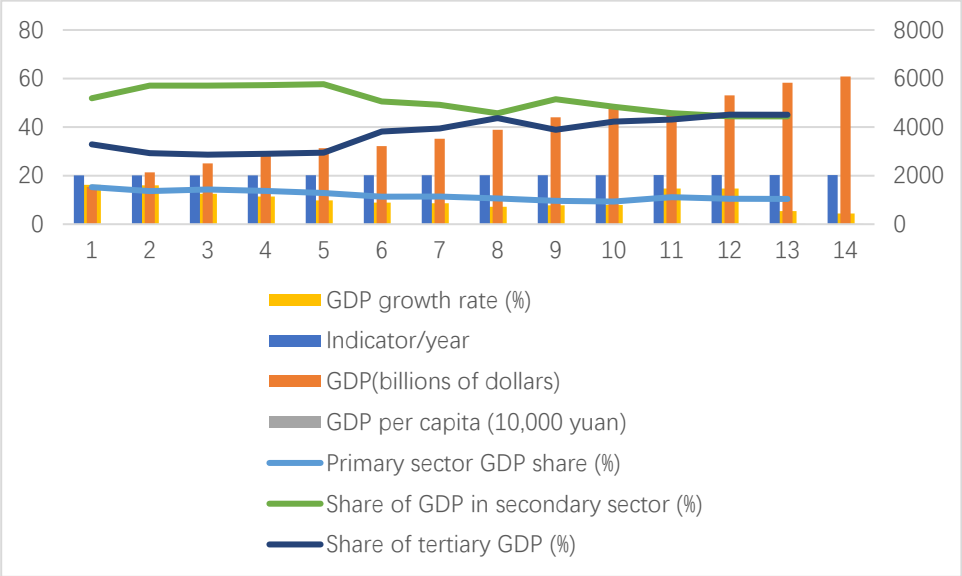

Figure 2. Summary of Development Indicators in Xiangyang City over the Past Ten Years

Data analysis from 2016 to 2023 shows significant differences in GDP growth rates and industrial structures between Nanyang and Xiangyang. Nanyang's GDP growth rate rose from 2.2% in 2016 to 8.5% in 2020, then slightly declined to 4.80% in 2023. In contrast, Xiangyang's GDP growth rate fluctuated more during the same period, from -5.3% in 2016 to 8.5% in 2020, decreasing to 4.43% by 2023. In terms of total GDP, Nanyang's GDP increased from 276.76 billion yuan in 2015 to 457.22 billion yuan in 2023, while Xiangyang's GDP increased from 321.56 billion yuan to 608.598 billion yuan, demonstrating Xiangyang's economic scale advantage.

In terms of industrial structure, Nanyang's tertiary industry share increased from 51.3% in 2020 to 53.1% in 2023, while Xiangyang's secondary industry still accounted for 44.4% in 2023, indicating stable growth in its manufacturing sector. The share of Nanyang's secondary industry in GDP decreased from 44.2% in 2016 to 28.8% in 2023, indicating a shift from traditional manufacturing to diversification and service orientation. Despite some growth in emerging manufacturing and high-tech industries, Nanyang still faces challenges in terms of technological content and industrial competitiveness. In contrast, Xiangyang's secondary industry remained stable, with its GDP share fluctuating between 44.4% and 51.5%, benefiting from its heavy industrial base and mature industrial chain, especially in the automotive manufacturing sector. Xiangyang's experience shows that a stable industrial foundation and mature industrial chain are its advantages. Nanyang should learn from Xiangyang, strengthen industrial chain integration and technological innovation, and promote the development of high-tech industries to enhance industrial competitiveness.

3. ARIMA Forecast of Nanyang's Secondary Industry GDP

After preprocessing the data, an ARIMA model was applied for detailed modeling and prediction analysis of the industrial development trend in Nanyang [8]. The stationarity of the historical data was tested using the Augmented Dickey-Fuller (ADF) test to determine whether differencing was needed. The Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots were used to identify the orders of autoregression and moving average. Ultimately, ARIMA(2, 1, 2) was selected as the optimal parameter combination for the model.

During model training, industrial production data from 1995 to 2023 were used for fitting. The model's fit was evaluated through residual analysis to ensure that the residuals conformed to a normal distribution and exhibited no autocorrelation, thereby verifying the model's accuracy and robustness. After fitting the model, the trained ARIMA model was used to forecast Nanyang's industrial production from 2024 to 2029. The results are illustrated in Figure 3.

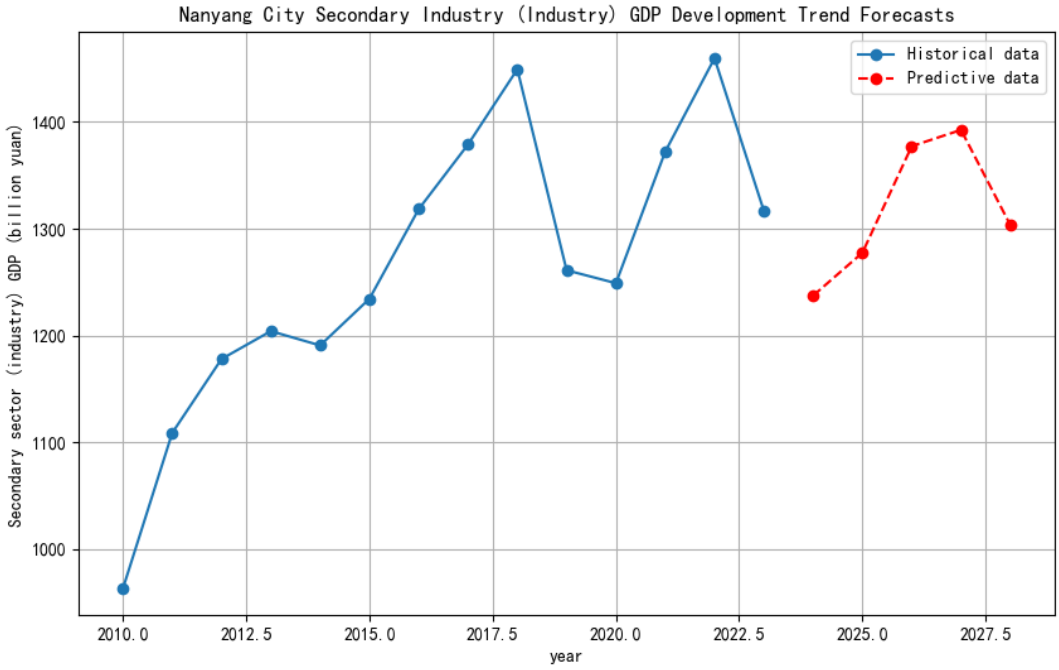

Figure 3. Forecast of the GDP Growth Trend for Nanyang's Secondary Industry

As shown in Figure 3, over the past decade, Nanyang's secondary industry GDP increased from 96 billion yuan in 2010 to 145.955 billion yuan in 2022. Although the overall trend was upward, there were several fluctuations. According to the ARIMA model prediction, the GDP will experience a slight decline in 2023, followed by a recovery in 2024. However, the growth rate is expected to slow down again by 2027. This indicates that while Nanyang's secondary industry has growth potential, its future development is limited by outdated industries.

The growth of Nanyang's secondary industry GDP was primarily driven by industrial restructuring and the increased output of large-scale enterprises between 2010 and 2015. However, since 2016, growth has slowed, particularly in 2020 impacted the global economy, further exposing the weaknesses in Nanyang's industrial structure. Excess capacity in some outdated industries and the failure to transition promptly have constrained further GDP growth.

The forecast indicates that the decline in Nanyang's secondary industry GDP in 2023 is mainly due to overcapacity in traditional industries and the pressure of environmental policies. Meanwhile, emerging industries have not yet developed sufficiently to generate significant economic impacts. Although traditional industries contribute to industrial growth, their low technological content and small added value are unable to meet market and environmental requirements, suppressing overall industrial growth. The development of intelligence and other emerging fields will take more time to significantly influence economic growth.

4. Evaluation of Nanyang's Industrial Environmental Indicators

In the cleaned dataset, this study extracted eight industrial environmental protection indicators for Nanyang from 2010 to 2021, including industrial wastewater discharge, sulfur dioxide, nitrogen oxides, dust emissions, and solid waste utilization rate, among others. We then used the Pandas library to calculate the Pearson correlation coefficients, generating an 8x8 correlation matrix [9]. This matrix displays the correlations between the indicators, where positive values indicate positive correlations,

negative values indicate negative correlations and values closer to ±1 represent stronger correlations. The generated correlation matrix is shown in Figure 4.

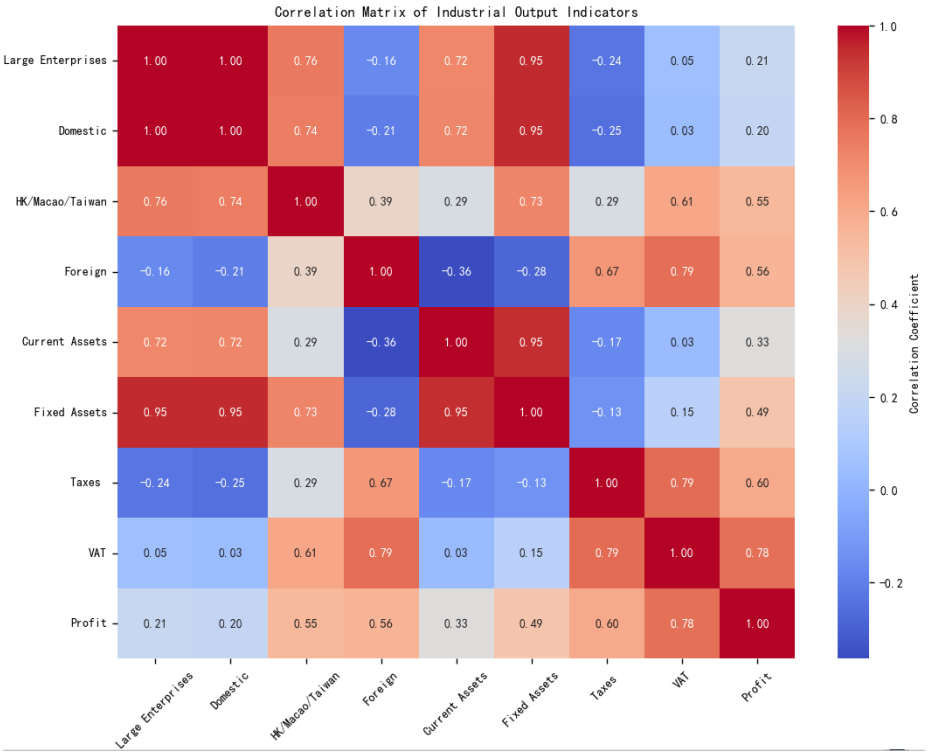

Figure 4. Industrial Pollution Indicators Matrix

Next, using the previously obtained correlation matrix coefficients and the Analytic Hierarchy Process (AHP) [10], we first calculated the weights of each indicator. Then, based on the ARIMA model's prediction results, we obtained the dynamic indicators, as shown in Figure 5.

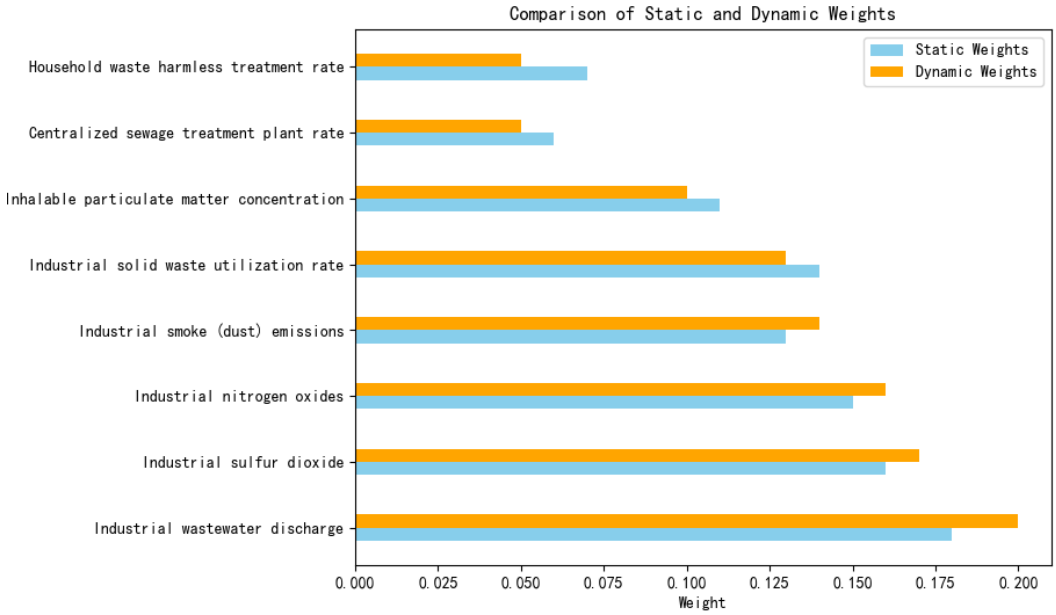

Figure 5. Comparison of Static and Dynamic Weights

The normalized scoring method was used to evaluate the green environmental development of Nanyang's industry in different years, comprehensively measuring the overall level of industrial green development in Nanyang. The results are shown in Figure 6.

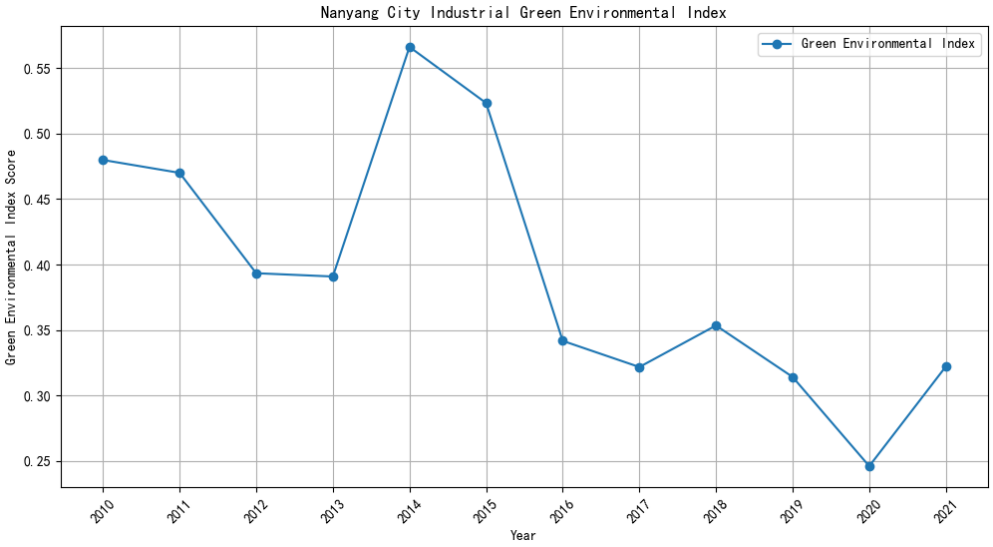

Figure 6. Green Environmental Protection Index of Nanyang's Industry

The trend of Nanyang's Green Environmental Protection Index shows some volatility in the city's performance in industrial green environmental protection. From the graph, it can be observed that after an initial decline, the index reached a significant peak between 2014 and 2015. This reflects the city's efforts during that period to strengthen environmental policies, promoting the environmental technological transformation and upgrading of traditional industries. However, in the following years, the index showed a declining trend again until it recovered somewhat in 2018, indicating the instability of environmental effectiveness.

This fluctuation may be related to Nanyang's strong traditional industrial base and insufficient development of emerging industries. Despite increased environmental regulation and technological upgrades by the government, the proportion of high-pollution traditional industries remains significant. Additionally, environmental technology and management levels in some emerging industries are also inadequate, which to some extent limits the continuous improvement of the environmental index. In pursuing high-quality industrial economic development, Nanyang needs to continue promoting the green transformation of traditional industries and strengthen environmental awareness and technological innovation in emerging industries to ensure the stability and sustainability of environmental effectiveness. This will not only help improve urban environmental quality but is also a necessary path to achieving sustainable development strategic goals.

5. Conclusion

This study analyzed industrial data from Nanyang City, sourced from the local statistics bureau. Key indicators like output value, number of enterprises, employees, and industrial pollution were preprocessed to ensure data quality and consistency. Missing values were imputed, outliers removed, and data standardized for ARIMA model analysis. The results reveal that Nanyang's economic growth, particularly in the secondary industry, has been hampered by over-reliance on traditional manufacturing and inadequate development of high-tech and emerging industries. The ARIMA model's forecast indicates a slow growth trend in the secondary industry, highlighting the need for industrial restructuring and technological innovation to sustain economic development. Moreover, the analysis of environmental indicators shows fluctuations in Nanyang's green environmental protection index, reflecting inconsistent efforts in industrial environmental sustainability. Despite progress in environmental policies and technological upgrades, the dominance of high-pollution traditional industries poses significant challenges to achieving continuous improvement in environmental quality.

To address these issues, Nanyang must prioritize the integration of industrial chains, enhance technological innovation, and promote the development of high-tech industries. Strengthening

environmental regulations and fostering environmental awareness and technological advancements in emerging sectors are crucial for achieving stable and sustainable industrial green development.

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