

Domestic and Foreign Trade Container Generation Measurement Based on GCM & RM Model

-- The Example of West African Countries

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Abstract: As a country's economy continues to develop, the supply of materials required for the development of the country's major industries increases, and many of the products produced need to be exported abroad, which leads to greater demand for foreign trade. The increasing demand for foreign trade has led to a great development of the country's logistics industry and has also put pressure on the basic transport conditions. As domestic and international trade becomes more frequent, the domestic industry is boosted, and it is a question of how to accurately calculate and forecast the volume of containers generated for external and domestic trade. In this paper, the generation coefficient method is applied to calculate the volume of domestic and foreign trade containers generated in the study area, taking the countries of the West African region as an example, to determine their logistics needs. On the basis of this, a regression model is used to forecast the future container volumes of West African countries in conjunction with economic development trends. The forecast results can be used as a reference basis for the construction of transport infrastructure, port development and further logistics planning in the study area.

Keywords: Container Generation; Generation Coefficient Method; Multiple Linear Regression Model.

1. Background

The West African region comprises a total of 29 countries in the West African region as well as the surrounding West African region, the study area including Nigeria (NG), Senegal (SN), Cameroon (CM) and other countries. The study area is shown in Figure 1.



Figure 1. Study area

West Africa is a region with poor infrastructure and low transport efficiency, but it is rich in resources. The growing demand for trade has led to an increase in the volume of goods transported, and with containers as the representative cargo type, it has become increasingly important to identify the key corridors for the transport of containerized goods and the

construction of related infrastructure. The container generation volume, i.e., the container supply and demand in the port hinterland [1], can be used as an important basis for determining the key corridors, and can also be used to evaluate the degree of development of domestic and foreign trade. At present, the common models for measuring the container generation volume include multiple linear regression equation [2] and multi-factor dynamic analysis method [3].

2. Domestic and Foreign Trade Container Volume and Volume Forecasting Model Construction

2.1. Domestic and Foreign Trade Container Volume Model

2.1.1. Construction of Foreign Trade Container Generation Volume Model based on GCM (Generation Coefficient Method)

Foreign trade container generation size by a variety of factors, these factors mainly include: the scale of foreign trade, development speed, trade mode, regional flow, commodity structure, etc..

Regional foreign trade scale and development speed is the carrier of foreign trade transport. Generally speaking, the larger the scale of foreign trade, regional foreign trade container generation (Q) is also the larger; the faster the speed of regional development, the faster the growth of foreign trade container generation, therefore, accurate evaluation and prediction of foreign trade scale and foreign trade development speed is an important basis for predicting foreign trade container generation. Generally speaking, reflecting the port foreign trade container throughput and foreign trade volume between the growth elasticity coefficient but show first high, after maintaining a stable trend.

In addition, such as foreign trade system reform and international economic and trade situation changes and other internal and external factors affecting the development of foreign trade, will have an impact on the volume of foreign trade container generation. Trade mode and trade scale, import and export structure, as well as foreign trade development speed and other factors, which in turn affect the generation of foreign trade containers. Such as the development of processing trade and the increase of foreign-funded enterprises, will bring about the speed of foreign trade development and the proportion of suitable container goods to improve, thus strongly promote the growth of foreign trade container generation. And foreign trade import and export of regional flow is mainly affected by the flow of foreign trade containers.

Foreign trade commodity structure mainly through the control of various coefficients affect the generation of foreign trade containers. These coefficients include.

(1) the generation of foreign trade goods density (m), that is, the weight of goods generated by each \$ foreign trade volume, generally with the evolution of foreign trade commodity structure is an exponential function of decline, that is, the weight of the unit value of foreign trade goods with the increase in technical content and constantly reduce.

(2) the proportion of foreign trade goods in the appropriate box goods (a), that is, the weight of the appropriate box goods and the total weight of foreign trade goods ratio. Suitable for a wide variety of goods, involving most industrial sectors, its scope with the development of the economy and the expansion of container transport and expanding, for the time being, difficult to box the goods mainly for bulk, liquid goods, as well as some bulky and bulky pieces of goods. With the level of industrialization corresponding to the evolution of foreign trade commodity structure, the proportion of suitable container goods is bound to gradually increase.

(3) the average weight of the container box (W). The weight of the container varies due to the containerized goods, and the accumulation of cargo factors are closely related. Therefore, the average weight of the container is also due to the different structure of foreign trade commodities and different, generally between 8 to 15 tons per TEU.

(4) suitable box cargo packing rate (b). That is, the actual box weight and the ratio of the appropriate box cargo weight, and the level of development of the transport system itself.

According to the above analysis on the container generation mechanism, this section adopts the generation coefficient method to predict the container generation volume. The basic idea of the method is: according to the foreign trade statistics to determine the generation density of foreign trade goods, according to the commodity structure of foreign trade to determine the proportion of foreign trade goods in the appropriate box, through the actual level of the market to determine the average box weight, in the comprehensive consideration of foreign trade goods generation coefficient, the appropriate box rate, the average box weight on the basis of the generation coefficient of the container (c). Then, according to the container generation coefficient and foreign trade volume to project the container generation volume ($Q = cV$). Formula section (next section) according to the research, export container generation volume and the cycle of trade exports (to the annual cycle), foreign trade exports of the proportion of suitable container goods, foreign trade exports of the weight coefficient of suitable container goods, foreign trade exports of container boxing rate, foreign trade exports

of the average container load, the establishment of the calculation formula is as follows:

$$Q_1 = V_1 \frac{a_1 m_1 b_1}{W_1} \quad (1)$$

Where:

Q_1 --the volume of export containers generated (TEU).

V_1 --Total export foreign trade (USD billion).

a_1 --ratio of exportable containerized goods in foreign trade (%)

m_1 --weight coefficient of containerized cargo for foreign trade exports (tons/US\$ billion)

b_1 --The containerization rate of foreign trade export (%)

W_1 --the average containerized weight of foreign trade exports (tons).

Imported container generation with the cycle of trade imports (to the annual cycle), foreign trade imports of suitable box cargo ratio, foreign trade imports of suitable box cargo weight coefficient, foreign trade imports of container boxing rate, foreign trade imports of container average load weight, the establishment of the following calculation formula.

$$Q_2 = V_2 \frac{a_2 m_2 b_2}{W_2} \quad (2)$$

Where:

Q_2 --the volume of imported containers generated (TEU).

V_2 --Total volume of imported foreign trade (USD billion).

a_2 --the proportion of foreign trade imports of container-worthy goods (%)

m_2 --The weight coefficient of foreign trade imports of containerized goods (tons/US\$ billion)

b_2 --The rate of containerization of foreign trade imports (%)

W_2 --Average load weight of foreign trade import containers (tonnes).

2.1.2. Construction of Domestic Trade Container Production Volume Model based on Multiple Regression Model

The development of domestic trade has important strategic significance to the economic and trade development of a country, and is the top priority of national economic construction. The development of domestic trade also put forward higher requirements for domestic trade container transport, but blind investment, too much development and other problems can not be ignored, so the study of the development trend of domestic trade freight generation volume, the future of domestic trade transport supply to make reasonable planning, has a very important significance. The development of China's domestic trade is very rapid, and there have been many scholars in China who have conducted a lot of research on the generation mechanism of domestic trade freight and related forecasts, and have achieved more fruitful results. However, for the West African region covered in this study, due to the lack of statistical information on domestic trade freight for each country in West Africa, it is impossible to directly obtain the domestic trade freight generation of each country in West Africa, let alone to forecast the future freight generation. Therefore, this paper needs to use multiple linear regression to obtain the relevant formulae to obtain the domestic freight generation of each West African country by analogy with the development of China from 1979 to 1988.

The general form of the multiple linear regression model is

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k + \varepsilon \quad (3)$$

where $\beta_0, \beta_1, \beta_2, \beta_k$ are k+1 unknown parameters, β_0 is called the regression constant, $\beta_1, \beta_2, \beta_k$ are called the regression coefficients, y is called the explanatory variable

(dependent variable), and x_1, x_2, \dots, x_k are called the explanatory variables (independent variables) and ε is the error term. For the error term ε it is assumed that $E(\varepsilon) = 0$ and that ε has the same variance σ^2 , $\varepsilon \sim \sigma^2(0, \sigma^2)$.

Under the assumptions of the regression model there are.

$$E(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k \quad (4)$$

The above equation is called a multiple regression equation.

Once the multiple regression equation is obtained, a goodness-of-fit test is performed. The multiple coefficient of determination is a measure of the goodness of fit of the estimated multiple regression equation. The coefficient of determination, R^2 , is calculated as

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \quad (5)$$

R^2 takes the value $[0,1]$, the closer it is to 1 the better the equation fits.

When testing the linearity of a multiple regression model, the F-test is usually used. The statistic F is calculated as.

$$F = \frac{SSR/k}{SST/(n-k-1)} \sim F(k, n-k-1) \quad (6)$$

Generally given $\alpha = 0.05$, F_α is found according to the F distribution table. if $F > F_\alpha$, the linear relationship is significant, and vice versa.

In testing the significance of the regression coefficients, the t-test is usually used to test the regression coefficients and the t-statistic can be constructed as follows.

$$t_i = \frac{\hat{\beta}_i}{S_{\hat{\beta}_i}} \sim t(n-k-1) \quad (7)$$

Where $S_{\hat{\beta}_i}$ is the standard deviation of the sampling distribution of the regression coefficient $\hat{\beta}_i$, i.e.

$$S_{\hat{\beta}_i} = \frac{S_\varepsilon}{\sqrt{\sum x_i^2 - \frac{1}{n}(\sum x_i)^2}} = \frac{\sqrt{\sum (y_i - \hat{y}_i)^2 / (n-k-1)}}{\sqrt{\sum x_i^2 - \frac{1}{n}(\sum x_i)^2}} \quad (8)$$

where S_ε is an estimate of the error term and the constructed t_i statistic follows a t-distribution with degrees of freedom of $n-k-1$, by Looking up the table yields the critical value $t_{\frac{\alpha}{2}}$ for the two-sided test. When $|t_i| > t_{\frac{\alpha}{2}}$, β_i is considered significantly non-zero and the linear effect of the independent variable x_i on the dependent variable y is significant; when $|t_i| < t_{\frac{\alpha}{2}}$, β_i is considered zero and the linear effect of the independent variable x_i on the dependent variable y is non-significant.

In the initial assumptions of the regression model, the random error term needs to satisfy.

$$E(\varepsilon_i) = 0, i = 1, 2, \dots, n \quad (9)$$

$$\text{Cov}(\varepsilon_i, \varepsilon_j) = \sigma^2, i = j(i, j = 1, 2, \dots, n) \quad (10)$$

$$\text{Cov}(\varepsilon_i, \varepsilon_j) = 0, i \neq j(i, j = 1, 2, \dots, n) \quad (11)$$

However, in the study of real economic problems, a situation that violates the above assumptions, or heteroskedasticity, occurs when an explanatory variable or some explanatory variables have different effects on the explanatory variable as the observations change, resulting in different variances in the random error term. When heteroskedasticity occurs, it has a significant impact on the estimate of $\hat{\beta}_i$. Although the estimate of $\hat{\beta}_i$ is unbiased, it is not a minimum variance linear unbiased estimate, and will affect the final significance test, resulting in a poor fit of the model. Residual plot analysis and rank correlation coefficient methods are generally used to test the heteroscedasticity of the model.

When studying economic issues, it is not common for the explanatory variables to be completely uncorrelated. There are more independent variables involved, so it is difficult to

find a set of independent variables that have a significant effect on the dependent variable and that are not correlated with each other. In the process of multiple linear regression analysis, it is generally assumed that the independent variables are not correlated with each other, i.e. there is no linear correlation. If the economic problem under study involves time-series information, often the economic variables will change together over time, and there will be multiple independent variables that are strongly correlated in the regression model, which may confuse the results of the regression and even have an impact on the value of the positive and negative signs of the parameter estimates. The test for multicollinearity in a regression model can generally be done by looking at the correlation coefficient matrix, with correlation coefficients between the independent variables close to 1, indicating the presence of linear correlation. It can also be judged on the basis of tolerance and variance expansion factors; the smaller the tolerance, the more severe the multicollinearity, and for the variance expansion factor, the larger it means the more severe the multicollinearity.

In the modelling process, the regression model's multicollinearity can generally be dealt with by the elimination of variables method, stepwise regression method, increasing variance method, principal component regression method and ridge regression analysis method, as well as Lasso regression. In this paper, the principal component regression method is chosen to deal with the multicollinearity problem in the regression model in the modelling process.

2.2. Domestic and Foreign Trade Container Generation Forecasting Model based on Linear Regression Model

The time series method is a class of forecasting methods commonly used in economics and production. The trend of the object under examination over time is analysed to obtain a forecast result. In general, the time series method requires that the trend of the sample data over time be more consistent and significant, and it is more suitable for near-term and short-term forecasting, and not for medium- and long-term forecasting. However, the advantage of the time series method is that it assumes that time is the only influencing factor and does not consider various other influencing factors, which makes it easier to use. In this paper, we use one-dimensional linear regression analysis, logistic regression analysis and exponential regression analysis for forecasting.

(1) The forecasting model of the one-dimensional linear regression analysis method is

$$y_t = b_0 + b_1 t \quad (12)$$

where:

t--the value for year t of time (year).

y_t --the value of freight generation in year t.

b_0, b_1 --parameters of the univariate linear regression equation.

(2) The predictive model for the logistic regression analysis method is

$$y_t = b_0 + b_1 \ln t \quad (13)$$

where:

t--the value for year t of time (year).

y_t --the value of freight generation in year t.

b_0, b_1 --parameters of the logistic regression equation.

(3) The prediction model based on the exponential regression analysis method is

$$y_t = b_0 e^{b_1 t} \quad (14)$$

where:

t --the value for year t of time (year).

y_t --the value of freight generation in year t .

b_0, b_1 --parameters of the exponential regression equation.

After calculating by the above method, three different prediction equations for the country's freight generation can be obtained. In this paper, by comparing the correlation coefficients of the three different regression equations and taking into account the level of development of different countries, the most suitable equation for forecasting the freight generation of that country is determined.

3. Calculation of Foreign Trade Container Generation Volume - Taking Countries in the West African Region as an Example

3.1. Foreign Trade Container Volume Calculation

3.1.1. Foreign Trade Container Volume Calculation Base Data

(1) Total foreign trade exports and imports

Most of the countries in the study area are agricultural and resource-producing countries, and their exports are mainly agricultural products and mineral resources, while their imports are mainly daily necessities and industrial products. These commodities account for a large proportion of the total exports and imports of the countries in the study region. In the context of the trade imbalances prevailing in the West African region, reducing logistics costs and increasing the value and volume of goods exported is a logical way to develop foreign trade.

(2) Ratio of foreign trade import and export of suitable box goods

Most of the export products of the countries in the study area are mainly ore resources and primary agricultural products, among which bulk ore and oil and gas do not belong to boxworthy goods, while general agricultural and livestock products can be exported as boxworthy goods. Imports are mainly machinery and equipment and foodstuffs, most of which are essential materials for production and living, and all imported goods, except for a small amount of fuel, are containerized. Therefore, the number of imported heavy containers in the region is generally much larger than that of exported heavy containers, and most containers are returned to the country of origin in the form of empty containers, which is an uneconomic trade mode in container transport and will inevitably lead to excessive logistics costs, which is not conducive to the sustainable development of the region. (According to the Ministry of Commerce of the People's Republic of China's foreign investment guide and the website of China's economic counsellor's offices in the Gulf of Guinea region, the types and proportions of containerized cargoes of each country are shown in the appendix.)

(3) The weight coefficient of containerized goods for foreign trade import and export

With the upgrading of the structure of foreign trade commodities, the industrial added value of commodities will continue to increase, and the weight coefficient of foreign trade commodities will also decrease with the increase of industrial added value.

As it is difficult to directly measure the weight of foreign trade containerized goods in the study area based on available

data, this study uses data from relevant reports and papers for estimation. The weight of foreign trade containerised goods is related to the structure of goods and the value of goods in each region. Generally speaking, the industrial structure of regions with higher level of economic development is more reasonable, the grade and value of products are relatively high, and the number of containers generated is relatively low. To China's Yangtze River Delta port hinterland foreign trade container generation as a base for prediction, the Yangtze River Delta region a natural box cargo value of about 25,000 U.S. dollars, according to each box 10t cargo weight conversion, then the Yangtze River Delta region of the appropriate box cargo weight coefficient of 40,000 tons / U.S. dollars, the Gulf of Guinea region of the country's economic development level is lower than the Yangtze River Delta, cargo structure is also relatively single, so its appropriate box cargo weight coefficient It should be greater than 40,000 tons/US\$ billion. According to the research, the weight coefficient of foreign trade import and export cargo of Nanjing port from 2008 to 2011 was 46,000 to 66,000 tons/US\$ billion, and it is estimated that the weight coefficient of containerized cargo generated by the hinterland of Nanjing port should be less than 46,000 tons/US\$ billion for every US\$100 million of foreign trade import and export volume, giving the current weight coefficient of containerized cargo of Nanjing port as 40000 to 50000 tons/US\$ billion, and predicting that the weight coefficient of containerized cargo will increase to 3.5 million to 4.5 million during the planning period. It is predicted that the AWCF will increase to 35000~45000 tons/US\$ billion during the planning period[4]. In the forecast of Eritrea's container generation and throughput, the AFTF for Eritrea, an East African country, was taken as 55-60 million tonnes/US\$ billion[5]. The degree of economic development of the study area is similar to that of East Africa, which is lower than the economic level of Yangtze River Delta, and because the added value of export goods is lower than that of imported goods, the appropriate containerized cargo weight coefficient for exports is taken as 60,000 tons/US\$ billion, and the appropriate containerized cargo weight coefficient for imports is 55,000 tons/US\$ billion.

(4) Foreign trade import and export containerization rate

The ratio of containerized goods, that is, the weight of containerized goods and the weight of foreign trade goods ratio. Suitable for a wide variety of goods, involving light industrial products, hardware and chemicals, pharmaceutical products, handicrafts, electronic instruments and most industrial manufactured products, so the proportion of suitable containerized goods with a country's industry and the development of the level of container transport to increase. Generally speaking, the higher the proportion of industrial products, the higher the proportion of suitable container goods, the proportion of suitable container goods with the upgrading of foreign trade commodity structure and increase. The container container rate of foreign trade goods and container transport development level, the higher the level of container development, the higher the container rate, the development trend is the container rate of suitable goods will gradually increase until the complete container.

In horizontal view, China's Shanghai, Guangdong and other economically more developed areas of the container box rate of 85%, the Yangtze River Delta region can also reach 70% ~ 80%, while the developed countries box rate has reached 90% [6]. Vertical view, China's foreign trade

container containerization rate level in 1985 only 18.5%, to 2005 the container containerization rate exceeded 70%. Therefore, the containerization rate is a parameter indicator that can be rapidly increased according to the international market and the improvement of its own economic level. In the forecast of Eritrea's container generation and throughput, its containerisation rate is taken as 65% to 70%. Considering that the structure of export commodities in the Gulf of Guinea region is mainly agricultural and sideline products, the containerisation rate is not as high as that of imported goods, so this study takes the containerisation rate of export-suitable

goods as 60% and that of import-suitable goods as 70%.

3.1.2. Foreign Trade Container Generation Calculation Results

According to the container coefficient generation method, the container generation volume of each country in the delineated region is calculated, and the export and import container generation volumes of 29 countries in the delineated region for the 20 years from 2000 to 2020 are shown in the table 1 and table 2.

Table 1. Export container production of countries in the study area (unit: TEU)

Country	2000	2005	2010	2015	2020
Burkina Faso (BF)	12843.6	14814.8	49064.4	72811.2	122491.6
Gambia (GM)	1563.1	2802.8	3773	2910.6	4015.55
Guinea (GN)	23111.55	29209.95	50970.15	61711.65	136209.15
Cabo Verde (CV)	954.8	2371.6	3788.4	4897.2	7145.6
Guinea-Bissau (GW)	1724.8	2772	3911.6	7761.6	7145.6
Ghana (GH)	22360.8	32363.1	91938	119207.55	167151.6
Ivory Coast (CI)	106560.3	175375.2	263825.1	271078.5	301940.1
Mali (ML)	2094.4	4238.85	7904.05	10460.45	13967.8
Mauritania (MR)	8200.5	14437.5	47909.4	42319.2	65373
Niger (NE)	7653.8	12882.1	31046.4	29321.6	30076.2
Liberia (LR)	1216.6	2032.8	3080	4358.2	8485.4
Sierra Leone (SL)	250.25	3542	6930	11184.25	12955.25
Nigeria (NG)	368291	1062619.25	1532665.75	883536.5	1076922
Senegal (SN)	17767.75	30684.5	41695.5	54342.75	77500.5
Sao Tome and Principe (ST)	34.65	80.85	127.05	127.05	161.7
Togo (TG)	4891.425	8543.15	13165.075	13623.225	14957.25
Chad (TD)	2113.65	35585.55	41580	28020.3	37017.75
Cameroon (CM)	57143.63	94334.63	124653.38	150698.63	127512
Central African Republic (CF)	3719.1	2956.8	3234	1986.6	2887.5
Benin (BJ)	12104.4	17802.4	39516.4	73673.6	99083.6
Morocco (MA)	93555	141064	236948.25	358415.75	455512.75
Algeria (DZ)	687737.05	1248701.3	1538791.1	928400.55	922067.3
Equatorial Guinea (GQ)	16893.8	108785.6	154000	100100	49280
Republic of the Congo (CG)	76753.6	146146	262754.8	144082.4	219357.6
Angola (AO)	182975.1	556917.9	1168744.5	766481.1	483644.7
Gabon (GA)	102132.8	168075.6	272826.4	249880.4	197797.6
Democratic Republic of the Congo (CD)	33656.7	55509.3	195841.8	237583.5	318525.9
Namibia (NA)	30237.9	47655.3	90528.9	74174.1	72534
South Africa (ZA)	1107067.5	1949443.65	3179484	2799408.15	2961327.6

3.2. Calculation of Domestic Freight Generation

3.2.1. Basic Data Required for the Calculation of Domestic Trade Freight Generation

(1) Statistical data for the calculation of domestic trade freight generation in China

Due to the lack of statistical information on domestic freight transport in various countries in West Africa, it is not

possible to directly obtain the domestic freight transport generation of various countries in West Africa, let alone to forecast the future freight transport generation. Therefore, this paper uses multiple linear regression to obtain the relevant formulae for domestic freight generation for each West African country by analogy with the development of China from 1979 to 1988. The data on GDP, population, road length and railway length for China from 1979 to 1988 were obtained from the official website of the National Bureau of Statistics and are shown in the Appendix.

Table 2. Import container production of countries in the study area (unit: TEU)

Country	2000	2005	2010	2015	2020
Burkina Faso (BF)	13798.4	27893.25	46488.75	70231.7	91953.4
Gambia (GM)	3632.48	7297.68	8050.35	10930.15	19045.95
Guinea (GN)	20304.9	25641	48440.7	75952.8	129140.55
Cabo Verde (CV)	7692.3	14795.55	27927.9	21794.85	27338.85
Guinea-Bissau (GW)	1455.3	2448.6	4550.7	4781.7	7992.6
Ghana (GH)	90550.08	174980.575	357422.45	440642.125	406739.03
Ivory Coast (CI)	156756.6	176680.35	270131.4	296777.25	323111.25
Mali (ML)	13860	25202.1	45784.2	75952.8	96026.7
Mauritania (MR)	12235.3	38484.6	52148.25	99795.85	73977.75
Niger (NE)	4989.6	11842.6	30245.6	30430.4	37976.4
Liberia (LR)	7384.3	8246.7	13879.25	41799.45	24820.95
Sierra Leone (SL)	3955.88	10452.75	25438.875	38894.625	43370.25
Nigeria (NG)	201362.7	600669.3	1143912	1208938.5	1209192.6
Senegal (SN)	36113	77777.7	110117.7	134184.05	227080.7
Sao Tome and Principe (ST)	673.75	1131.9	2587.2	3207.05	3260.95
Togo (TG)	3742.2	7068.6	10980.2	15738.8	13752.2
Chad (TD)	5492.03	16458.75	41580	64102.5	46344.38
Cameroon (CM)	28432.25	55536.25	89127.5	107626.75	98078.75
Central African Republic (CF)	4054.05	6063.75	10395	11988.9	20859.3
Benin (BJ)	11919.6	19958.4	41048.7	67359.6	83414.1
Morocco (MA)	243951.4	450011.1	798447.65	897623.65	1055658.5
Algeria (DZ)	375421.2	457772.7	896210.7	1139222.7	929082
Equatorial Guinea (GQ)	10418.1	30261	126703.5	81427.5	39824.4
Republic of the Congo (CG)	11386.38	32657.63	99349.25	144819.675	117091.98
Angola (AO)	81928	225113.35	449175.65	557676.35	257183.85
Gabon (GA)	18433.8	31392.9	72210.6	73250.1	61838.7
Democratic Republic of the Congo (CD)	50415.75	77673.75	232241.63	305353.125	342601.88
Namibia (NA)	30261	53615.1	120697.5	146708.1	94040.1
South Africa (ZA)	943346.3	1960219.8	2895631.2	2948056.65	2345978.3

Based on this data set, which spans a period of 20 years, future forecasts of foreign trade container volumes for the 29 countries in the delimited region can be made later on.

(2) Calculated statistics on domestic freight generation for West African countries

After obtaining the relationship between domestic freight generation and GDP, population, road length and railway length using the multiple linear regression analogy method, the GDP, population, railway length and road length of West African countries from 2000 to 2020 can be found and then substituted into the formula to find the domestic freight generation of West African countries. GDP and population data for West African countries are obtained from World Bank statistics. The data for railway length and road length were obtained from the GIS database prior to the project. Annual GDP, population, rail length and road length data for West African countries in the delineated region are presented in the Appendix. And the information related to inland waterways of West African countries is mainly obtained from the national Belt and Road website.

3.2.2. Calculation Results of Domestic Freight Generation

The calculation of the domestic trade generation by road and rail for the 29 countries in the delineated region for the period 2000-2020 was obtained. Most of the countries in West Africa are constrained by economic development and natural conditions, as well as a serious lack of government investment in inland waterways. This paper considers the volume of domestic trade generated by river shipping as a separate issue, as most West African countries are lagging behind in terms of development in relation to maritime transport and have poor inland port and waterway infrastructure, and as river shipping accounts for a very small proportion of the total national domestic trade volume. The volume of inland trade generated by inland waterways shipping is calculated by obtaining data on the inland trade of certain countries as far as possible by searching for information. A correlation coefficient is obtained by comparing the volume of inland trade in inland waterway shipping with the volume of public and rail transport in that country.

Table 3. Domestic trade container generation in the countries of the study area (unit: 10000 tons)

Country	2000	2005	2010	2015	2020
Burkina Faso (BF)	12378.78	13838.14	15496.70	16981.80	19068.83
Gambia (GM)	693.93	847.69	1044.1	1165.42	1384.237
Guinea (GN)	9892.26	11866.8	14373.92	16692.04	19729.07
Cabo Verde (CV)	256.04	318.51	410.2	412.59	435.39
Guinea-Bissau (GW)	594.77	681.34	784.34	890.44	1025.1
Ghana (GH)	20130.42	21806.9	25487.30	28689.66	32152.13
Ivory Coast (CI)	17670.21	21115.44	24961	28953.65	33536.44
Mali (ML)	16100.04	18195.09	20568.13	22723.69	25248.68
Mauritania (MR)	12924.37	13705.36	14690.45	15443.53	16354.71
Niger (NE)	5593.85	7088.91	8929.66	10777.05	13126.16
Liberia (LR)	2414.36	4038.9	5868.12	7692.087	9367.08
Sierra Leone (SL)	1890.75	2642.96	3298.65	4037.385	4570.99
Nigeria (NG)	97502.42	121124.51	156481	184646.1	189062.3
Senegal (SN)	18430.84	21585.52	24829.42	27760.92	31367.06
Sao Tome and Principe (ST)	142.45	156.26	171.91	197.01	219.4832
Togo (TG)	6537.86	7321.48	8182.94	9023.7	10193.24
Chad (TD)	4572.25	6332.48	7968.99	9221.06	10469.87
Cameroon (CM)	22568.61	24868.65	27167.89	29162.23	31728.59
Central African Republic (CF)	2610.266	3180.07	3787.44	4133.14	4720.232
Benin (BJ)	9932.82	11030.54	12147.97	13177.32	14548.32
Morocco (MA)	41616.12	47623.79	54572.5	58928.08	63924.66
Algeria (DZ)	76675.52	88724.99	102249.3	109297.7	113314.9
Equatorial Guinea (GQ)	442.1	1375.48	2439.0136	2168.52	1902.41
Republic of the Congo (CG)	13507.22	14676.63	16336.52	16871.26	17369.80
Angola (AO)	48141.26	54143.04	62650.52	69620.05	66020.54
Gabon (GA)	10342.34	11568.56	12857.46	13524.16	14301.83
Democratic Republic of the Congo (CD)	86390.7	97803.37	112319	128450.5	144355.34
Namibia (NA)	35485.92	38043.79	40713.87	42835.46	44982.95
South Africa (ZA)	457521.1	543005.7	627580.7	688541.5	756544.5

Table 4. Calculation formula for predicting freight production

Country	Prediction formula of export output	Prediction formula of import output	Prediction formula of domestic trade output
Burkina Faso (BF)	$y_t = 6353.92t - 12715268.9$	$y_t = 4618.04t - 9227628.376$	$y_t = 332.296t - 652362.14$
Gambia (GM)	$y_t = 98.21t - 194178.37$	$y_t = 663t - 1322778.2$	$y_t = 34.534t - 68396.71$
Guinea (GN)	$y_t = 8466.71t - 16966569.4$	$y_t = 6336.9t - 12672287.7$	$y_t = 480.9t - 952149.57$
Cabo Verde (CV)	$y_t = 769746.51nt - 5850460.37$	$y_t = 392.96t - 765606.27$	$y_t = 20658.251nt - 156740.58$
Guinea-Bissau (GW)	$y_t = 772767.881nt - 5872851.01$	$y_t = 299.01t - 596875.2$	$y_t = 22.246t - 43916.24$
Ghana (GH)	$y_t = 18401101.581nt - 139860675$	$y_t = 44015881.71nt - 334553792$	$y_t = 662.601t - 1305916.93$
Ivory Coast (CI)	$y_t = 9862.41t - 19595997.1$	$y_t = 9898.56t - 19650298.5$	$y_t = 797.743t - 1578236.09$
Mali (ML)	$y_t = 619.042t - 1236099.4$	$y_t = 2768.28t - 334553792$	$y_t = 462.444t - 908923.43$
Mauritania (MR)	$y_t = 2693.77t - 5378125.8$	$y_t = 9362456.1871nt - 71152944.7$	$y_t = 175.24t - 337593.75$
Niger (NE)	$y_t = 3086498.1451nt - 23451333.6$	$y_t = 1766.34t - 3527839.6$	$y_t = 377.629t - 749966.69$
Liberia (LR)	$y_t = 364.76t - 729030.9$	$y_t = 3551309.871nt - 26988352.3$	$y_t = 354.649t - 706961.52$
Sierra Leone (SL)	$y_t = 1778140.051nt - 13515045.6$	$y_t = 2278.575t - 4553706.25$	$y_t = 135.44t - 268917.32$
Nigeria (NG)	$y_t = 38026.05t - 75337345.3$	$y_t = 109242867.31nt - 830038140$	$y_t = 10204384.831nt - 77462468$
Senegal (SN)	$y_t = 3011.975t - 6008265.8$	$y_t = 8474.095t - 16911383.9$	$y_t = 642.893t - 1267382.18$
Sao Tome and Principe (ST)	$y_t = 7.17t - 14293.45$	$y_t = 333158.621nt - 2531615.26$	$y_t = 7497.111nt - 56847.15$
Togo (TG)	$y_t = 1157464.781nt - 8791566.57$	$y_t = 1298712.421nt - 9866916.24$	$y_t = 182.935t - 359441.88$
Chad (TD)	$y_t = 2662648.591nt - 20220492.6$	$y_t = 1298712.421nt - 9866916.24$	$y_t = 301.876t - 599002.598$
Cameroon (CM)	$y_t = 10134836.971nt - 76959307.5$	$y_t = 8972963.71nt - 68162778.1$	$y_t = 460.235t - 897875.47$
Central African Republic (CF)	$y_t = 19.09t - 34855.9$	$y_t = 851.63t - 1701196.35$	$y_t = 101.615t - 200552.572$
Benin (BJ)	$y_t = 5027.6t - 10056262$	$y_t = 4074.78t - 8143871.3$	$y_t = 227.634t - 445356.84$
Morocco (MA)	$y_t = 21274.475t - 42494039.1$	$y_t = 51374.47t - 102487808$	$y_t = 2479.497t - 4944738.921$
Algeria (DZ)	$y_t = 0.692 * e^{0.007*t}$	$y_t = 85147614.21nt - 646803178$	$y_t = 4226232.991nt - 32044367.6$
Equatorial Guinea (GQ)	$y_t = 2815.28t - 5541197.6$	$y_t = 3390.09t - 6740391.9$	$y_t = 191749.381nt - 1456493.68$
Republic of the Congo (CG)	$y_t = 16119019.371nt - 122411202$	$y_t = 13085692.581nt - 99486189.9$	$y_t = 455355.461nt - 3447459.74$
Angola (AO)	$y_t = 70748668.031nt - 537271262$	$y_t = 38609991.181nt - 293279635$	$y_t = 3043050.41nt - 23095322.1$
Gabon (GA)	$y_t = 13142838.841nt - 99764019$	$y_t = 6488140.71nt - 49292655.8$	$y_t = 429426.071nt - 3253513.65$
Democratic Republic of the Congo (CD)	$y_t = 263488.79t - 53156837.6$	$y_t = 20391.375t - 40769875.8$	$y_t = 2997.19t - 5910958.87$
Namibia (NA)	$y_t = 6597985.061nt - 50136055.7$	$y_t = 11913379.21nt - 90536180.2$	$y_t = 491.757t - 947959.47$
South Africa (ZA)	$y_t = 21934855.91nt - 1665785621$	$y_t = 2144239741nt - 1628385939$	$y_t = 15282.85t - 30102522.4$

For the missing data, the inland waterway navigation conditions and quality of shipping infrastructure of the country are compared with the inland waterway navigation conditions and quality of shipping infrastructure of the country for which data is available by searching the relevant literature, and the correlation coefficients are adjusted appropriately in turn, and then multiplied with the existing data of public and railway traffic to obtain the inland waterway shipping domestic trade volume of the country. The total amount of inland freight generated in each country is obtained by adding the respective inland trade volume and the public and railway traffic volume. The calculated domestic freight generation for the 29 countries in the delimited region for the period 2000-2020 is shown in the table 3.

3.3. Forecast of Domestic and Foreign Trade Generation for West African Countries

After the calculation, the formula for the forecast of freight generation for the 29 countries in the West African region was selected and obtained as shown in the table 4.

From the formula, the freight generation in 2030 for the 29 African countries in the delimited region can be calculated as shown in the table 5.

4. Conclusion

The huge logistics demand brought about by the rapid economic development of the West African region has led to an increasing demand for infrastructure and logistics corridor construction. According to the measurement results in Table 5, countries such as South Africa, Nigeria, Algeria and Morocco are represented by a large volume of import and export generation, which represents a large logistics demand. And most of the countries in West Africa region have the problem of imbalance between import and export trade, with most of the countries represented by Gambia, Ghana, etc., the trade import volume is larger than the export volume, which subsequently brings the problem of container utilization rate.

The volume of containers generated by the countries in the West African region will have a large growth in the future, bringing huge logistics needs, and the improvement of infrastructure and logistics corridors should meet their needs. While considering the construction of logistics corridors, reducing logistics costs and improving logistics efficiency, attention should also be paid to the issue of container utilisation.

Table 5. Freight production in study area by 2030

Country	Forecast results of Export Production by 2030 (TEU)	Forecast results of Import Production by 2030 (TEU)	Forecast results of domestic trade production in 2030 (10,000 tons)
Burkina Faso (BF)	183188.7	146992.82	22198.74
Gambia (GM)	5187.93	23111.8	1707.31
Guinea (GN)	220851.9	191619.3	24077.43
Cabo Verde (CV)	11768.15	32102.53	588.33
Guinea-Bissau (GW)	12387.71	10115.1	1243.14
Ghana (GH)	278270.12	661966.87	39163.1
Ivory Coast (CI)	424695.2	443778.3	41182.2
Mali (ML)	20555.86	118892.2	29838.02
Mauritania (MR)	90231.36	149565.54	18143.45
Niger (NE)	54791.41	57830.6	16620.18
Liberia (LR)	11431.9	57681.7	12975.95
Sierra Leone (SL)	26897.52	71801	6025.88
Nigeria (NG)	1855536.2	1932713.46	251994.88
Senegal (SN)	106043.45	291028.95	37690.61
Sao Tome and Principe (ST)	261.65	5651.18	249.27
Togo (TG)	23443.36	23806.21	11916.17
Chad (TD)	57682.75	60311.82	13805.68
Cameroon (CM)	225493.41	173438.73	36401.58
Central African Republic (CF)	3896.8	27612.55	5725.88
Benin (BJ)	149766	127932.1	16740.18
Morocco (MA)	693145.15	1802366.1	88639.98
Algeria (DZ)	1026669.55	1663262.03	141739.87
Equatorial Guinea (GQ)	173820.8	141490.8	3829.53
Republic of the Congo (CG)	347881.8	171710.82	20432.3
Angola (AO)	1535812.34	765991.12	79913.96
Gabon (GA)	329095.69	109668.29	16905.58
Democratic Republic of the Congo (CD)	615406.1	624615.45	173336.83
Namibia (NA)	112820.01	193626.82	50307.24
South Africa (ZA)	4727145.83	4622247.82	921663.1

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