Research on container demand analysis and volume forecasting in the hinterlands of Pinglu Canal

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Abstract. In order to solve the problem of measuring the transferred and induced container volume of the new transportation projects, we analyze container demand from a perspective of hinterlands, and divide the advantages of the new transportation projects into the reduction of the transportation costs and time. By applying the rate, we are able to transform the transportation time into a monetary figure, quantifying the cost of time, thereby setting up generalized transportation cost model. We determine the container transferred volume utilizing Attraction-Logit model. We translate the decrease in costs into an increase in foreign trade export value, and leverage the improved multi-factor dynamic generation method to derive the induced container volume. The prediction consequences indicate that by 2050, the container volume is anticipated to arrive at 3967.999 thousand TEUs, of which the transferred container volume will be 3210.685 thousand TEUs, and the induced container volume will arrive to 757.314 thousand TEUs. We find the proportion of transfer traffic and inducement traffic is about 79% and 21%, respectively, and transferred volume dominates container demand. We forecast the container volume to provide effective reference for the future planning of freight transport development in Pinglu Canal.

Keywords: Pinglu Canal; transferred container volume; induced container volume; Attraction-Logit model; improved multi-factor dynamic generation method

1 Introduction

1.1 Container Volume Structure Analysis

The freight volume of the new transportation projects in the initial stage of operation, can be divided into transferred freight volume and induced freight volume[1][2]. At the initial stage of operations, we categorize the container volume structure into two distinct components: transferred container volume and induced container volume.

There have been scholars on transferred and induced freight volume in-depth research. Logit model[3][4][5] [6] is mature in the application of research on the prediction of transferred freight volume. When forecasting induced freight volume, traditional

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prediction methodologies are not entirely suitable for our task. For instance, the growth curve model[6][7] serves to pinpoint crucial time points and values during data analysis or forecasting, which can indeed require a personal touch in terms of manual effort. The elasticity coefficient method[8] only considers transportation distance and ignores transportation time. Gravity model[9] relies on historical freight volume data, making it inapplicable for assessing transportation corridors that lack such historical records. Multi-factor dynamic generation method[10][11][12] can show the container generation volume and the interrelationship of its influencing factors, which possesses a high level of flexibility, so we have opted for this method.

1.2 Definition of Hinterlands and Freight Transportation Demand Analysis

Definition of Hinterlands.
From the analysis conducted in the *Pinglu Canal Project Feasibility Research Report*, we conclude it highlights the significant potential of the direct hinterlands adjacent to the Pinglu Canal to revolutionize and boost water transportation in Guangxi. Liuzhou port historical annual container throughput does not exceed 0.5 million TEU, whose main mode of transportation is railroad transportation. We do not consider the Liuzhou City and we confirm direct hinterlands as Nanning, Guigang, Baise, Laibin, Chongzuo and Wuzhou, and we only analyze the direct hinterlands as the sources of freight.

Analysis of the Sources of Containerized Freight.
Through the freight transportation analysis of *China Port Year Book* and statistical bulletin, Guangxi inland waterway transportation is dominated by freights such as coal, metal ores, building substances, cement, farming products, cereal, etc., and the main flow direction is Guangzhou and Southeast Asia.

2 Prediction Model Construction

2.1 Container Transferred Volume Prediction Model Construction

We argue that the Pinglu Canal has greater advantages over the West River for water transportation, and therefore attracts a portion of the container volume in West River to be transferred to the Pinglu Canal. We make prediction from 2027 to 2050. We generalize the attraction factors as the reduction in transportation costs and transportation time, and then we set up the Attraction-Logit model.

Attraction-Logit Model Construction.
Only one mode of transportation, direct transportation, is considered in the paper. We prioritize and assign weight to the utility value in our selection process, so as to mitigate the potential for exponential growth in transportation volume[6].

$$Q_i^t = Q_i * P_i \tag{1}$$

$$P_i = \exp\left(\frac{U_i}{\sum_{i=1}^{n} U_i}\right) * \left(\sum_{i=1}^{n} \exp\left(\frac{U_i}{\sum_{i=1}^{n} U_i}\right)\right)^{-1} \quad (2)$$

Here, Q_i^t is the transferred container volume, i is the transportation corridor which represents West River or Pinglu canal, Q_i is the initial volume of the transportation corridor, and P_i is the transferred rate, and U_i is the utility .

$$U_i = \sum_{i=1}^{n} Z(i) \quad (3)$$

$$Z_k(i) = MAX\left(Y(i)\right) * \left(Y(i)\right)^{-1} \quad (4)$$

The value of the evaluation indicator is paramount, and we incorporate the generalized transportation cost as a negative utility.

We use the rate to change transportation time to time value, as exhibited in equation (5).

$$C_t = \frac{P * IR}{H} \quad (5)$$

Here, H is the transportation time, whose unity is hour, IR is the rate of a loan, whose unity is yuan/TEU, T is the waiting time at the gate, P is the average containerized freight rate, whose unit is yuan/(km*TEU*h). C_t is the time value, whose value is ten yuan/(km*TEU*h).

Subsequently, we arrive at equation (6), which serves to represent the general transportation cost.

$$C = Q_i * D * H_y * C_t + Q_i * C_c \quad (6)$$

Here, C is the general transportation cost, D is the distance of transportation corridor. H_y is the annual operating time, whose value is3650h. C_c is the container rate, whose unity is yuan/TEU.

2.2 Prediction of Induced Container Volume

Analysis of the Inducing Mechanism of Container Generation Volume.

Compared with the original transportation corridor, the transportation benefits of the new corridor bring about the improvement of the efficiency, stimulate the economic growth of hinterlands, facilitate other related industries in those areas, and ultimately play a role in those regions to develop the new freight demand.

We argue that the induced factors are the transportation benefits, and the direct consequence is an increase in economic efficiency. We generalize the inducing mechanism as follows: the new waterway stimulates the economic growth of hinterlands through its own advantages of transportation, and then induces hinterlands to generate the new freight demand. By combining the induced mechanism with a multi-factor dynamic generation method, we recognize that since the container flow in the hinterland of the new waterway primarily comprises international foreign trade, the economic growth spurred by this new waterway is reflected in an increase in foreign trade export value.

Improvement of Multi-factor Dynamic Generation Modeling.

Equation (7) is the general expression of multi-factor dynamic generation method.

$$Q' = \frac{V * K_1 * K_2 * K_3}{(K_4 * K_5)} \tag{7}$$

Here, Q' is the container generation volume, V is the foreign trade export value, K_1 is the ratio of adequate containerized freight value, K_2 is the container fitness factor, K_3 is the rate for containerized freight, K_4 is the average weight of a heavy container, and K_5 is the ratio of foreign trade container.

We generalize the factors affecting the foreign trade export value as endogenous and exogenous factors. Endogenous factors are related to the region's own development, and exogenous factors are driven by the development of other regions or the impact of other changes in external conditions. According to research of Yin [12], the endogenous influencing factors are mainly: regional GDP, light and heavy industrial output. At present, there are few studies on exogenous factors. Taking into account the transportation benefits brought about by the opening of the new waterway, we assign the exogenous factors to the reduction in generalized transportation costs resulting from the opening. By refining the multi-factor dynamic generation method, we arrive at the following equation (8).

$$\Delta Q' = \frac{\Delta V * K_1 * K_2 * K_3}{(K_4 * K_5)} \tag{8}$$

$$\Delta V = f(\Delta C) \tag{9}$$

We choose the appropriate function to set up the foreign trade export value and generalized transportation costs of the one-way function fitting model. Through the model, we calculate the annual reduction in transportation costs, and bring it into the fitting model to calculate the increase of foreign trade export value, and finally substitute into the improved multi-factor dynamic generation method to get the induced container volume.

3 Example validation and analysis of prediction consequences

3.1 Prediction of Container Transferred Volume of Pinglu Canal

We retrieve port throughput data from 2003 to 2022 through the *China Port Year Book*. To measure the throughput of Chongzuo Port and Baise Port, we employ the multi-factor dynamic generation method. In selecting sample hinterland regions, we consider Nanning, Guigang, Baise, Laibin, Chongzuo, and Wuzhou as our six target cities. Where data was missing, we used linear interpolation techniques to compensate and finalize our source dataset, as illustrated in Figure 1.

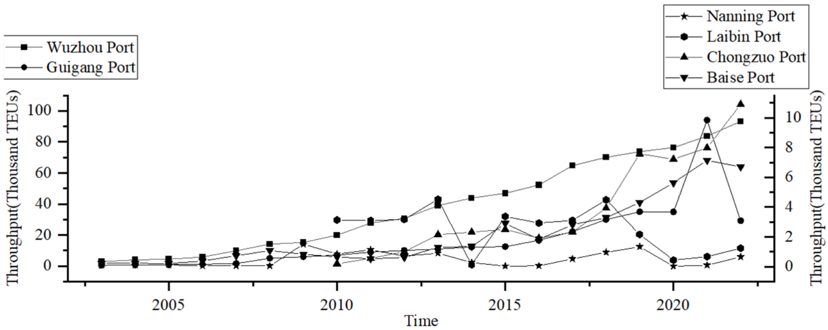

Fig. 1. Summary of historical throughput

By checking the tariff information of the major shipping enterprises in the West River, we determine the base tariff to be 3.7 Yuan/(TEU*km), and the specific tariffs are determined according to the routes and years. We only consider direct transportation when calculating the transportation costs, and no consideration is given to intermediate conversion and loading. The original corridor's distance refers to the transportation route from the starting port via the West River to the Guangzhou Port, and the distances of the new transportation corridor are defined as the water distances between the starting port via the Pinglu Canal and Beibu Gulf Port, and these distances are summarized in Table 1.

Table 1. Summary of distances between OD ports.

OD Port	Distance (km)	OD Port	Distance (km)
Baise Port-Guangzhou Port	925	Baise Port-Beibu Gulf Port	800
Chongzuo Port-Guangzhou Port	1250	Chongzuo Port-Beibu Gulf Port	650
Nanning Port-Guangzhou Port	1375	Nanning Port-Beibu Gulf Port	620
Guigang Port-Guangzhou Port	630	Guigang Port-Beibu Gulf Port	330
Laibin Port-Guangzhou Port	690	Laibin Port-Beibu Gulf Port	650
Wuzhou Port-Guangzhou Port	312	Wuzhou Port-Beibu Gulf Port	450

We calculate the transfer rate generalized in Table 2, so we get transferred container volume in Figure 2.

Table 2. Summary of Transfer Rate by Hinterlands.

Hinterland	Transfer Rate
Nanning	0.638
Wuzhou	0.542
Guigang	0.577
Laibin	0.507
Chongzuo	0.578
Baise	0.566

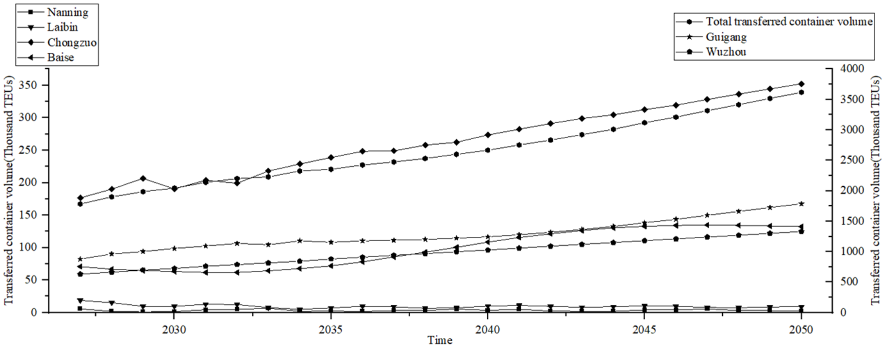

Fig. 2. Transferred Containerized Volume, 2027-2050

3.2 Pinglu Canal Induced Container Volume Prediction

We select six cities, which are fore-mentioned, according to the historical data of statistics bulletin, the exchange rate is 7.24, and get the source data, as illustrated in Figure 3.

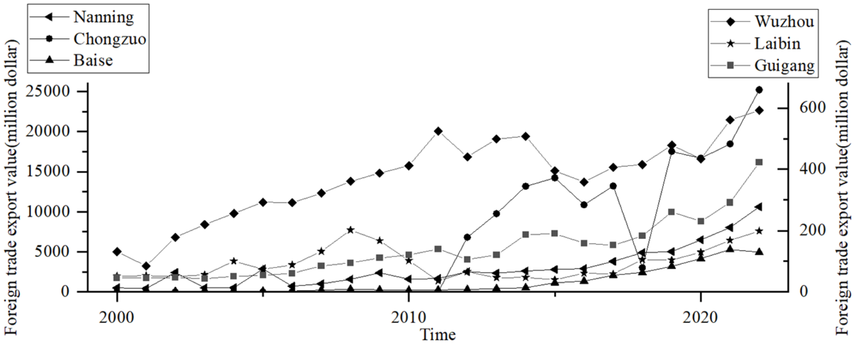

Fig. 3. Summary of historical foreign trade export value

Combined with the data published by Nanning Customs, we determine that the ratio of adequate containerized freight value is about 0.07. By checking the shipper enterprises and shipping enterprises in West River, the container fitness factor generally takes the value of 4.8, the container loading rate is 0.85, the average container load weight is 7.5, and the ratio of foreign trade container is 0.6. We choose 2022 data for prediction validation as exhibited in Table 3 below.

Table 3. Data validation of multi-factor dynamic generating method.

Laibin's Foreign Trade Exports in 2022 (million dollars)	Ratio of Adequate Containerized Freight Value (million dollars/t)	Container Fitness Factor (Thousand TEUs)	Rate for containerized freight	Average Container Load Weight(t)	Ratio of Foreign Trade Container	Container Generation Volume (Thousand TEUs)
198	0.07	4.8	0.85	7.5	0.6	12.6

The predicted value of 12.6 thousand TEUs and the actual throughput of 12.5 thousand TEUs, the error is only 0.8%, the prediction effect is good.

We exclude the data with a significant degree of departure. We generalize regression functions and R^2 in Table 4, which indicates foreign trade export value and generalized transportation cost.

Table 4. Aggregate results of regression equations and R^2.

Hinterlands	Regression equations for foreign trade export value (y) and generalized transportation costs (x)	The fit R^2
Wuzhou	$y = 0.999x + 21.466$	0.847
Guigang	$y = 0.826x + 4.579$	0.853
Laibin	$y = 1.758x + 2.435$	0.892
Chongzuo	$y = 60x$	0.999
Nanning	$y = 82.83x+50.454$	0.912
Baise	$y = 53x$	0.999

We calculate the induced container volume, and generalize them in Figure 4.

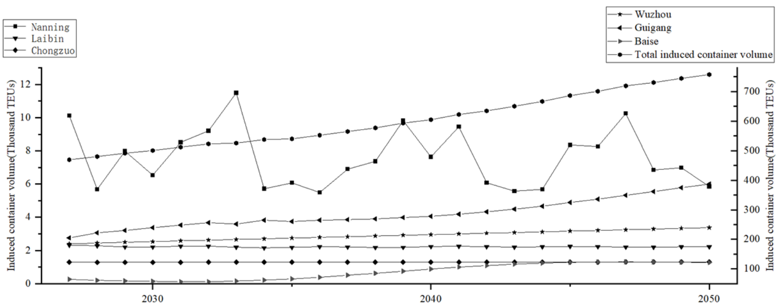

Fig. 4. Induced Container Volume, 2027-2050

4 Conclusion

We begin by analyzing the demand for containerized freight in the Pinglu Canal from a hinterland perspective, which includes six cities as direct hinterlands. We have identified attractive benefits associated with the Pinglu Canal, primarily the reduction in transportation costs and time. We aim to quantify these benefits to demonstrate their significance by generalized transportation cost model. We set up Atrraction-Logit model to figure up transferred container volume of in Pinglu Canal. We firstly analyze container induced mechanism of the Pinglu Canal, and generalize the inducing factors as the reduction of the generalized transportation costs. We establish a functional relationship between foreign trade export value and generalized transportation costs, and formulate an enhanced multi-factor dynamic generation method.

In summary, we predict that in 2035, the containerized demand of the Pinglu Canal will reach 2679.166 thousand TEUs, of which the transferred volume will be 2138.983 thousand TEUs and the induced volume will be 540.183 thousand TEUs. Further, we predict that in 2050, the containerized demand of the Pinglu Canal will reach 3967.999 thousand TEUs, which is about 1.5 times the freight demand in 2035. In 2050, the transferred volume will be 3210.685 thousand TEUs and the induced volume will be 757.314 thousand TEUs. We find transferred and induced traffic account for 79% and 21% of the total containerized freight demand. Respectively, transferred volume dominates the transferred traffic. Guigang Port and Wuzhou Port are the vital ports in West River, and the percentage of their transferred traffic reached about 48% and 37% respectively, and the percentage of induced traffic will reach about 48% and 36% respectively. Meanwhile, Guigang and Wuzhou are also the most important hinterland cities of the Pinglu Canal.

In order to solve the problem of freight demand measurement for newly opened transportation projects, we measure the transferred and induced traffic to provide a reference for the future water transportation planning and sustainable construction of the Pinglu Canal.

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