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EXPLORATION OF LAND DEVELOPMENT INTENSITY INDEX OF PORT CONTAINER LOGISTICS PARK BASED ON QUANTITATIVE ALGORITHM AND PENT ANALYSIS METHOD

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ABSTRACT

To give full play to the circulation function of the port container logistics park, it is urgent to study the development intensity of the land in the port container logistics park and to guide the scientific development of the port logistics park with reasonable development intensity control index. The current situation of land development intensity control index of container logistics park at home and abroad is analysed, the PENT (politics, economy, society and technology) analysis method is used to analyse the factors influencing the land development intensity control index of container logistics park, and the index system structure of influencing factors is constructed. Finally, index value is obtained quantitatively with the proposed calculation method of the land development intensity index of the port container logistics park. Its practicability is verified in case analysis.

Keywords: development intensity, logistics park, container; indicator, land, port

INTRODUCTION

The research and construction of logistics park in China started late, but the development is very rapid. Although the development and construction of China's port container logistics park is commendable, there are also serious problems. First of all, in the case that the country's available land resources are becoming scarcer, the explosive growth of the number of logistics parks and land scale inevitably raises concerns. Based on a study, due to its large size and low development intensity, port container logistics park has become a hot topic in the field of logistics and urban planning [1, 2]. Secondly, some port logistics park projects are rushed to start without detailed feasibility study, which makes the logistics demand, functional positioning and planning layout unclear. Finally, the construction of some port container logistics parks seeks to be large and complete, which is inconsistent with local economic conditions, resulting in a large number of idle lands in the logistics park, low development intensity and serious resource waste [3, 4]. Study showed to fully implement the scientific concept of development, realize the conservation of land resources, promote the optimized allocation and intensive use of industrial land, and improve the management level of construction land for logistics projects, it is urgent to scientifically and reasonably determine the land scale and land development intensity control indicators of the port logistics park to guide the development and construction of the port container logistics park [5].

LITERATURE REVIEW

At present, domestic and foreign scholars don't directly calculate and study the land development intensity control indicators of the port container logistics park, the research on the port container logistics park mainly focuses on the scale of the park, the layout of the internal facilities of the park and the prediction of the logistics quantity in the park. Foreign researches on the land scale of port container logistics park are mainly conducted quantitative analysis by building mathematical models, as well as qualitative analysis from the relevant factors affecting the scale of logistics parks. Some researchers proposed a mathematical model based on bi-level programming to quantitatively analyse the scale and location of logistics park; based on the analysis of port location factors and port operational quantities, some scholars proposed the model of optimal port size and site location with integer programming [6, 7]. There are many researches on the prediction of the logistics quantity, and many mathematical prediction models are proposed. In particular, there are many research achievements on the combined prediction. In addition, Multiple Probability Model (MNP) is also studied to solve the high spatiotemporal variability in the process of cargo demand, and Monte Carlo method is adopted to evaluate the accuracy of the prediction results [8].

There are many methods for predicting the logistics quantity of logistics parks. Domestically, it is mainly based on quantitative calculation, supplemented by qualitative analysis. The mathematical methods used include Grey Forecast Model, Multiple Linear Regression (MLR), Exponential Smoothing, Neural Network Forecasting Method and combination prediction. For example, grey system theory is used to study the logistics quantity of logistics park scale, and the quantity demand of logistics is determined by establishing Grey Forecast Model and the qualitative modification of predicted value [9]. The calculation of logistics land scale is mainly carried out from three aspects: one is to get the total scale of regional logistics land through the calculation of social logistics quantity, and then calculate the land scale of a certain direction or specific logistics park. Secondly, start with the functional layout inside the logistics park, measure and calculate the area of each functional land, and then summarize. The third is to conduct an analogy analysis of relevant regulations and other mature logistics parks. At present, there are many studies on the urban land development intensity in China, but there is little research on the land development intensity for logistics, especially for port logistics park [10].

METHODOLOGY

PENT ANALYSIS OF INFLUENCING FACTOR OF THE DEVELOPMENT INTENSITY CONTROL INDICATORS

Based on a study, the PENT analysis method is adopted to analyse the influencing factor of the land development intensity control indicators of port logistics park [11]. And the index system structure as shown in the following figure is constructed through the refinement of the indicators of policy and regulation, economic environment, natural environment and technical environment.

Policy and regulation factors: the continuous improvement and innovation of policies related to the logistics industry is the basic guarantee for the development and prosperity of the port logistics park, and the prosperity of the logistics park is also the prerequisite for the improvement of its land development intensity [12]. Under the new situation of logistics development, it is necessary to focus on the impact of land policy, tax revenue policy and expense of taxation policy on the land development intensity index of port container logistics park [13].

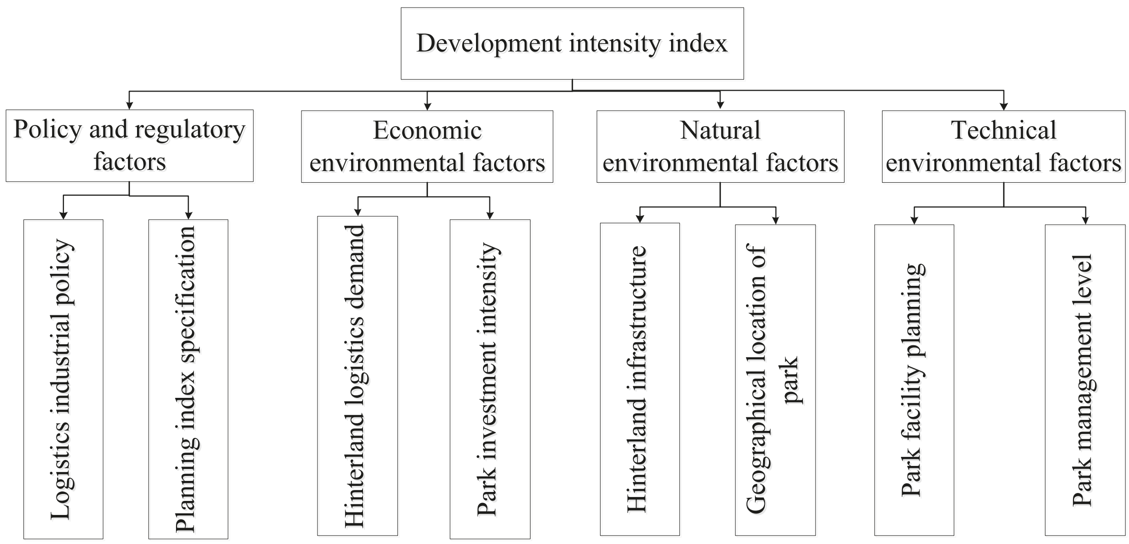

Fig. 1. The structure of index system of PENT analysis method

In terms of environmental factors, the improvement of economic development level of port hinterland will generate big logistics quantity and huge logistics demand, thus promoting the development intensity of port logistics park [14]. Therefore, the prosperity of hinterland economy in port area is an important factor to improve the development intensity of port logistics park. The investment intensity is widely applied to the land approval system, which reflects the scale operation and intensive utilization level of land. However, there is a lack of relevant regulations in China to adjust the investment intensity of logistics land. Since China's fixed asset investment statistics include the relevant fees paid for land acquisition, the investment intensity included here includes land price and infrastructure investment [15].

Natural environmental factors: the infrastructure of the hinterland of the port logistics park will also have an extremely important impact on the development intensity of the port logistics park. As the geographical location of each industrial land is different, there are differences in infrastructure conditions, traffic conditions, resources and environmental conditions, resulting in land grade differences. Therefore, there are different levels of land rent, different industries have different requirements on the bearing capacity of land rent and specific location, and different types of industrial land have different location choice.

Technical environmental factors: whether the planning and design of the facilities in the port logistics park is reasonable will affect the operational efficiency and the development intensity of the park [16]. The management level of the logistics park is directly reflected in whether it can respond to the market quickly and efficiently, and whether it can complete various logistics operations in the shortest time. Therefore, the management level affects the operational efficiency of the park, and the operational efficiency under the market economy conditions often becomes a key factor for enterprises to win.

RELEVANT THEORETICAL METHODS AND MODELS FOR DETERMINING DEVELOPMENT INTENSITY CONTROL INDICATORS

Container throughput prediction method: assume that the time series observed value of a predicted object is xt, t=1, 2,…, N. There are m feasible single prediction methods, and x_{it} is called the fitting value (predicted value) of the i-th prediction method at time t. Among them, i=1, 2, 3, …, m, t=1, 2, 3, …, N. Let L = (l_1, l_2, … l_m) be the weighting coefficient of the m kinds of single-term predictions in the combined prediction, and $\sum_{i=1}^{m} l_i = 1$, l_m≥0, i=1, 2, …, m, Then, the IOWGA combined prediction value at the t-th moment generated by the prediction precision sequence p_{1t}, p_{2t}, …,p_{mt} is:

$$IOWGA_L(<p_{1t},x_{1t}>,<p_{2t},x_{2t}>,\cdots,<p_{mt},x_{mt}>)=\prod_{i=1}^{m} x_{p-index(\mathrm{it})}^{L_i} \quad (1)$$

Taking the square sum of logarithmic error as the criterion, the combined prediction model based on the Induced Ordered Weighted Geometric Averaging (IOWGA) operator can be expressed as the following model:

$$\min S(L)=\sum_{\mathrm{i}=1}^{m}\sum_{j=1}^{m} L_i L_j \left(\sum_{\mathrm{t}=1}^{N} e_{a-index(\mathrm{it})} e_{a-index(\mathrm{jt})}\right)$$
$$S\cdot t=\begin{cases}\sum_{i=1}^{m} L_i = 1\\ L_i \geq 0\end{cases} \quad (2)$$

Calculation method of the total area of the park: at present, the typical research on the calculation method of the scale of logistics parks in China is the proportional summary method and the space-time consumption method. The model of the proportional summary method is shown in figure 2. As the logistics quantity (container throughput) of the port container logistics park is directly measured, the model formula of the proportion summary method can be simplified as:

$$S_j = S\times\beta_j = (Li_1 i_2\alpha/365)\times(L_j/L) = (L_j i_1 i_2)\alpha/365 = qa/365 \quad (3)$$

Among them: q is the logistics quantity of port container logistics park, unit: t
α is the land parameter of unit production capacity, the unit is m²/t, and its value ranges from 30 to 50.

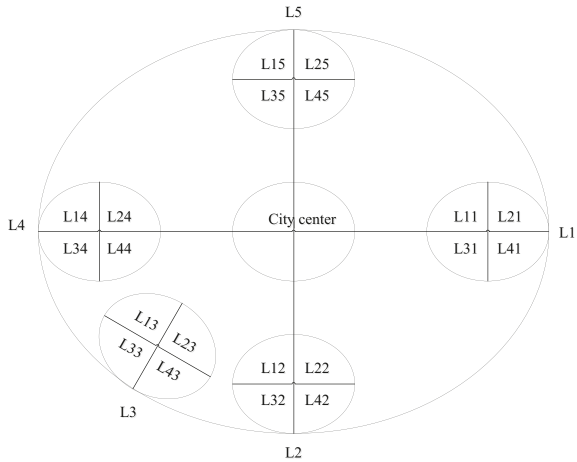

Fig. 2. The collecting of proportion

The model of the improved space-time consumption method is shown in the following figure. As the main business of the port container logistics park is the storage and distribution of containers and cargo, the type of cargo in the park can be considered as a kind of container. Meanwhile, the revised parameters β and γ, as well as the modified mathematical model formula are introduced:

$$A=\beta(VTQF/365S)/\gamma \quad (4)$$

Among them, β is the utilization factor of the warehouse area, and its value ranges from 1.7 to 2.0. And γ is the ratio of warehouse area to total park size, which ranges from 0.3 to 0.4.

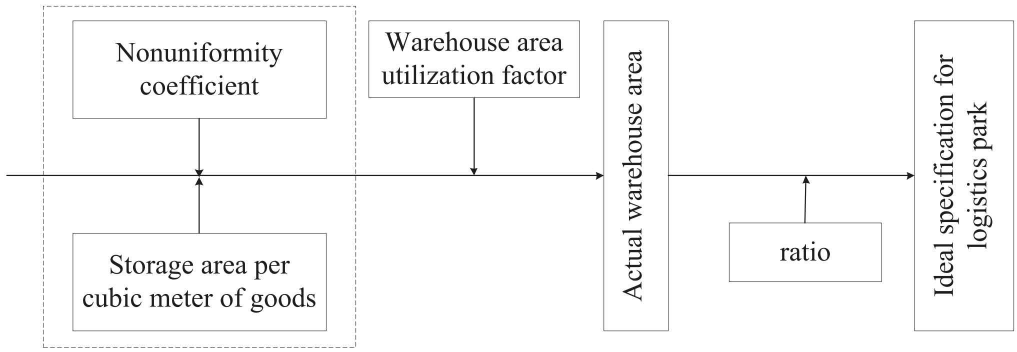

Fig. 3. The structure of improving mathematical model

Calculation model of yard area of container: the actual area of container, the land area of the gantry crane operation and the area of corridor make up the yard area of container. Factors such as stacking height, average stacking period of container, and area of unit container determine the yard area of container. The calculation formula is as follows:

$$S_1 = Q_1 \times D_1 \times kt_1 / (T \times H_1 \times k_H) \times S^1 \quad (5)$$

Among them:
S_1 – The yard area required for the container, unit: m^2
Q_1 – Annual container throughput of container yards entering the logistics park, unit: TEU
D_1 – Average storage period of container, unit: d
k_{t1} – Yard imbalance coefficient
T – Annual operating days of the yard, unit: d
H_1 – Stacking layer of container
k_H – The utilization factor of the height
S^1 – Area required for unit plane box, unit: m^2/TEU

Estimation model of the site area of the freight station: the site area of the freight station is determined by factors such as the amount of disassembly and assembly of container into and out of the site, the floor area of the unit cargo, the operating days and the average storage period of containers. The following calculation formula is adopted:

$$S_2 = Q_2 \times D_2 \times kt_2 \times S^2 \times f_2 / T \quad (6)$$

Among them:
S_2 – The area required for the freight, unit: m^2
Q_2 – The annual total amount of containers entering the freight station, unit: TEU
D_2 – Average stockpiling period of container, unit: d
k_{t2} – Stockpiling imbalance coefficient
T – Annual operating days of freight station, unit: d
f_2 – The utilization coefficient of the site area
S^2 – Area required for unit container cargo, unit: m^2/TEU

Calculation model of the floor area of circulating warehouse: generally, for a stable container logistics park, its warehouse area accounts for about 30–40% of the total park scale. The size of warehouse area is influenced by factors such as quantity of work, utilization rate of area and turnover cycle of the warehouse. The following calculation formula is adopted:

$$S_3 = Q_3 \times D_3 \times kt_3 / T \times S^3 \times f_3 \times \eta_3 \quad (7)$$

Among them:
S_3 – The floor area of the circulating warehouse, unit: m^2
Q_3 – The amount of cargo entering the circulating warehouse, unit: t
D_3 – Average storage period of warehouse cargo, unit: d
k_{t3} – Unbalance coefficient of storage yard of warehouse
T – Annual operation days of logistics warehouse, unit: d
f_3 – The area utilization coefficient of logistics warehouse site
S^3 – Average stockpiling area per unit cargo, unit: m^2/t
η_3 – Influence coefficient of cargo operation

Calculation model of building area of the park: the size of the building area is directly related to the logistics quantity in the park. The more cargo, the larger the required building area. Just like the principle of the space-time consumption method established by Cheng Shidong, the following calculation formula is adopted:

$$S = \frac{Q}{q} \times \frac{1}{a} \times \frac{T}{365} \quad (8)$$

Among them:
S – Building area of the park, unit: m^2
q – volume of unit cargo in storage, unit: t/m^2
T – Cycle time of warehouse cargo, unit: d
α – Utilization coefficient of building area

RESULTS AND DISCUSSION

PREDICTION OF CONTAINER THROUGHPUT

The container throughput is used to replace the logistics quantity of the park. The investigation of the logistics quantity of the Cuntan port logistics park from 2003 to 2011 is as follows:

Tab. 1. Logistics quantity from 2003 to 2011(TEU)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Quantity	49321	79726	109901	150154	204171	241467	203048	250034	321000

According to the weighting idea of the IOWGA operator algorithm, calculate the combined predicted value based on the combined prediction model, and the above combined predicted value is substituted into the combined prediction model based on IOWGA operator according to the criterion of sum of squares of logarithm error, the optimal weight coefficients of the combined prediction model based on IOWGA operator calculated with the quadratic programming model are L_1=0.8662771 and L_2=1337229. By substituting L_1 and L_2 into the combined prediction model, the combined predicted value from 2003 to 2011 is obtained, and the obtained mean mean square error is 2144.64.

MEASUREMENT AND CALCULATION OF THE TOTAL AREA OF THE PARK

According to the formula of proportional summary method and space-time consumption method, based on the predicted value of the combined forecast for the target year's logistics quantity, the land scale of Cuntan port logistics park in different years is calculated. The scale measured by the space-time consumption method is the lower limit, and the scale measured by the proportional summary method is the upper limit. The total theoretical scale of the park takes the average of the upper and lower limits. The results are shown in the table below.

Tab. 2. Total scale of park land using of target year (square meter)

Measure	2015	2020	2030
Proportional summary method	879611.08	1580878.55	3946733.2
Space time consumption method	431052.52	774707.93	1934092.62
Total theoretical scale	655331.80	1177793.24	2940412.92

METHOD FOR CALCULATING THE AREA OF THE CORE FUNCTIONAL AREA

Based on the predicted value of the combined forecast for the target year's logistics quantity, the relevant formula is used to calculate the yard area, the area of the container freight station, the area of the circulating warehouse of the Cuntan port logistics park and the total floor area of the park. The calculation results are shown in the following table.

Tab. 3. The prediction of scale of functional areas (square meter)

Year	2015	2020	2030
Yard area	157878.91	283747.43	708388.01
Cargo terminal area	19937.85	35833.25	89459.29
Warehouse	134580.50	241874.42	603850.18
Construction area	270250.88	485707.63	1212590.60

CALCULATION OF INDEX CORRECTION COEFFICIENT

The container throughput obtained above only reflects the logistics demand volume factor which belongs to the economic influencing factors. To correct the development intensity index of park obtained by container throughput, firstly, the ranking weights that are relatively important to the target layer are used as the weights of the factors in the factor layer, and it is determined by the analytic hierarchy process, namely:

A= (0.0461, 0.0092, 0.4238, 0.1413, 0.1967, 0.0656, 0.0294, 0.0881)

On this basis, the evaluation on whether all the influencing factors are favourable for improving the land development intensity of Cuntan port logistics park is conducted, and the normalization is carried out to obtain the evaluation matrix R.

$$R = \begin{bmatrix} 0.30 & 0.40 & 0.20 & 0.05 & 0.05 \\ 0.20 & 0.30 & 0.30 & 0.10 & 0.10 \\ 0.70 & 0.30 & 0.00 & 0.00 & 0.00 \\ 0.50 & 0.45 & 0.05 & 0.00 & 0.00 \\ 0.60 & 0.35 & 0.05 & 0.00 & 0.00 \\ 0.35 & 0.45 & 0.15 & 0.05 & 0.00 \\ 0.25 & 0.35 & 0.25 & 0.10 & 0.05 \\ 0.40 & 0.45 & 0.10 & 0.05 & 0.00 \end{bmatrix} \quad (9)$$

The most common matrix multiplication method is used for fuzzy operations:

B=A*R=(0.56655, 0.360225, 0.05488, 0.01385, 0.004695). According to the principle of maximum membership degree, the corresponding evaluation is very favourable, and the correction coefficient is 10%.

DETERMINATION AND APPLICATION OF DEVELOPMENT INTENSITY INDEX

To calculate the development intensity index, firstly, the lower limit value of relevant indicators is determined based on the predicted total scale (parcel area) of theoretical land in the park in 2020; secondly, for the guiding and operational principles of the indicators, the upper limit of the development intensity index is calculated based on the relevant land data of Cuntan port logistics park in 2030; finally, the theoretical development intensity index obtained is revised, and a reasonable land development intensity control index of the Cuntan port logistics park is obtained to guide the future development and construction of the park.

Tab. 4. The related land scale of port logistics park of Cuntan port (square meter)

Year	2015	2020	2030
Total theoretical scale	655331.80	1177793.24	2940412.92
Yard area	157878.91	283747.43	708388.01
Cargo terminal area	19937.85	35833.25	89459.29
Warehouse	134580.50	241874.42	603850.18
Construction area	270250.88	485707.63	1212590.60

According to the proportion of the land with various functions, the theoretical land development intensity control index of Cuntan port logistics park is calculated, and the obtained 10% of the correction coefficient of the land development intensity control index of the Cuntan port logistics park is adopted to calculate the revised land development intensity control index of the Cuntan port logistics park, as shown in table 5.

Tab. 5. The revised index of land development intensity of logistics park of Cuntan port

Average plot ratio of the park	0.45~1.13	Average building density (%)	32~60
Storage function area volume rate	0.45~2.20	Building density of warehouse function area (%)	52
Vegetation rate (%)	6~20	Construction coefficient (%)	65

The revised land development intensity control index is also valuable for the planning and construction of other port container logistics parks. Among them, the plot ratio and building density of the warehouse functional area can be directly applied to control the development intensity of specific plot of land; the average plot ratio, building density and ratio of green space of the park can control the development intensity of the whole land; and the index of greening rate also applies to the control of specific plot of land.

CONCLUSION

On the basis of comparing the land development intensity index of port container logistics park at home and abroad, a three-level index system structure for the analysis of the influencing factors of the land development intensity index of port container logistics park is constructed, and the PENT analysis method is adopted to analyse the influencing factor of the land development intensity index in the park from four aspects: policy and regulation, economic environment, natural environment and technical environment. On this basis, the research method to measure the land development intensity control index of port container logistics park is proposed. By referring to and improving the relevant models, the land development intensity control index of the port container logistics park is finally calculated with an example. Although the feasibility of the method is verified by a special case, the method for calculating the development intensity control index and the results calculated therefrom have general applicability.

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