ISSN:2790-1661 DOI: 10.56028/aemr.1.1.178

Manufacturing decision scheme based on grey prediction and AHP

Yunshuo Zhao[1, a], Rui Chen[1, b], Ying Cao[1, c], Yifan Feng[1,d], Ziru Tian[1, e], Jingchen Han[1, f]

[1]School of Hebei University of Technology, Tianjin 300401, China.

[a]203082@stu.hebut.edu.cn, [b]201683@stu.hebut.edu.cn, [c]204820@stu.hebut.edu.cn, [d]203055@stu.hebut.edu.cn, [e]202941@stu.hebut.edu.cn, [f]203010@stu.hebut.edu.cn

Abstract. In order to promote carbon reduction in the manufacturing industry, measures have been taken to promote the low-carbon transformation of the manufacturing industry, and then promote the harmonious development of the economy and ecology. Data were found from bp World Energy Statistical Yearbook and CEADs database, and the method of gray prediction was used to predict the carbon emissions in the coming years. At the same time, measures were found by finding literature, and the implementation order of measures was finally determined according to their AHP model. It was found that the carbon emissions in 2022 are estimated to be 10179.18 million tons, and the carbon emissions in 2023 are estimated at 10213.53tn, which shows that the carbon emissions in the next few years are at a high level, so as a high carbon emission manufacturing industry must take measures. According to data search and expert opinions, we can determine the weight and calculate the final measures that need to be taken to focus on process optimization, raw material substitution, low-carbon travel of enterprise personnel, etc. Through the estimation of future carbon emissions and the decision model of measures, we can find that the manufacturing industry, as a large part of carbon emissions, has high economic, environmental and social benefits after taking effective actions.

Keywords: manufacturing; high carbon emissions; grey forecast; AHP

1. Introduction

Among the current large coal power countries, five countries, including China and Japan, account for more than 60% of the global coal electricity generation[1], China already generates more than 50 percent of its coal electricity. With the proposal of "carbon peak, carbon neutral" related policies, energy conservation and emission reduction have become more and more important, Zhang Fan et al.[2] summarized and analyzed the current situation of carbon emissions in the development of China's manufacturing industry, and put forward the countermeasures such as carbon reduction, energy replacement, CCUS, the combination of industrial manufacturing and industrial Internet, and introduced the low-carbon production process of key industries such as steel process, coal chemical process and petroleum refining process. Based on the carbon emission-energy integration model, Xue Yinglan et al.[3] have studied the development of coal control and carbon reduction path under the target of "double carbon". Ren Shihua et al.[4]calculated the carbon emissions in coal development, analyzed the carbon emission characteristics of different links, and put forward the carbon emission reduction technology approach. Kang Chongqing et al.[5]analyzed the problems existing in the power industry to low-carbon transformation, and put forward the research content and technology of the new low-carbon power system. Zheng Lu et al[6] studied government subsidies to the garment industry and guided carbon emission reduction investment decisions in the garment industry. It can be found that the current scholars have done a lot of researches on how to effectively reduce carbon emissions.

Through the use of the gray forecast for the next few years, we find that the results are more accurate. On this basis, carbon emissions are estimated for manufacturing, which accounts for a large proportion of them. The reason for this treatment is mainly because there are many classifications of manufacturing industries, and the use of carbon emission factors for industry

ISSN:2790-1661 DOI: 10.56028/aemr.1.1.178

carbon emission measurements takes more time, and there are also certain errors in the use of carbon emission factors for many industries, so this paper selects gray forecast. As one of the main carbon emissions in China, the manufacturing industry undoubtedly faces many challenges. In order to better promote the emission reduction in China, this paper uses AHP to provide measures for the manufacturing industry and guide the development of the manufacturing industry more scientifically.

2. Carbon emission forecast

China's overall GDP ranked second in 2010 and became the second largest economy in the world[7]. As a result, China's growth rate since 2010 has entered rapid growth, and its carbon emissions have been increasing for nearly a decade.To predict carbon emission data in recent years, data obtained from the CEADs database is first needed.

Table 1 Raw and cumulative data (in million tons)

Year	Initial data	Accumulate data
2011	9274.55	9274.55
2012	9858.99	19133.54
2013	10144.59	29278.13
2014	10013.06	39291.19
2015	9773.74	49064.93
2016	9598.69	58663.62
2017	9774.61	68438.23
2018	10071.63	78509.86
2019	10434.84	88944.70

Gray prediction is the prediction of systems that contain both known and uncertain information[8], gray prediction GM (1,1) uses the original discrete non-negative data column to obtain an approximate estimate of the original data generated by the solution at the discrete point, and thus predicts the subsequent development of the original data.

Set $x^{(0)}=(x^{(0)}(1),x^{(0)}(2),...,x^{(0)}(n))$ as the initial non-negative data column, and then accumulate it to obtain the new generated data column $x^{(1)}$ ($x^{(0)}$'s 1-AGO (Accumulating Generation Operator Sequence)), thereinto

$$x^{(1)}=(x^{(1)}(1),x^{(1)}(2),...,x^{(1)}(n)) \tag{1}$$

Let $z^{(1)}$ be the immediate neighbor of the sequence $x^{(1)}$ to produce the sequence, i.e. $z^{(1)}=(z^{(1)}(2),z^{(2)}(3),...,z^{(1)}(n))$

$$z^{(1)}(m)=\delta x^{(1)}(m)+(1-\delta)x^{(1)}(m-1),m=2,3,...,n\text{且}\delta=0.5 \tag{2}$$

The basic form of the GM (1,1) model is (b for the gray action amount, $-a$ for the development number):

$$x^{(0)}(k)+az^{(1)}(k)=b,k=2,3,...,n \tag{3}$$

Introduce the matrix form:

$$u=(a,b)^{T},Y=\begin{bmatrix}x^{(0)}(2)\\x^{(0)}(3)\\...\\x^{(0)}(n)\end{bmatrix},B=\begin{bmatrix}-z^{(1)}(2)&1\\-z^{(1)}(3)&1\\...\\-z^{(1)}(n)&1\end{bmatrix} \tag{4}$$

Thus, the GM (1,1) model can be expressed as $x^{(0)}(k)+az^{(1)}(k)=b$

$$Y=Bu \tag{5}$$

a,b for unknown parameters, estimated using least squares:

ISSN:2790-1661 DOI: 10.56028/aemr.1.1.178

$$\hat{u}=\begin{pmatrix}\hat{a}\\ \hat{b}\end{pmatrix}=(B^TB)^{-1}B^TY \tag{6}$$

$\hat{a}=0.008926, \hat{b}=10182.82$. Therefore, it can be predicted using the gray prediction model:

$$x^{(1)}(k)-x^{(1)}(k-1)=\int_{k-1}^{k}\frac{dx^{(1)}(t)}{dt}dt \tag{7}$$

The differential equation $\frac{dx^{(1)}(t)}{dt}=-\hat{a}x^{(1)}(t)+\hat{b}$ is called the whitening equation of the GM (1,1) model, and if we take the initial value:

$$\hat{x}^{(1)}(t)=\left[x^{(0)}(1)-\frac{\hat{b}}{\hat{a}}\right]e^{-\hat{a}(t-1)}+\frac{\hat{b}}{\hat{a}} \tag{8}$$

So:

$$\hat{x}^{(1)}(m+1)=\left[x^{(0)}(1)-\frac{\hat{b}}{\hat{a}}\right]e^{-\hat{a}m}+\frac{\hat{b}}{\hat{a}}, m=1,2,...,n-1 \tag{9}$$

Owing to:

$$x^{(1)}(m)=\sum_{i=1}^{m}x^{(0)}(i), m=1,2,...,n \tag{10}$$

So we can get this by:

$$\hat{x}^{(0)}(m+1)=\hat{x}^{(1)}(m+1)-\hat{x}^{(1)}(m)=\left(1-e^{\hat{a}}\right)\left[x^{(0)}(1)-\frac{\hat{b}}{\hat{a}}\right]e^{-\hat{a}m}, m=1,2,...,n-1 \tag{11}$$

In the evaluation, the residuals are often used for testing:

Absolute residuals:

$$\varepsilon(k)=x^{(0)}(k)-\hat{x}^{(0)}(k), k=2,3,...,n \tag{12}$$

Relative residuals:

$$\varepsilon_r(k)=\frac{|x^{(0)}(k)-\hat{x}^{(0)}(k)|}{x^{(0)}(k)}\times 100\%, k=2,3,...,n \tag{13}$$

Average relative residual difference:

$$\bar{\varepsilon}_r(k)=\frac{1}{n-1}\sum_{k=2}^{n}|\varepsilon_r(k)| \tag{14}$$

Level deviation test:

The grade ratio of the original data $\sigma(k)$ is calculated from $x^{(0)}(k-1)$ and $x^{(0)}(k)$

$$\sigma(k)=\frac{x^{(0)}(k)}{x^{(0)}(k-1)}(k=2,3,...,n) \tag{15}$$

The corresponding grade ratio deviations and average grade ratio deviations are calculated from the predicted development coefficient ($-\hat{a}$):

$$\eta(k)=|1-\frac{1-0.5\hat{a}}{1+0.5\hat{a}}\frac{1}{\sigma(k)}|, \quad \bar{\eta}=\sum_{k=2}^{n}\eta(k)/(n-1) \tag{16}$$

The result is $\bar{\varepsilon}_r(k)$=0195 and$\eta(k)$=0274, which indicates a very good fit to the original data.

Later prediction data can be obtained in the following table:

ISSN:2790-1661 DOI: 10.56028/aemr.1.1.178

Table 2 Prediction Data (unit: tn)

a particular year	Predicted data
2020	10110.82
2021	10144.94
2022	10179.18
2023	10213.53
2024	10248.00

According to the 2021 bp World Energy Statistical Yearbook, China's carbon dioxide emissions reached 10.24 billion tons (including Taiwan and Hong Kong) in 2020, accounting for 31.7 percent of the global carbon dioxide emissions[9].

According to the gray forecast data can be obtained error in 1%, so the gray forecast data has high accuracy. It is further roughly estimated that the carbon emissions that can be obtained in the manufacturing industry have been more than 30,000 million tons in recent years, and the carbon emissions will have a certain upward trend on this basis in the next few years, so in order to respond to national policies, high-emission enterprises must take certain carbon reduction measures.

Since the reform and opening up, the industrial sector (especially the manufacturing industry) has occupied an important position in the national economy, supporting economic and social development[10], and many of them have been listed in the "two highs", so the manufacturing industry should become an important area for carbon emission reduction.

3. Implementation measures

In order to better guide the implementation of measures, the AHP method is selected, and this paper decomposes the factors related to emission reduction decisions into several levels such as target layer and program layer, and provides a reference basis for the manufacturing industry through the calculation and comparison of these factors.

In order to increase the stability of the results, the weights of the arithmetic averaging method, the geometric averaging method, and the eigenvalue method are summed and the average value is taken, and the final weight result of each indicator is wi = (0.60, 0.28, 0.13) T. The following table is finally obtained.

ISSN:2790-1661 DOI: 10.56028/aemr.1.1.178

Table 10 Total the target layers

Target layer M	Criterion layer D	Scheme layer P	Total score (ranking)
Comprehensive evaluation of implementation measures contribution index A	Enterprise-level D 1 (0).595	Process optimization d 11 (0).348	0.2070（1）
		Raw material replacement d 12 (0.323)	0.1920（2）
		Industrial structure adjustment d 13 (0.052)	0.0310（9）
		Using Clean Energy d 14 (0.027)	0.0160（12）
		Carbon Capture d 15 (0.158)	0.0940（4）
		Process innovation d 16 (0.092)	0.0550（7）
	Related level D 2（0.277）	Low-carbon travel d 21 (0.477)	0.1320（3）
		Paperless Office d 22 (0.264)	0.0730（6）
		Strengthening employee awareness d 23 (0.1606)	0.0440（8）
		Develop other low-carbon products d 24 (0.066)	0.0180（11）
		Carbon sink (afforestation) d 25 (0.033)	0.0090（14）
	Social aspects of the D 3（0.1284）	Accelerating the digital transformation of d 31 (0.227)	0.0290（10）
		Develop emission reduction policy d 32 (0.671)	0.0860（5）
		Building an economical society, d 33 (0.102)	0.0130（13）

4. Results analysis

① From the perspective of the characteristic vector of the standard layer to the target layer, the weight at the enterprise level is the largest, while the weight of the social aspect is the smallest, indicating that for the carbon reduction of the manufacturing industry, the most important thing is to actively start from the enterprise, which is also in line with the actual situation.

②From the perspective of the weight of the scheme layer to the target layer, the weight of process optimization, raw material substitution, and low-carbon travel of enterprise personnel is the largest, which is consistent with the weight ranking of the scheme layer.

③From the results, the ranking is process optimization, raw material substitution, low-carbon travel of enterprise personnel, carbon capture, formulation of emission reduction policies, paperless office, process innovation, strengthening employee awareness, industrial structure adjustment, accelerating digital transformation, developing other low-carbon products, using clean energy, building a conservation-oriented society, and carbon sinks (afforestation). Therefore, for the manufacturing industry, we can first choose process optimization rather than innovation, and actively seek alternative raw materials, low-carbon travel, etc.

5. Conclusion

Based on the carbon emission data of previous years, this paper uses the method of grey prediction to predict the carbon emissions in the next few years, and then uses the AHP model to determine the final implementation order of carbon reduction measures. Based on the analysis results of this paper, the following conclusions are drawn: First, for the manufacturing industry, the reduction of carbon emissions should first start from the enterprise level. Enterprises should optimize the production process, replace high carbon emission raw materials with low carbon emission raw materials, use clean energy, increase carbon sink, appropriately adjust the industrial structure, and achieve carbon reduction from the source. Second, the employees try their best to

ISSN:2790-1661 DOI: 10.56028/aemr.1.1.178

achieve low carbon travel, achieve paperless office, and improve the awareness of low carbon environmental protection, to build a clean and economical society.

Through the implementation of the measures in this article and the combination of enterprise characteristics, it is conducive to generating greater economic, environmental and social benefits, enhancing its corporate image, and to some extent promoting the development of manufacturing enterprises in society. Therefore, it is of great significance to study the carbon emissions and carbon reduction policies of the manufacturing industry, and the amount of information covered by the gray forecasting model in this paper is small, but the data error is 1%, indicating that the accuracy is high, which has a guiding effect on the carbon emission prediction and carbon reduction measures of the manufacturing industry.

References

[1] Wang Feng, An Ruikun & Zhao Jingyi.(2021).Government institutional innovation under the goal of carbon neutrality.Journal of Nanjing University of Technology (Social Science edition) (06), 85-93 + 112.

[2] Zhang Fan, Wang Shuzhen, Li Yanhui, Yang Jianqiao, Sun Shenghan.Analysis of carbon emission problems and emission reduction countermeasures in China's manufacturing industry [J / OL].Chemical industry progress: 1-11 [2022-03-20].

[3] Xue Yinglan, Zhang Jing, Liu Yu, Chen Yu, Sun Jian, Jiang Hongqiang, Zhang Wei, Cao Dong."Double-carbon" target under the steel industry coal control and carbon reduction roadmap [J / OL].Environmental Science: 1-21 [2022-03-20].

[4] Ren Shihua, Xie Yachen, Jiao Xiaomomiao, Xie Heping.Carbon emission characteristics of coal development process and the technical ways of carbon neutrality development [J].Engineering Science and Technology, 2022,54 (01): 60-68.

[5] Kang Chongqing, Du Ershun, Li Yaowang, Zhang Ning, Chen Qixin, Guo Hongye, Wang Peng.The "Carbon Perspective" of the new power system: Scientific problems and Research framework [J].Power Grid Technology, 2022,46 (03): 821-833.

[6] Zheng Lu, Zhang Mingxia, Hu Jueliang, Han Shuguang.Carbon emission reduction decision issues in the garment industry under carbon trading and consumption subsidies [J].Journal of Textile Engineering, 2022,43 (01): 193-200.

[7] Lin Hong, Chen Qingkang, Chen Kaixin & Chen Xiaoguo.(2019).China's economic and social development looks at the changes in the statistical bulletin.China Statistics (08), 7-8.

[8] Xiong and Jin, Chen Mianyun, Qu Tan.(1998).Gray prediction methods based on similar relationships.Journal of Wuhan University of Communications, Science and Technology (03).

[9] Chen Huanhuan (2021-08-23).The latest bp world Energy Statistical Yearbook is released.Chinese Journal of Science, 003.

[10] Hu Lin, Yang Jianjun, Visa, Guo Nan & Ma Yuanye.(2021).Construction and implementation path of industrial Internet standard system.Chinese Engineering Science (02), 88-94.