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Multi-Model Intelligent Prediction of Pakistan Port Throughput under the Background of China-Pakistan Economic Corridor

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***Abstract*—China-Pakistan Economic Corridor is model project and flagship project of China's "One Belt One Road "initiative. The cooperation between China and Pakistan covers all levels of power, roads, ports, and even education. A large number of investment in infrastructure and industrial projects will greatly promote Pakistan economic development greatly, which will bring strong industrial development , transportation logistics and increase port throughput, so we carry out forecast analysis of Pakistan port throughput in order to provide relevant government enterprises with a valuable reference for decision-making. This paper uses three intelligent forecasting models: neural network model, logistic model and grey theory model to predict Pakistan's port throughput and container throughput in 2020, 2025, 2030, and 2035. The forecast result data shows: in good times, economic trends by 2035. The optimistic high forecast results in port throughput reaching about 220 million tons and container throughput reaching 6.91 million TEU. On the contrary, when the economic trend is relatively weak, the low forecast result of Pakistan's port throughput is 113 million tons, and the container throughput is 2.89 million TEU.**

***Index Terms*—grey theory model prediction, logistic model prediction, neural network model prediction, Pakistan port throughput.**

I. INTRODUCTION

China-Pakistan Economic Corridor is the model project and flagship project of China's "One Belt One Road " initiative. Investment in a large number of infrastructure and industrial projects will greatly promote Pakistan economic development, increase GDP and improve cargo flow. Seaports are generally important to the country portal, because its throughput is generally positively correlated with GDP and cargo flow. Karachi Port, Qasim Port and Gwadar is the three major ports of Pakistan and Gwadar Port is continuous construction of China. After taking over in, Karachi Port and Qasim Port bear 96% of the import and export cargo transportation volume. There is almost no inland water transportation in Pakistan. The power of port transportation comes from the flow of commodities brought about by international trade, including commodity import, export, re-import and re-export. Pakistan's import and export transportation mainly relies on sea transportation, and the total value of seaborne goods accounts for more than 84% of the total import and export value, which is currently stable at about 87%.Since most of the imported commodities are commodities with lower price per unit weight, such as petroleum, chemicals, transportation equipment, etc., the cheaper shipping method is determined as the main import channel. In 2012, the total import and export weight of Pakistan reached 316,600 million tons. In 2017, the total import and export volume of Pakistan was 312.3 million tons. In order to meet the needs of future import and export of goods, Pakistan has invested a lot of money in port infrastructure, and its port construction rating has also been upgraded from 3.7 to 4.1 in the past. The International Monetary Fund approved Pakistan's US$6.4 billion loan application for national construction, and Pakistan, through the strategic cooperation of the China-Pakistan Economic Corridor, in the development of energy, infrastructure, industrial parks and economic zones, and the development of Gwadar Port Cooperate in four areas to promote national construction. It is planned to add 10,000 megawatts of electricity to the national grid to meet future development needs and lay a solid foundation for industrial electricity use. Pakistan has signed the construction of two major highways with China, one is the Karachi-Lahore highway, and the other is the Kashgar-Gwadar highway connecting China and Pakistan, from Xin Jiang Province to Pakistan. It is planned to set up 4 to 5 locations in the country as pilot projects in industrial parks to promote regional economic development. This article believes that the construction of the China-Pakistan Economic Corridor will drive the growth of Pakistan's GDP ,bring about strong industrial development and transportation logistics, and increase port throughput. The forecast and analysis of Pakistan's port throughput are carried out in order to provide a valuable reference for relevant government enterprises. Basis for decision-making.

II. LITERATURE REVIEW AND RESEARCH METHODS

A. Literature review

From the perspective of relevant domestic and foreign research, many scholars have done a lot of academic discussion on port throughput forecasting. For example, Zhang Lijun, Zhang Ping and others used the principal component analysis method to find that the regional GDP, the output value of the secondary industry, the output value of the tertiary industry, the railway freight route, and the total

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import and export volume have a positive impact on the port throughput, and the output value of the primary industry, road freight volume has a negative impact on port throughput. Xu Jianhua and Wang Dan analyzed the macro environment of Ningbo Port and Tianjin Port in China, and pointed out that economic development, improvement of people's living standards, scientific and technological progress, development of foreign trade, improvement of cross-strait relations, acceleration of urbanization, development of hinterland resources and promotion of throughput. Zhu Jian established a VAR model based on the gravity model of my country's coastal port cargo throughput, and used the data since the financial crisis as a sample to test the model. It is found that the RMB exchange rate, fixed investment in the transportation industry, and world economic conditions all have a greater impact on port traffic, while domestic economic conditions have no significant impact on port cargo throughput. Tomás Serebrisky, Bruce A. Blonigen, etc. used 10 years of panel data to return to 63 ports along the Latin American and Caribbean Sea, and found that port technical efficiency represented by terminal area, berth length and number of cranes has an impact on port economic development Plays a decisive role. Liu Yan and others used the grey system theory to study the throughput forecast of Huainan Port and pointed out that when making long-term and short-term forecasts, the GM (1,1) model and Verhulst model should be changed to make the results more accurate. Rashed Y and Chen are using multiple models to compare and find that the seasonal ARIMA model is more realistic. Lubo et al. put forward a new idea for port throughput forecasting and established a port forecast model based on context changes. The purpose is to adjust the penalty coefficient to quickly adapt the model to the status quo when the port context changes. Through the throughput data of Dalian Port and Tianjin Port from 1980 to 2014, the model is compared with the SARIMA model, and it is concluded that the port throughput forecast model with changing circumstances is more realistic. At present, through regression models, the method of forecasting based on the influencing factors of port throughput is not completely applied due to influencing factors. At present, the main forecasting method is to analyze time series data and predict future throughput based on past throughput. From the aspect of data results, the fitting effect is better. But there are also disadvantages. This model cannot reflect the forecast of emergencies or port throughput that is still in its infancy stage, because ports in the infancy stage are still under construction, and the past throughput has little reference for the future. More forecasting requires planning and strategic insight, combined with expert forecasting methods to achieve better results.

B. Research methods

According to existing research, the main forecasting methods generally include time series method, regression analysis method, grey model forecasting method, neural network method and combination forecasting method. In actual forecasting, different methods are suitable for different situations due to their inherent forecasting logic and model limitations. However, a purely single model will be biased in the prediction behavior. Therefore, combining different prediction models, combining the predicted values with weights, and fusing the advantages of each model will make the prediction more scientific and referential .Therefore, this paper chooses to predict the throughput of Pakistan's ports with neural network prediction models, growth curve models, multivariate prediction vector error correction models and their combined models.

1. Neural network prediction model

Neural network model is a new information processing method, imitating the brain operation mode, by inputting multiple sets of data, performing non-linear processing, and outputting predicted values through its own continuous learning and testing. A neural network usually consists of three layers: input layer, hidden layer and output layer. The functional relationship between output and input of each hidden layer and output layer neuron is:

$$Ij=\sum iWijOi$$

$$Oj=sigmod(Il)=11+e-Il$$

Among them, Wijrepresents the weight of the connection between neuron i and neuron j, Oj represents the output of neuron j, and sigmod is a special function used to map any real number to the (0,1) interval.

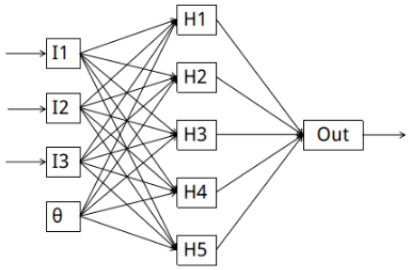

Figure 1. Schematic diagram of neural network prediction model

2. Growth curve model

Growth curve (also known as Logistic model) is a kind of growth curve, which belongs to the nonlinear model of time series model. It mainly describes the growth process of things that are in the upward development stage over time. The growth process has gone through three stages: slow start, rapid growth and slow growth and finally stabilized, which is in line with the logic and facts of the growth cycle of things. The throughput of Pakistan's ports is shown in Figure 2. It can be seen that due to port facilities and road-to-port connectivity, the growth phase of Pakistan's port throughput is between the initial period and the rapid growth period. The formula of the growth model is as follows:

$$Y = 1 / (1/u + (b0 * (b1^{**}t)))$$

$$\text{or } \ln(1/y-1/u) = \ln(b0)+(\ln(b1) * t)$$

Among them, u, b0, b1 are parameters, and the independent variable t is time. The values corresponding to the three parameters can be calculated through calculation, so that y can be predicted through time t.

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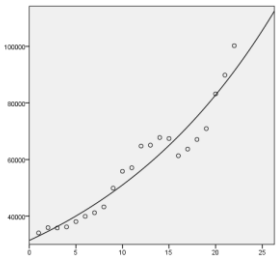

Figure 2 Time trend of Pakistan port throughput

3. *Grey prediction model*

The gray model is to establish a gray differential prediction model through a small amount of incomplete information, and make a fuzzy long-term description of the development of things. The essence of establishing the GM(1,1) model is to accumulate the original sequence once to make the generated sequence show a certain law, and then establish the first-order linear differential equation model to obtain the fitting curve to predict the system. The general form of the model is:

Let the original sequence：

$$x(0)=\{x(0)(1),x(0)(2),\cdots, x(0)(n)\} \quad (1)$$

Do an accumulation to generate：

$$x(1)=\{x(1)(1),x(1)(2),\cdots, x(1)(n)\} \quad (2)$$

$$X^{(1)}=\sum_{j=1}^{i} X^{(0)}(j)X^{(1)}$$

Where (i=1,2,⋯, n)

For the first-order linear whitening differential equation $\frac{dx^{(1)}}{dt}+ax^{(1)}=u$ (3)

Solve the parameters a, u using the least square method.

The gray prediction GM(1,1) model of $x^{(1)}$ is $\hat{X}^{(1)}(k+1)=[X^{(0)}(1)-\frac{u}{a}]e^{-ak}+\frac{u}{a}$ (k=0,1,2,⋯)

After the calculation of $\hat{X}^{(1)}(k+1)$, the actual forecast value can be obtained $X^{(0)}(k+1)=\hat{X}^{(1)}(k+1)-\hat{X}^{(1)}(1)$.

III. Model Estimation and Result Analysis

A. *Pakistan port throughput forecast*

1. *Neural network prediction*

Using the neural network method to predict, take GDP denominated in constant US dollars in 2010, total import and export of goods, total population, and total household consumption denominated in constant US dollars in 2010 as covariates, and use port throughput from 1996 to 2017 The amount (thousand tons) is used for machine learning, and the final fitting results are as follows:

Table 1 Neuro predictive covariate index

years	Total population (100 million people)	GDP (tens of billions of dollars)	Import and export of goods and services (100 million US dollars)	Residents' final consumption expenditure (10 billion US dollars)
1996	1.273	10.428	374.773	8.534
1997	1.311	10.534	357.389	8.892
1998	1.348	10.803	337.181	9.031
1999	1.386	11.198	321.582	9.702
2000	1.423	11.675	332.523	9.741
2001	1.460	12.090	351.263	10.079
2002	1.495	12.394	370.911	10.261
2003	1.531	13.110	436.961	10.626
2004	1.567	14.099	412.370	11.309
2005	1.603	15.018	525.321	12.528
2006	1.640	15.904	605.781	12.852
2007	1.678	16.673	593.457	13.407
2008	1.716	16.956	604.880	13.884
2009	1.755	17.436	535.534	13.818
2010	1.794	17.717	582.324	14.123
2011	1.833	18.203	587.596	14.771
2012	1.873	18.842	540.222	15.514
2013	1.913	19.670	574.527	15.846
2014	1.953	20.590	571.883	16.731
2015	1.994	21.564	551.648	17.216
2016	2.036	22.756	601.543	18.528
2017	2.079	24.020	681.997	20.103
2018	2.572	25.422	791.724	21.352
2019	2.887	25.673	850.543	21.975
2020	3.227	17.833	791.240	22.556
2025	5.280	21.649	978.374	28.648
2030	7.936	26.146	1231.514	36.534
2035	11.207	31.427	1,566.897	46.549

Table 2 Pakistan port throughput (unit: 100,000 tons) forecast results

years	Port throughput (100,000 tons)	fitted value	Error ratio	years	Port throughput (100,000)	fitted value	Error ratio
1996	340.60	359.74	-5.62%	2010	674.27	655.12	2.84%
1997	359.35	359.74	-0.11%	2011	613.51	655.12	-6.78%
1998	357.98	359.74	-0.49%	2012	636.90	655.19	-2.87%
1999	361.90	359.74	0.60%	2013	671.01	709.41	-5.72%
2000	380.62	378.60	0.53%	2014	709.41	709.41	0.00%
2001	399.18	412.03	-3.22%	2015	832.18	709.41	14.75%
2002	412.03	412.03	0.00%	2016	898.51	919.56	-2.34%
2003	432.65	421.31	2.62%	2017	1002.40	950.26	5.20%
2004	498.94	498.94	0.00%	2018		987.74	
2005	558.55	561.15	-0.47%	2019		989.19	
2006	570.97	568.15	0.49%	2020		1021.29	
2007	647.61	64812	-0.08%	2025		1040.38	
2008	650.87	649.01	0.29%	2030		1042.85	
2009	677.79	655.04	3.36%	2035		1136.93	

It can be seen from the above table that the results of port throughput (100,000 tons) predicted by neural network, except for the abnormal value in 2015, the remaining basic error ratios are all below 6%.Analyzing the port throughput in 2017, the port throughput growth in 2017, in terms of the ratio of absolute and relative volume, increased too fast compared to previous years, and the throughput of Pakistan's ports in the first half of 2018 did not exceed 40 million tons, namely It did not reach 50% of 2016. It is inferred that the port throughput in 2017 is an abnormal value. According to the forecast results, the throughput of Pakistan's ports is expected to reach 113 million tons by 2035, an increase of

10% over 2017.

2. Logistic model

According to the regression of the 1996-2017 time series model, the model results obtained with high goodness of fit are as follows:

Y = 1 / (1/0.000032 + (0.952687**t))) R 2 =0.941

Table 3 Pakistan port throughput (unit: 100,000 tons) forecast results

years	Port throughput	fitted value	Error ratio	years	Port throughput	fitted value	Error ratio
1996	340.6	329.800	3.17%	2010	674.27	650.023	3.60%
1997	359.35	346.178	3.67%	2011	613.51	682.302	-11.21%
1998	357.98	363.369	-1.51%	2012	636.9	716.185	-12.45%
1999	361.9	381.413	-5.39%	2013	671.01	751.750	-12.03%
2000	380.62	400.354	-5.18%	2014	709.41	789.082	-11.23%
2001	399.18	420.236	-5.27%	2015	832.18	828.267	0.47%
2002	412.03	441.104	-7.06%	2016	898.51	869.398	3.24%
2003	432.65	463.009	-7.02%	2017	1002.4	912.571	8.96%
2004	498.94	486.002	2.59%	2020		1055.377	
2005	558.55	510.137	8.67%	2025		1,344.754	
2006	570.97	535.470	6.22%	2030		1,713.463	
2007	647.61	562.061	13.21%	2035		2,183.245	
2008	650.87	589.972	9.36%				
2009	677.79	619.270	8.63%				

It can be seen from the error ratio between the actual value of the port throughput and the fitted value that the Logistic model has a lower degree of fit than the neural model, and the error ratio of different years has a large gap. A few years have a higher degree of fit. In 15 years, the error ratio is below 10%, which can be used as a rough reference.

B. Forecast of container throughput

1. Neural network prediction

Uses the neural network method to predict. The GDP, total import and export volume of goods, total population, and the total consumption of residents priced in US dollars at constant prices in 2010 are used as covariates. 1996 From 2016 to 2016, the port throughput (ten thousand TEU) was subjected to machine learning, and the final fitting results are as follows:

Table 4 Pakistan container throughput (unit:ten thousand TEU) forecast results

years	TEU (ten thousand pieces)	Predictive value	Relative error
2003	78.76	102	-29.51%
2004	126.94	120.66	4.95%
2005	168.64	153.48	8.99%
2006	177.69	166.26	6.43%
2007	193.59	183.31	5.31%
2008	193.8	195.34	-0.79%
2009	205.81	197.5	4.04%
2010	214.9	205.6	4.33%
2011	213.2	221.73	-4.00%
2012	224.4	237.02	-5.62%
2013	244.5	246.5	-0.82%
2014	253.46	260.43	-2.75%
2015	275.56	267.52	2.92%
2016	264.51	270.46	-2.25%
2020		282.36	
2025		286.36	
2030		288.25	
2035		288.99	

The prediction results of port container throughput using neural prediction method show that, except for the error of 29% in 2003, the error value of the remaining years is basically below 6%, and since 2013, the relative error is below 3%, and the degree of fit is very high.The forecast results show that by 2035, Pakistan's container throughput is expected to reach 2.89 million 20-foot standard containers, an increase of only 190,000 from 2016, indicating that the results of the neural forecasting method indicate that the future economic development of Pakistan is still in a slow start stage. , So the increase in forecast results is not obvious.

2.GM(1,1) model prediction

Due to the unstable exchange rate of the ruble, the legal currency of Pakistan, the total amount of seaborne cargo denominated in rubles cannot reflect the actual total volume of imported goods. Therefore, the port throughput and port throughput weight indicators are used in the gray forecast. The principle of the GM(1,1) model is to accumulate the original sequence once to make the generated sequence present a certain law, and then establish a first-order linear differential equation to obtain a fitting curve to predict the system.

Table 5 Pakistan port throughput (unit: 100,000 tons)

years	Cargo throughput (100,000 tons)	years	Cargo throughput (100,000 tons)
1996	340.60	2006	570.97
1997	359.35	2007	647.61
1998	357.98	2008	650.87
1999	361.90	2009	677.79
2000	380.62	2010	674.27
2001	399.18	2011	613.51
2002	412.03	2012	636.90
2003	432.65	2013	671.01
2004	498.94	2014	709.41
2005	558.55	2015	832.18

Table 6 container throughput (unit: 20'TEU million pieces)

years	Container throughput (ten thousand TEU)	years	Container throughput (ten thousand TEU)
2003	78.76	2010	214.9
2004	126.94	2011	213.2
2005	168.64	2012	224.4
2006	177.69	2013	244.5
2007	193.59	2014	253.46
2008	193.80	2015	275.56
2009	205.81	2016	264.51

The GM(1,1) model is used to predict the total weight of Pakistan's maritime cargo and the port container throughput. The data comes from the Pakistan Statistical Yearbook and the EPS platform. The specific data is shown in the following table. Use models to predict port cargo throughput data from 1996-2015 and 2006-2015 data; predict port container throughput from 2003-2016 data, compare model results, and select the best prediction model, The model prediction results are as follows:

Table 7 Pakistan port container throughput fitting results

(unit: ten thousand TEU)

years	Actual value	fitted value	Relative error
2003	78.76	78.76	0.000
2004	126.94	156.73	-0.190
2005	168.64	164.44	0.026
2006	177.69	172.52	0.030
2007	193.59	181.01	0.070
2008	193.80	189.91	0.020
2009	205.81	199.25	0.033
2010	214.9	209.04	0.028
2011	213.2	219.32	-0.028
2012	224.4	230.11	-0.025
2013	244.5	241.42	0.013
2014	253.46	253.29	0.001
2015	275.56	265.75	0.037
2016	264.51	278.81	-0.051

Table 8 Pakistan port throughput fitting results (unit: 100,000 tons)

years	Actual value	fitted value	Relative error	years	Actual value	fitted value	Relative error
1996	340.60	340.60	0.00	2007	647.61	620.89	0.04
1997	359.35	361.58	0.01	2008	650.87	634.82	0.02
1998	357.98	377.77	0.06	2009	677.79	649.06	0.04
1999	361.90	394.68	0.09	2010	674.27	663.62	0.02
2000	380.62	412.35	0.08	2011	613.51	678.50	0.11
2001	399.18	430.80	0.08	2012	636.90	693.72	0.09
2002	412.03	450.09	0.09	2013	671.01	709.28	0.06
2003	432.65	470.23	0.09	2014	709.41	725.19	0.02
2004	498.94	491.28	0.02	2015	832.18	741.46	0.11
2005	558.55	513.27	0.08				
2006	570.97	570.97	0.00				

It can be seen that the GM(1,1) model's prediction of container throughput is better than the prediction of port cargo weight. The relative error between the fitted value of the container throughput prediction and the true value fluctuates at the level of 3%, from 2010 to 2014 The degree of annual fitting is getting better and better, the best fitting is 0.1% in 2014, and the highest relative error of forecast in the past seven years is 2016, reaching 5%.

Due to the large amount of container throughput data, the forecast is divided into two parts, one is based on 20 years of data for forecasting, and the other is based on nearly 10 years of data for forecasting. The above table shows the fitting after residual correction. As a result, it can be seen that compared with the container throughput forecast, the prediction fitting effect of cargo weight is not ideal. The average relative error based on 20-year data forecast fluctuates around 8%, and the average error based on the past 10 years is around 5%. Floating, but the error fluctuates greatly.

Therefore, the GM(1,1) prediction formula for the container throughput of Pakistan ports is:

$$X(1)(k+1) = 3187.46e^{0.04797k} - 3108.707$$

The forecast results are as follows:

Table 9 Forecast of container throughput of Pakistan ports

(unit: ten thousand TEU)

years	Forecast value (ten thousand TEU)	Average annual growth rate	Forecast value (100 million tons)
2020	337.07	6.86%	1.1258
2025	428.37	5.42%	1.43
2030	544.39	5.42%	1.818
2035	691.86	5.42%	2.311

By 2025, the container throughput of Pakistan's ports is expected to reach 3.37 million TEU, and by 2035, the container throughput of Pakistan's ports is expected to reach 6.92 million TEU, quadrupling the container throughput of 2016.

IV. Conclusion

In summary, this article predicts Pakistan's port throughput and container throughput based on three methods: neural prediction method, logistic curve prediction, and gray prediction method. It uses different logical thinking to analyze and compare the three methods. The forecast method has the lowest forecast

value of port throughput and container throughput. The forecast in 2035 is only 11.37 million tons and 2.89 million TEU; the logistic model forecast results show that by 2035, Pakistan's port throughput will be higher than 2017 Doubled to around 220 million tons. The gray forecast method shows that Pakistan's container throughput can reach 6.91 million TEU in 2035 .In addition, due to changes in the international situation, the "Afghanistan-Pakistan Transit Trade Agreement" signed by Pakistan and Afghanistan has been implemented. According to the plan, after 2040, the annual import and export goods will reach 400 million tons per year. Most of the goods traded between Afghanistan and Pakistan will be Through the port of Gwadar.

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