Harbin 2020 R&D Personnel Demand Forecast Based on Manufacturing Green Innovation System

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Abstract. Because of the constraints of energy conservation and the impact on the environment, the manufacturing industry has adopted sustainable development as the goal, and a green manufacturing innovation system based on environmental protection has emerged. In order to provide R&D personnel support to manufacturing enterprises in Harbin, and in order to promote the construction of a green innovation system for manufacturing and the realization of the 13th Five-Year Plan, this article used the grey forecasting model and the univariate linear regression prediction to predict the number of R&D personnel in Harbin in 2020 based on the number of R&D personnel in 2010-2016, and the predicted values were 24,952 and 31,172 respectively. The results show that if Harbin continues to use its original development model, it will not be able to achieve the established development goals by 2020 because of the shortage of R&D personnel. Therefore, it is necessary to increase investment in R&D personnel so as to achieve the 13th Five-Year Plan of Harbin City and protect the ecological green development goals.

1 Introduction

In response to global climate change, energy conservation and emission reduction have been advocated by countries. As one of the major industries for energy consumption and pollutant emissions, manufacturing industry needs to assume specific tasks and responsibilities [1]. The manufacturing industry has become one of the major industries with high energy consumption, high pollution, and high emissions [2]. It is the municipal industry of Harbin which is the focus of development and plays an important role in achieving energy-saving emission reduction targets and green development strategies.

Today's society regards talent development as a strategic core. Talent has features that can be developed indefinitely. It is therefore seen as the main source of profit creation and has become the most important resource in social development. James M.W. Wong, Albert P.C.Chan, and Y.H.Chiang believe that the highest correlation with human resources demand forecast is economic indicators [3]. Chinese scholar Liu Fengchao once pointed out that when talent demand needed to be predicted, it is determined by economic development [4]. Therefore, based on the development goals of Harbin's 13th Five-Year Plan, the article forecasts the number of talents needed in Harbin in 2020. What are the requirements of the development goals in the 13th Five-Year Plan for the enterprises in the green innovation system of manufacturing industry in Harbin? Does the current development trend of the number of talents in Harbin City support the implementation of the corresponding 13th Five-Year Plan? These issues have become the main content of this study.

2 The Talent Types Needed by Enterprises in the Green Innovation System of Harbin Manufacturing

From the point of view of the development of the green innovation system for manufacturing industries in developed countries, most of them have high R&D strength and high R&D investment. According to the data released by the 2012 World Economic Forum, developed countries such as the United States and Japan rank top in R&D investment in companies (sixth and lth respectively), while China ranks 23rd in R&D investment rankings. Judging from this, R&D investment has a great influence on the ability of manufacturing green innovation.

R&D personnel is the main body of corporate R&D activities, and it is the most dynamic and the most important input factor in R&D activities of enterprises. It reflects the R&D input scale of the enterprise to some extent. Nowadays, green, low-carbon, and environmental protection are the themes advocated by industrial development in various countries. R&D personnel can carry out green technological innovation to achieve the goal of protecting the ecological environment. Therefore, this article will examine the needs of R&D personnel.

3 Forecasting Process

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The R&D expenditure and R&D population table shown in Table 1 can be obtained by consulting the 2010-2016 Harbin Statistical Year book.

Table 1. Summary of R&D Expenditure and R&D Population.

Year	R&D Expenditure (Ten thousand)	R&D Population (Person)
2010	351282	15339
2011	404742	16997
2012	473101	16768
2013	548669	21314
2014	578513	19762
2015	585984	20156
2016	654493	20799

3.1 GM (1.1) Model

The grey forecasting model is based on the evolution of the system. Through grey forecasting is used, the evolution of the system can be accurately described, and valuable information can also be obtained through the analysis of known information.

The manufacturing green innovation system can be considered as a gray system because it includes not only known information but also unknown information. The grey forecasting model has three advantages. First, there is no special requirements or restrictions on the sample data. Second, human subjective assertions can be avoided because each person's experience, knowledge, and preferences are different. This method can avoid this error. Third, the growth trend of R&D in Harbin can be reflected. The steps to create a grey forecasting model are as follows:

Step1: Set the known historical load raw data sequence:

$$X^{(0)} = (\mathrm{x}^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(\mathrm{n}))$$

Step2: Establishing the one-time AGO sequence:

Where, $X^{(1)}(\mathrm{k}) = \sum_{\mathrm{i}=1}^{\mathrm{k}} x^{(0)}(i)$

Step3: Establishment of the following first order differential equation: Where, a,b is the unknown elements.

$$\frac{\mathrm{d}x^{(1)}(t)}{dt} + ax^{(1)}(t) = b \quad (1)$$

Step4: Determine the data matrix:

$$\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} = \begin{bmatrix} -\frac{1}{2}\left[x^{(1)}(1) + x^{(1)}(2)\right] & 1 \\ -\frac{1}{2}\left[x^{(1)}(2) + x^{(1)}(3)\right] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}\left[x^{(1)}(n-1) + x^{(1)}(n)\right] & 1 \end{bmatrix} \begin{pmatrix} a \\ b \end{pmatrix}, \quad X_{\mathrm{n}} = BN$$

Where, $X_n = (\mathrm{x}^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(\mathrm{n}))^T$, $N = \begin{pmatrix} \mathrm{a} \\ \mathrm{b} \end{pmatrix}$

Step5: With the least square method, substituting a,b into the formula (1) and then solve the differential equation. The grey forecasting model available:

$$x^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right]e^{-ak} + \frac{b}{a}(k = 0,1,2\cdots)$$

Step6: Predicting the value of . The predicted value of can be estimated as:

$$X^{(0)}(k+1) = (\mathrm{X}^{(1)}(k+1) - X^{(1)}(k) \qquad k = 1,2,\ldots\ldots)$$

When, $\mathrm{k} = 1,2,3,..n-1$, the above equation yields the fitted value; when $\mathrm{k} \geq \mathrm{n}$, $\mathrm{x}^{(0)}(k+1)$ is the predicted value. Therefore, the steps using the grey forecasting model to predict the number of R&D people in Harbin in 2020 are as follows:

Step1: Set the known historical load raw data sequence:

$x^{(0)}$ = (15339,16997,16768,21314,19762,20156,20799)

Step2: Using an accumulated generating series:

$x^{(1)}$ = (15339,32336,49104,70418,90180,110336, 131135)

Step3: Quasi-smoothness test for $X^{(0)}$:

$P(k) = X^{(0)}(k)/X^{(1)}(k-1)$, If $P(t) < 0.5$ then the quasi-smooth condition is satisfied. After the calculation, the following data is obtained, and when $\mathrm{k} > 3$, a quasi-smooth test is passed.

$$\mathrm{p}(2) = 1.11; \mathrm{p}(3) = 0.52; \mathrm{p}(4) = 0.43$$
$$\mathrm{p}(5) = 0.28; \mathrm{p}(6) = 0.22; \mathrm{p}(7) = 0.19$$

Step4: Quasi-exponential law test on $x^{(1)}$:

$m^{(1)}(k) = X^{(1)}(k)/X^{(1)}(k-1)$, if $m^{(1)}(k) \in [1,1.5]$, then the quasi-exponential law test is satisfied. After the calculation, the following data is obtained, and when $\mathrm{k} > 3$, through the quasi-exponential law test.

$$\mathrm{m}^{(1)}(2) = 2.11; \mathrm{m}^{(1)}(3) = 1.52; \mathrm{m}^{(1)}(4) = 1.43$$
$$\mathrm{m}^{(1)}(5) = 1.28; \mathrm{m}^{(1)}(6) = 1.22; \mathrm{m}^{(1)}(7) = 1.19$$

Step5: If all of the above conditions are satisfied, a grey forecasting model can be established for $x^{(1)}$, otherwise it needs to continue accumulating. After calculation, a grey forecasting model is obtained:

x(k+1)=428336.324271exp(0.03988k)-412997.324271. Where, a=-0.03988,b=16470.423409

Comparing the actual values of the 2010-2016 R&D figures with the forecasted values, the calculation results shown in Table 2 and the predicted value of the R&D population in 2020 are obtained.

Table 2. Relative Errors and Forecasts

Year	Historical data (Person)	Predicted value (Person)	Residual	Residual
2010	15339	15339	0	0
2011	16997	17427	430	2.53
2012	16768	18136	1368	8.16
2013	21314	18874	-2440	11.45
2014	19762	19642	-120	0.61
2015	20156	20441	285	1.42
2016	20799	21273	474	2.28
2020		24952		

In order to ensure that the model has a good accuracy, the model must be tested. Table 3 is an accuracy check table.

Table 3. Accuracy check level reference table

Accuracy level	Index close value			
	Relative Error	Relational degree	Standard Deviation ratio	Small error possibility

	α	ε_0	C_0	P_0
First level	0.01	0.9	0.35	0.95
Second level	0.05	0.8	0.5	0.8
Third level	0.1	0.7	0.65	0.7
Fourth level	0.2	0.6	0.8	0.6

Where

$$S_1^2 = \frac{1}{n}\sum_{k=1}^{n}\left[x^{(0)}(k) - \bar{x}\right],$$

$$S_2^2 = \frac{1}{n}\sum_{k=1}^{n}\left[\varepsilon^{(0)}(k) - \bar{\varepsilon}\right]^2, C = \frac{S_2}{S_1}$$

$$p(k) = \left|\varepsilon^{(0)}(k) - \bar{\varepsilon}\right|$$

So: Raw sequence variance: S_1^2= 4629691.67

Residual sequence variance: S_2^2= 1190031.96

Standard Deviation ratio: C= 0.5

Small error possibility: P_0= 0.6475*S_1= 1393.21

As can be seen from Table 4, P(k) values are less than 1393.21 in all other years except 2013. So P=0.86.

Table 4. P(k) calculation result summary table

Year	P(k)
2010	0.43
2011	430.43
2012	1368.43
2013	2439.57
2014	119.57
2015	285.43
2016	474.43

Therefore, the prediction accuracy grade of this model is shown in Table 5.

Table 5. Accuracy level results

Index	Calculation results	Accuracy level
-a	0.03988	Medium and long term forecast
Relative Error	0.04	Second level
Relational degree	0.994	First level
Standard Deviation ratio	0.5	Second level
Small error possibility	0.86	Second level

-a is the coefficient of development and reflects the development of the system, indicating that the model is suitable for medium and long-term prediction. Other indicators are graded two, one, two, and two. So, the prediction accuracy of the model is acceptable. Therefore, the number of R&D personnel in Harbin in 2020 using the grey forecasting model is 24952.

3.2 Univariate Linear Regression Prediction

Taking The Thirteenth Five-Year Plan of Harbin as the research background, the development goal of the The Thirteenth Five-Year Plan of Harbin City has a guiding role for the number of R&D personnel required. Set the target as an independent variable, and sets the required number of R&D personnel as dependent variables, and establish a univariate regression prediction model to obtain the number of R&D personnel required for a given year and target. Therefore, it is particularly important to look for a variable that has a linear relationship with the number of R&D people. Cao Qinrun and other Chinese scholars have researched in this area. They used multiple linear regression method to obtain a significant positive correlation between R&D spending and R&D personnel turnover [5]. Therefore, the article sets R&D spending as an independent variable, and sets the required number of R&D personnel as the dependent variable, and establishes a univariate linear regression prediction, so as to obtain the number of R&D personnel required under the 2020 target.

The equations for R&D expenditures and R&D personnel numbers for Harbin manufacturing companies from 2010 to 2016 are established in Table 1. The results are as follows:

$$Y=0.0195X+8724 \quad R^2=0.824 \qquad (2)$$

In 2015, the GDP of Harbin was 575.12 billion yuan, with an average annual growth rate of 6.25%; The Thirteenth Five-Year Plan of Harbin Municipality requires that by 2020, the goal of the economic development of manufacturing enterprises is to regulate that the industrial added value exceeds 140 billion yuan, with an average annual increase of 7%; According to "Harbin Statistical Yearbook 2016", the total industrial output value of the manufacturing industry in 2015 was 328.308 billion yuan; The Thirteenth Five-Year Plan of Harbin requires that the total R&D input of the whole society up to 2.5% of GDP by 2020. Calculated from the above 4 information, Harbin's 2020 manufacturing R&D expenditure will be 11.517 billion yuan. Therefore, the R&D expenditure of RMB 11.5171 billion was included in formula(2), and the number of R&D personnel in manufacturing in 2020 totaled 31,172.

3.3 Analysis of Forecast Results

By using the grey forecasting model and the univariate linear regression prediction to predict the number of R&D personnel in 2020, the prediction results show that the number of R&D personnel in 2020 is not equal between the two prediction methods. The number of R&D personnel predicted by the univariate linear regression prediction based on R&D expenditure is 31,172, which is 6,220 more than the number of R&D personnel obtained from the grey forecasting model. The grey forecasting model predicts the number of R&D personnel required according to the historical development law, while the univariate linear regression prediction uses the historical data to establish the equation, and predicts the number of R&D personnel required under the requirements of future development goals. The predictive value is to achieve the future development goals, so it is more valuable.

R&D personnel is the main body of corporate R&D activities, and it is the most dynamic and the most

important input factor in corporate R&D activities. The number of R&D personnel in the company reflects the importance of the company's R&D activities, and it also reflects the R&D investment scale of the company to some extent. According to the forecast of relevant agencies, R&D personnel is the most popular people currently and in the future [6]. The R&D level of a company embodies the competitiveness of a company. R&D personnel is the core strength of science and technology activities. Their current status and development trends can reflect the national level of scientific and technological competitiveness in a certain way. Obviously, the number of R&D personnel has played a key role in the green development of the city.

As Harbin's 13th Five-Year Plan puts forward requirements for green innovation,advocating vigorous efforts to cultivate green economy, promoting green consumption, focus on the development of green food, energy conservation and environmental protection and other green industries, and creating more “green wealth”, it is necessary to in the ecological environment.

Under the requirements of the 13th Five-Year Green Development in Harbin, the effect of R&D investment on green technology innovation is positive and will continues to grow with time [7]. Large R&D investment will help improve the company's enthusiasm for innovation and willingness to develop new products, increase company productivity and energy conversion efficiency, and bring economic benefits to enterprises while reducing the amount of polluting waste and improving environmental conditions. Therefore, it is necessary to increase the input of R&D personnel to achieve the purpose of protecting the ecological environment.

To sum up, we should continue to increase investment in R&D personnel and enhance R&D personnel's important role in promoting green technology innovation so as to achieve the 13th Five-Year Plan of Harbin City and protect the ecological green development goals.

4 Suggestions for increasing the number of R&D personnel

Harbin is in a relatively backward area of economic and technological development. There is a phenomenon of insufficient input and loss of R&D personnel. Therefore, we must take active measures to cultivate R&D personnel, create opportunities for R&D personnel to display their talents, and increase their attractiveness so as to increase the input of R&D personnel.

4.1 Raising the income level of R&D personnel

The improvement of the disadvantages of Harbin's low level of development and poor technological environment can be achieved by appropriately raising the income level of R&D personnel. It can increase the government's investment in the basic construction of science and technology, widen the channels, and guide the entire society to provide basic hardware conditions for scientific and technological innovation so as to enhance the attractiveness of R&D personnel.

4.2 Perfecting R&D personnel incentive mechanism

Good incentive mechanisms and methods can increase the enthusiasm and passion of R&D personnel. The enterprises can attract R&D personnel by developing reasonable and appropriate incentive mechanisms for R&D personnel taking steps such as salary increase, promotion, continuing learning, and further education.

4.3 Increasing the number of R&D positions in companies, universities and research institutions

With the gradual implementation of Harbin's innovation strategy and policies, the market demand and social demand for science and technology activities will further increase, and the number of R&D employment positions will also increase year by year. Therefore, it is possible to increase the number of R&D positions in companies, universities, and research institutions. The proportion of R&D personnel in the labor force should be increased.

5 Conclusion

In order to forecast the number of R&D personnel in 2020, this paper is based on the green innovation system of manufacturing industry using the grey forecasting model and the univariate linear regression prediction according to the historical data of R&D personnel in Harbin from 2010 to 2016, the predicted values of R&D personnel in Harbin in 2020 are respectively 24952, 31172 .

Univariate linear regression prediction based on R&D expenditure is 6220 more than R&D personnel out of the grey forecasting model. It means that if Harbin will still be operating in accordance with the current development laws, the number of R&D personnel will not be sufficient to complete the corresponding development goals by 2020. At the same time, R&D personnel is required to carry out green technological innovation in order to achieve environmental protection and promote green development. This article proposes a total of three suggestions to increase the number of R&D personnel: Raising the income level of R&D personnel, perfecting R&D personnel incentive mechanism, and increasing the number of R&D positions in companies, universities and research institutions to provide personnel support for the implementation of the 13th Five-Year Plan of Harbin City and the protection of the environment.

References

1. Zhu, Q&Sarkis. An inter-sectoral comparison of green supply chain management in china: Drivers and practices[J]. Journal of Cleaner Production,

2006, 14(5): 472-486.

2. Cao H, DuY, ChenY. Exploring a new low-carbon development paradigm for China's future manufacturing sectors[J]. Journal of Science and Technology Policy in China, 2011, 2(2): 159-170.
3. James M. W. Wong, Albert. C. Chan, Y. H. Chiang. Construction Manpower Demand Forecasting: A Comparative Study of Univariate Time Series, Multiple Regression And Econometric Modeling Techniques[J]. Engineering Construction and Architectural Management, 2011, 18(1).
4. Liu Fengchao. Some Methodological Considerations on Personnel Needs and Research[J]. Prediction, 2001, (4): 11-13.
5. Cao Qinrun, Liang Laiyu, Xiao Yangyang. An Empirical Study on the Relationship between R&D Expenditure and R&D Personnel Change[J]. Science & Technology Progress and Policy, 2009, 26(8): 20-24.
6. Zhang Xu, Wang Yu. Influence of Environmental Regulation and R&D Investment on Green Technology Innovation[J]. Science & Technology Progress and Policy, 2017, 34(17): 111-119.
7. Zhu Changming, Chen Yongli, Deng Ying. Analysis on the Development Trend of R&D Resources in Hubei Province Based on Grey Prediction[J]. Pioneering With Science & Technology Monthly, 2012, (8): 14-17.