Chapter 51
The Multi-objective Optimization Model of the Industrial Structure in the Processes of Urbanization: A Case Study of Shizhong District, Neijiang City

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Abstract This article analyzes the structure of the three industries in Shizhong District, Neijiang city. Considering the economy, employment, resources, energy and environmental constraints with the achievement of the optimal economic and social benefits, a two-goal programming model is established. Based on the relevant data, this article uses fuzzy algorithm to solve the established planning model. The results of the model calculations demonstrate that industrial structure optimization is an effective way to achieve low-carbon development and also it provides a scientific basis for the industrial structure optimization in Shizhong District.

Keywords Industrial structure optimization · Multi-objective planning · Uncertain variable

51.1 Introduction

Detailed theories of industrial structure have been proposed for a couple of years. Marx [8] proposed the theory of industrial division, industrial structure equilibrium and adjustment mechanism of Industrial structure in nineteen century. It is the basement of analysis and adjustment of industrial structure. Fisher [5] put forward the three industry classification which classified the three industries firstly into primary, secondary and tertiary industries. Gonchijany [6] summarized the changing law of industrial structure and testified its importance to economic development.

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Chenery [3] standardized the open industrial structure theory and put forward the development type theory. Besides, he got a group of standard data about the weight of vary manufacturing department related to the change of per capita income after calculation of fifty-one different countries. Lewis [7] proposed the binary structure transformation theory to explain the economic issues for developing countries. He thought that the whole economy is composed by the modern industrial department and traditional agriculture department and developing countries could make use of the advantage of labor resources to accelerate economic development.

Through maximizing (or minimizing) many different objective functions under a set of constraints, Multi-objective programming (MOP) is suitable for making decisions for the system involving two or more goals. MOP can deal with this situation and get solution. MOP has been greatly developed and used in many aspects. Zhao [12] used MOP to seek for Pareto optimal decision. Abdelaziz et al. [1] studied the portfolio selection by MOP. It's also been used in some other aspects [4, 9, 11]. Since Zimmermann [13, 14] first introduced conventional linear programming and multi-objective linear programming into fuzzy set theory, there is now an overwhelming amount of research on using fuzzy programming technique to solve multi-objective programming [2, 10].

51.2 Research Background

In the past 30 years, the region's GDP increased from 1.79 billion yuan in 1978 to 113.5 billion yuan in 2008, and the average annual growth rate is 11.5 %. In 2000, the region's GDP reached 30 billion and then the expansion of the total economy continues to accelerate. Since the Tenth Five-Year Plan, the average annual GDP growth rate has reached 12.9 %, which is 3.4 % points higher than the average annual growth rate since the reform and opening up. In particular, since 2002, the GDP maintains a double-digit growth for seven consecutive years. With an average annual growth rate of 12.8 %, the region's GDP per capita increased from 460 yuan in 1978 to 15,304 yuan in 2007. In 2008, the national economy continued to maintain a rapid growth in Shizhong District, and the quality of management achieved further improvement. Validated by the Municipal Bureau of Statistics, with an increase of 14.1 % over the previous year, the region's GDP in 2008 is 11,351,370,000 yuan, and the growth rate is 1.3 % points lower than last year. To be more specific, with an increase of 3.4 %, the added value of primary industry is 1.21845 billion yuan. With an increase of 17.1 %, the added value of the secondary industry is 5.40334 billion yuan. And with an increase of 13.0 %, the added value of tertiary industry is 4.72958 billion yuan. The contribution rates of the three industries in the economy are 2.2, 56.4 and 41.4 %, respectively, and the percentage points of stimulating economic growth are 0.3, 8.0 and 5.8, respectively. The added value of the three industries accounted for the proportion of GDP in the previous year is 11.0:45.5:43.5 and the proportion are adjusted to 10.7:47.6:41.7. As a result, The proportion of primary industry dropped by 0.3 % points, the secondary industry increased by 2.1 % points,

Fig. 51.1 The output value of three main industries

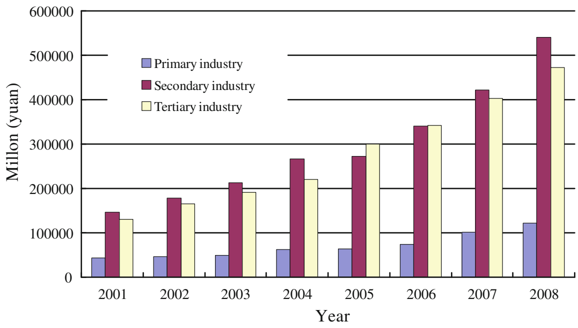
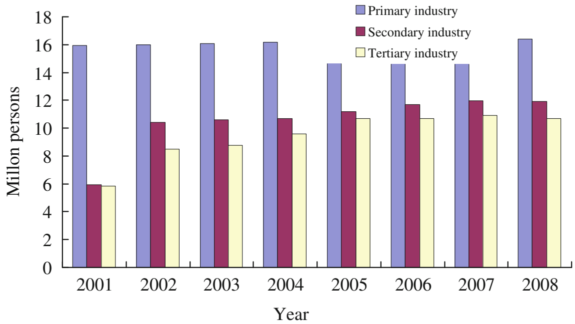


Fig. 51.2 The employment from 2002 to 2008



and the tertiary industry dropped by 1.8 % points. The total employments of the three industries are 16.4, 11.94 and 10.71 million respectively. Figures 51.1 and 51.2 show the output value and attracted employment in Shizhong District from 2002 to 2008.

According to the current exchange rate, the GDP per capita of Shizhong District is about $2,600 in 2008. Hence, it is appropriate to estimate the level of real income at a range of $2000–$3000. By comparing the industrial structure of Shizhong District with that of Chenery Standard in Table 51.1, it can be found that the proportion of secondary industry of Shizhong District in 2008 was significantly higher than that of geneary standard industrial structure and the proportion of tertiary industry was apparently lower than that of the standard industrial structure. The proportion of primary industry was slightly lower than the standard industrial structure. The productivity per capita in primary industry is low, and the GDP per capita is 7,430 yuan, only as weak as 1/5 of secondary industry and 1/6 of tertiary industry. According to the employment structure in 2008, the employment of primary industry was significantly higher than that of the standard industrial structure in Shizhong District; the employment of secondary industry was close to the standard industrial structure; the proportion of employment in tertiary industry was slightly lower than that of the standard industrial structure.

In this paper, a model which aims to solve industrial structure optimization problems is built by using multi-objective planning methodology. According to the development goals and reduction targets, the industrial structure optimization model under the constraints of environment and resource is established. By using the weighted fuzzy algorithm, a satisfactory solution is obtained. According to the decision-makers' different attentions on the two goals to assign different weights, adjustment and optimization program in different industries can be gained.

51.3 Modeling Techniques

The model of the industrial structure established in the low-carbon context should focus on economic efficiency as well as social interests. Economic development is the material security to promote social progress and enhance national strength. The realization of the social interest is the indispensable requirement of practicing people-oriented and building a harmonious society. At the same time, multiple targets are considered and expressed as multi-objective optimization in mathematics. This section will first introduce the multi-objective optimization theory, and then a model is built. Finally the data are input and by using the weighted fuzzy algorithm to get the optimized program.

1. Modeling Ideas

Taking economic construction as the center is a basic national policy determined at the beginning of reform and opening up. The rapid development of the economy is the right way to achieve the great rejuvenation of the nation. However, in China, a populous country, the blind development of technology-intensive and capital-intensive enterprises will inevitably lead to massive unemployment, thus causing social instability, which is contrary to build a harmonious society. Consequently, the building of industrial optimization model in Shizhong District should consider maximizing GDP and the employment as another target. The restraint system consists of the economic constraints, employment constraints, energy constraints and environmental constraints.

2. Modeling Process

In order to create a model and exclude secondary factors, some necessary assumptions of the problem should be made first. Then on the basis of these assumptions, a multi-objective programming model is established.
Modeling Assumptions

1. Assume that GDP growth in 2020 triples, then the average annual growth rate would be not less than 7 %. To avoid overheating of the economy, it is assumed that annual GDP growth rate does not exceed 20 %.
2. In 2008, the labor force absorbed by the three industries among which whose output values are over 10,000 yuan were 1.35, 0.22 and 0.23, respectively. Taking the rise in labor costs into account and based on the historical data that labor absorbed in the three industries whose output values are over ten thousand

yuan compared with that of last year, the ratio is 0.87:1, 0.92:1 and 0.91:1, we assume that such ratio will be uniformly maintained in a future period of time. Then $b_1(t) = 1.37 \times 0.87^t$, $b_2(t) = 0.22 \times 0.23^t$. Assuming that the new labor force was also 0.1 %, thus the net growth rate of the population 0.1 % in Shizhong District can be measured based on the historical data. In order to maintain the current unemployment rate, the annual number of new jobs can not be less than 0.1 % of the previous year.

3. Suppose that all energy consumptions are translated into standard coal, the conversion rate of carbon dioxide from standard coal is constant.
4. The base year energy consumption per unit of GDP is 1.23 tons of standard coal. The energy consumptions in the three industries are 0.36 tons of standard coal, 1.8 tons of standard coal and 0.72 tons of standard coal, respectively.
5. The adjustment period is one year.

Model Building

The basic framework of the model is shown as follows. The objective function:

1. The growth of the maximum output value of the total output reflects the growth of the economic benefits, that is to say, it can reflects the size of the economy. It is shown by the following objective function:

$$\max f_1(t) = x_1(t) + x_2(t) + x_3(t).$$

2. The growth of the employment reflects the growth of social welfare and the degree of social stability. It can be shown by the following objective function:

$$\max f_2(t) = 1.35 \times 0.87^t \times x_1(t) + 0.22 \times 0.91^t \times x_2(t) + 0.23 \times 0.92^t \times x_3(t).$$

Constraints:

1. Output value constraints: In order to achieve the overall objective of quadrupling the region's GDP in 2020, the annual economic growth rate 7 % can be calculated by assumption (1).

$$x_1(t) + x_2(t) + x_3(t) \geq 1135137 \times (1 + 7\,\%)^t.$$

2. Employment constraints: In order to control the unemployment rate, the annual increase in employment shall not be less than 1 % of the previous year.

$$1.35 \times x_1(t) \times 0.9^t + 0.22 \times x_2(t) \times 0.9^t + 0.23 \times x_3(t) \times 0.9^t \geq 580000 \times (1 + 0.1\,\%)^t.$$

3. Carbon emissions intensity constraints: In order to achieve the overall target of reducing the region's carbon emission intensity by 60 % lower than that of 2005 in 2020, the annual carbon emission intensity reduction target 6 % can be calculated. The carbon emission intensity constraint can be expressed as:

$$\frac{(0.36 \times p_1 \times x_1 + 1.8 \times p_2 \times x_2 + 0.72 \times p_3 \times x_3) \times 2.66}{x_1 + x_2 + x_3} \leq 0.68 \times 2.66 \times (1\text{–}6\,\%)^t,$$

which is equal to the following function:

$$0.36 \times p_1 \times x_1 + 1.8 \times p_2 \times x_2 + 0.72 \times p_3 \times x_3 \leq 1.23 \times (1\text{–}6\%)^t \times (x_1 + x_2 + x_3).$$

4. Sulfur dioxide emissions constraints: Considering the increased controlling efforts, an average annual increase of the sulfur dioxide processing rate 5 % is assumed. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also multiplying. The annual absolute increase is limited to not more than 5 % of last year, and then the following constraint is established:

$$2.8 \times (1 - 0.05)^t \times x_2 \leq 1494000 \times (1 + 0.05)^t.$$

5. Industrial wastewater discharge constraints: Considering the increased controlling efforts, an average annual increase of the wastewater treatment rate 5 % is assumed. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also multiplying. The annual absolute increase is limited to not more than 5 % of last year, then the following constraint is established:

$$28.9 \times (1 - 0.05)^t x_2 \leq 11127000 \times (1 + 0.05)^t.$$

6. Industrial soot emissions constraints: Considering the increased controlling efforts, an average annual increase of the soot handling rate 5 % is postulated. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also multiplying. The annual absolute increase is limited to not more than 5 % of last year, and then the following constraint can be established:

$$1.2 \times (1 - 0.05)^t x_2 630000 \times (1 + 0.05)^t.$$

7. Industrial dust emissions constraints: Considering the increased controlling efforts, an average annual increase of the dust processing rate 5 % is postulated. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also augmenting. The annual absolute increase is limited to not more than 5 % of last year, then the following constraint can be established:

$$0.281.2 \times (1 - 0.05)^t x_2 \leq 151000 \times (1 + 0.05)^t.$$

Solution to the Model

Let $t = 1$, then the following functions can be obtained: $f_1^0(1) = 1248651$, $f_1^1(1) = 1265678$, $f_2^0(1) = 390891$, $f_2^1(1) = 406406$.

Construct the membership function of the two goals

$$u_1(f_1(1)) = \frac{1265678 - (x_1(t) + x_2(t) + x_3(t))}{17027}, \tag{51.1}$$

$$u_2(f_2(1)) = \frac{406406 - (1.35x_1(t) + 0.22x_2(t) + 0.23x_3(t))}{15515}. \tag{51.2}$$

Table 51.1 Optimize results

Year	The proportion of primary industry	The proportion of secondary industry	The proportion of tertiary industry
2014	11.5	38.3	50.1
2015	11.5	38.4	50.0
2016	9.8	368.6	53.6
2017	9.5	35.5	55.0
2018	9.4	35.1	55.5
2019	9.3	33.7	57.0
2010	9.3	33.5	57.2

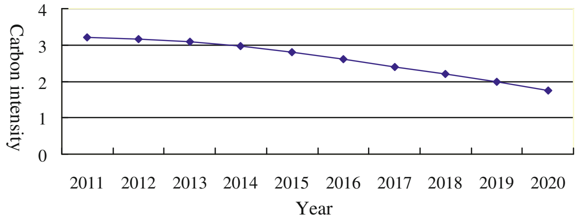


Fig. 51.3 Carbon intensity optimal value

If the decision-makers pay equal attention to the economic growth and employment promotion, then it can be assumed that weights of the two targets are 0.5 and the two membership functions are aggregated as $0.5u_1(f_1(1)) + 0.5u_2(f_2(1))$.

By using the Matlab Optimization Toolbox, the adjustment programs and results for 2014–2020 can be obtained (see Table 51.1).

When policy maker believes that the economic development is a very urgent task, he will confer more weight to GDP, such as 0.7. In turn, if policy maker believes that the economic development is not a very urgent task, he will confer less weight to GDP, such as 0.3.

51.4 Comprehensive Evaluation

Based on the above calculation results, it is not difficult to find that the overall trend is the same regardless of what kind of weights are assigned to the two targets by the decision-makers. That is, the primary industry remains stable and there is an obvious increase with the industrial efficiency. With the continuation of the industrialization process, the secondary industry's proportion of the national economy declines. The tertiary industry develops rapidly and replaced the secondary industry to become the leading industry in the national economy during the "Twelve Five-Year" Plan. By 2020, the proportion of the three industries is basically stable.

As for the aspect of energy conservation and carbon emissions intensity reduction, industries, in the existing technical conditions, should minimize the energy consumption per unit. At the same time, the optimization of industrial structure ought to shift to the low-emission industries. The superposition of twofold effect leads to an accelerated downward trend of the carbon emission intensity. By 2020, set $w_1 = w_2 = 0.5$ as an example, the carbon emission intensity will be 1.86 as shown in Fig. 51.3.

51.5 Policy Recommendations and Conclusion

Based on the calculation and analysis of the model, the following suggestions are proposed.

1. Consolidate the fundamental status of agriculture and improve agricultural efficiency. With the principle of "reduce, reuse, recycle", develop and utilize natural resources rationally, maintain essential ecological processes and life support systems in agricultural producing areas. Adhere to develop agriculture with the industrial concept, and around the central task of increasing income of farmers to adjust the industrial structure in rural areas. Focus on characteristic agriculture, and vigorously introduce and use eco-agricultural technology to innovate agricultural operation mechanism and speed up the construction of characteristic agricultural products in deep-processing enterprises. Strive to shift the traditional agriculture to the cycling ecological agriculture in Luzhou. And increase investment as well as strengthen infrastructure construction to promote the industrialization of agriculture, rural industrialization and rural urbanization. Furthermore, comprehensively improve the overall agricultural production capacity and agricultural efficiency and increase rural incomes to realize rural stability, and promote the cycling development of agricultural production and rural economic and social construction. Ultimately, establish a new socialist countryside which adheres to "integration of urban and rural areas, the development of production, affluent life, civilization, clean and tidy villages and democratic management".
2. Absorb advanced productive forces from science and technology and make good use of it. In accordance with the new requirements of the scientific concept of development and combined with the industry practice in Shizhong District, energetically develop low-carbon economy and circular economy, and finally do a good job in energy conservation. Such as photovoltaic in polysilicon industry, organic brand in tea industry and low-carbon economy in shoes industry. Use high-tech to grafting salt and phosphorus chemical industry, metallurgy and construction materials, machinery manufacturing and other traditional industries, and develop fine phosphorus chemical titanium, vanadium with low alloy steel, pure steel and other high-end new products. Furthermore, expand high-tech industries and develop silicon material, carbon fiber, rare earth, vanadium, titanium and other new materials to establish a cluster base for polycrystalline silicon photovoltaic energy industry. Finally, accelerate the strategic new industries, and

actively develop non-power civilian nuclear technology industry, the Internet of Things Radio Frequency technology industry and so on.

3. Develop the tertiary industry vigorously. Develop the tertiary industry energetically is the focus of the industrial adjustment. Tertiary industry bears the features of low energy consumption, less pollution and high efficiency. With the Buddha-Emei scenic tourist resources and a better transportation system and urban infrastructure in Shizhong District, it is potential to develop tourism, logistics and commerce. Tourism industry should be bigger and stronger. Increase the development of tourism resources integration and combine the tourism development with urban construction and the development of cultural industries with the beautiful mountains to further enhance the tourism grade. Improve the consumption environment and cultivate consumer hotspots, thus increasing the proportion of the services sector in the economy of the District.

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