Evaluation of port development based on the theory of the driving force and the law of entropy weight

Rongtai Lin *a, Jian Tan b

Wuhan University of Technology, Heping Street 1040, Wuchang District, Wuhan, 430063, China

Abstract

The global shipping industry suffered a huge blow during 2008 financial crisis, which has become the main tone of the shipping industry in recent years. Faced with new changes in the new era, port development strategy in the past has become limited due to the changeable objective conditions. Based on the needs of the port development strategy planning and Entropy Method, this paper establishes the evaluation model of port development level by introducing the driving force theory. Through the example analysis, it's certain that the model has rationality and feasibility. The model can be used as the scientific basis for guiding the port development strategy-making.

Keywords: Driving force; development strategy; Vicissitude; Entropy Weight

1. Introduction

Port as a node of the waterway transport, is not only as a logistics center, a transportation hub, but also becomes a way of foreign trade, the driving force of the regional economic development. Port construction in China, the development of strategic research has played a very important role in guiding the port construction. More frequent economic exchanges between the countries in contemporary, closer relationships of economics, and the economic trend of globalization has been formed, the more important the development strategy plays.

The so-called development strategy is the guiding ideology and methods that studying the development of large-scale complex system, from the points of overall, fundamental and long-term points. Combined with the definition of the port and the development of strategic, port development strategy refers the guiding ideology in
all decision-making within a certain historical period, and the major, decisive plans of overall importance under the guidance of the port development strategy.

Along with the development of the world economy, the competition among ports is also becoming more intense. Meanwhile, the global shipping industry suffered a huge blow by the 2008 financial crisis, which has become the main tone of the shipping industry in recent years. Faced with new changes in the new era, port development strategy in the past has become limited due to the changeable objective conditions. Making timely scientific development strategy in this environment is the inevitable choice for the port’s development in the future.

In recent, many scholars have applied the theory of enterprise development strategies to the shipping sector, which is, making differentiated port’s development strategic goals and missions to make a large number of ports successively to grow up. The practice has proved that rational allocation of port’s resources can greatly enhance the ability of the city’s economic agglomeration and industrial derived, change the port city from the passive distribution of productive forces into active distribution of productive forces, from past over-reliance on the hinterland resources into comprehensive utilization of resources at home and abroad to create a new economic growth point and the industry chain.

Presently, scholars’ study about port development strategy mostly focus on two aspects: one is that proposing the status and nature; the other is that bringing forward the port development goals and countermeasures based on the evaluation of the level of development of the port, combined with the port status. The latter one which takes a comprehensive analysis and evaluation of the port, which takes more factors into consideration than the former relatively, is more reliable. Nowadays, most of the ports adopt the latter to make development strategy. As for the construction of the evaluation system, many predecessors have done a lot of research on evaluation methods. This paper attempts to establish more scientific and reasonable index system, by introducing the driving force theory from the aspect of selection of evaluation index, in purpose of providing a more scientific basis for strategic planning for the development of China’s port.

2. Introduction of the port driving force theory

The vicissitudes of ports are the results of many different factors, which are the port driving force factors or driving force. This includes internal and external factors; however, these factors all affect the ports from different dimensions of the structure and function of the port. The port driving force theory developed from the theory of the driving theory of the port changes. The evolution of the port of each generation all boils down to the factors of port driving force, and, the size of the port driving force indicates the potential for port development and also represents the level of the current stage of development of the port, according to the basic law of the port changes. Based on the analysis of the influencing factors of port driving force (Zhang, et.al, 2009; Zhang & Zhen, 2009), the factors of port driving force include three levels, which is economic dimension, the management dimension and strategic dimension. Factors of economic dimension include factors such as, social division of labor, industry globalization, uncertainty of market demand (flexibility) and risk diversification; factors of management dimension include factors such as, scientific development, supply chain management technology and agile manufacturing style; factors of strategic dimension include factors such as, cost control motivation, complementary motivation and resources utilization. The above is the theoretical framework of the driving force of the port changes. However, port development has characteristic of timeliness. So combined with the characteristics of level of development of the port, we can establish the evaluation index system based on the port driving force, which shows in Table 1.
### Table 1 Theoretical framework of evaluation of the port driving force

| Dimension                  | Driving force factors (First layer of indexes) | Evaluation index of level of port development (Secondary indexes) | Definition of Indexes (quantitative/qualitative) |
|----------------------------|-----------------------------------------------|---------------------------------------------------------------|-------------------------------------------------|
| Economic dimension         | Influencing factors of global industry        | Global economic factor (Fu, 2010) State policy factor          | The level of national economic security (Gu et al., 2012) |
|                            | Factors of social division of labor           | Proportional relationship of the national economy Port cargo proportion relationship | Proportion of secondary and tertiary industries accounting GDP Proportion of port container throughput accounting the port’s total throughput |
|                            | Factors of market demand                      | Market demand of economic hinterland Level of integration of port and city(Huang, 2011) | Proportion of port throughput accounting urban freight volume |
|                            | Factors of risk diversification               | Competition among nearby ports Competition among other modes of transportation | The proportion of port throughput accounting the province water freight Proportion of the port throughput accounting the freight volume of other modes of transport |
| Management dimension       | New technology                                | Level of information Level of green(Liu, 2011)                 | The level of integrated information services of coverage rate of AI, tracking rate of GPS ships and capacity of online services Comprehensive level of waterway greening rate, energy-saving compliance rate of shipping companies and the EIA pass rate of port and shipping construction |
| Strategic dimension        | Cost control                                  | Channel maintenance water depth High-grade channel Wharf construction | The year guarantee rate of waterway maintenance of water depth The proportion of high-grade channel Proportion of piers more than 5000t |
|                            | Common interests                              | Quantity of industry associations Quantity of joint ventures Degree of local enterprise boom | Quantity of industry associations Quantity of joint ventures Business confidence index |
|                            | Resource utilization factors                  | Quantity of human resources The level of talent pool The level of material resources | Quantity of labor resources Number of students undergraduate Quantity and size of material resources |
3. Establish evaluation model for evaluation of level of port development based on the theory of port driving force and Entropy Method

Entropy Method (Peng, 2009) is a method to quantify and integrate the information of each unit to be evaluated for each unit in the process of evaluation. Using Entropy Method to empower the evaluation factors, not only simplifies the evaluation process, but also determines the index weight objectively.

In order to reduce the interference of the subjective factors in determining the weight coefficient, this paper adopts the Entropy Weight to determine the index weight of the level of port development evaluation (Jiang, et.al, 2001). Firstly, only a limited number of key indicators to be selected to evaluate the level of port development, for the factors affecting the level of port development are numerous and miscellaneous. Secondly, among the data of the selected evaluation indicators, some are known which can be obtained from existing statistical data; others are unknown that cannot be obtained from the statistics. Thirdly, the evaluation of port development level is related to the management level, so there is a lot of uncertainty and qualitative analysis. Therefore, level of port development has the characteristic of incomplete information or “gray” information. Based on the above analysis, this paper establishes the evaluation model of the level of port development based on the Entropy Method and Grey Correlation Degree comprehensive evaluation.

On the basis of the relevant data of the level of port development at home and abroad, the rank index value is set reference to the development goals such as, “China Maritime regulatory Development Goals”, “Outline of the conservation and management of national inland waterways(2011-2015)”, “12th Five-Year Plan of the Ministry of Transport” and so on. After screening, the evaluation model of port development level based on the port driving force and Entropy Method is showed in Table2.

Table 2. Evaluation model for evaluation of level of port development based on the theory of port driving force and Entropy Method

| Indexes of First layer | Seq sequence | Secondary indexes | Definition of indexes | Rank | Backward stage | Starting stage | Developing stage | Mature stage |
|-----------------------|--------------|-------------------|----------------------|------|----------------|----------------|-----------------|--------------|
| Influencing factors of global industry U1 | 1 | Global economic factor U11 | The level of national economic security (Point) Positioning of national development and strategic planning | qualitative quantitative | Extremely unsafe | Mild unsafe | Basic safe | Safe |
| | | | | | 20 | 60 | 80 | 100 |
| National policy factor U12 | 2 | Proportional relationship of the national economy U21 | Proportion of secondary and tertiary industries accounting GDP | quantitative | 1 | 3 | 7 | 10 |
| | | | | | 70% | 80% | 90% | 95% |
| Factors of social division of labor U2 | 3 | Port cargo proportion relationship U22 | Proportion of port container throughput accounting the port’s total throughput | % | 1% | 5% | 10% | 50% |
| | | | | | | | | |
| Factors of market demand U3 | 5 | Market demand of economic hinterland U31 | Port’s predicted throughput of ten years later | % | 500 | 2000 | 5000 | 10000 |
| | | | | | | | | |
| Level of integration of port and city | 6 | Proportion of port throughput accounting urban freight volume | % | | 10% | 30% | 50% | 70% |
| No. | Category                                      | Description                                                                 | Values         |
|-----|-----------------------------------------------|-----------------------------------------------------------------------------|----------------|
| 7   | Factors of risk diversification U4            | Competition among nearby ports U41                                           | 1% 5% 20% 40% |
| 8   | Factors of risk diversification U4            | Proportion of the port throughput accounting the freight volume of other modes of transport | 40% 60% 80% 100% |
| 9   | New technology U5                             | Level of information U51                                                    | 70% 80% 90% 100% |
| 10  | New technology U5                             | Level of greening and environment U52                                      | 85% 90% 95% 100% |
| 11  | New technology U5                             | Channel maintenance water depth U61                                         | 85% 90% 95% 100% |
| 12  | Channel maintenance water depth U61          | The proportion of high-grade channel                                        | 25% 40% 50% 60% |
| 13  | Channel maintenance water depth U61          | Proportion of piers more than 5000t                                         | 5% 10% 25% 40% |
| 14  | Common interests U7                           | Quantity of industry associations U71                                       | 5 10 20 40 |
| 15  | Common interests U7                           | Quantity of joint ventures U72                                              | 1 5 10 15 |
| 16  | Common interests U7                           | Degree of local enterprise boom U73                                         | 85 100 115 130 |
| 17  | Resource utilization factors U8               | Quantity of labor resources U81                                              | 100 300 500 700 |
| 18  | Resource utilization factors U8               | Number of students undergraduate U82                                        | 3 5 10 20 |
| 19  | Resource utilization factors U8               | The level of material resources U83                                          | quantitative 4 qualitative 6 quantitative 8 quantitative 10 |
4. Feasibility test- taking Anqing Port as an example

4.1. Establish development evaluation system of Anqing Port

The evaluation index system of development of Anqing Port is showed as Table 2, including eight first layer indexes, that is, influencing factors of global industry $U_1$, factors of social division of labor $U_2$, factors of market demand $U_3$ , factors of risk diversification $U_4$, new technology $U_5$, cost control $U_6$, common interests $U_7$, resource utilization factors $U_8$; nineteen secondary indexes ($U_{11}, U_{12}, ..., U_{83}$).

Index value and each evaluation grade values of the evaluation model of Anqing Port are showed in Table 3.

| Rank | Indexes | $X_0$ (Anqing) | $X_1$ | $X_2$ | $X_3$ | $X_4$ |
|------|---------|----------------|------|------|------|------|
| U11  |         | 66             | 20   | 60   | 80   | 100  |
| U12  |         | 3              | 1    | 3    | 7    | 10   |
| U21  |         | 81.0%          | 70%  | 80%  | 90%  | 95%  |
| U22  |         | 5.2%           | 1%   | 5%   | 10%  | 50%  |
| U31  |         | 7780.23        | 500  | 2000 | 5000 | 10000|
| U32  |         | 48.3%          | 10%  | 30%  | 50%  | 70%  |
| U41  |         | 0.95%          | 1%   | 5%   | 20%  | 40%  |
| U42  |         | 93.3%          | 40%  | 60%  | 80%  | 100% |
| U51  |         | 80%            | 70%  | 80%  | 90%  | 100% |
| U52  |         | 95%            | 85%  | 90%  | 95%  | 100% |
| U61  |         | 98%            | 80%  | 85%  | 90%  | 95%  |
| U62  |         | 33.28%         | 25%  | 40%  | 50%  | 60%  |
| U63  |         | 5.8%           | 5%   | 10%  | 25%  | 40%  |
| U71  |         | 8              | 5    | 10   | 20   | 40   |
| U72  |         | 3              | 1    | 5    | 10   | 15   |
| U73  |         | 118.9          | 85   | 100  | 115  | 130  |
| U81  |         | 478            | 100  | 300  | 500  | 700  |
| U82  |         | 12.6           | 3    | 5    | 10   | 20   |
| U83  |         | 30             | 4    | 6    | 8    | 10   |

4.2. Standardization of index value

Adopt the method of equalization for standardization of raw data. The index value after standardization is showed in Table 4.
Table 4 Index value after standardization

| Rank | X0 (Anqing) | X1     | X2     | X3     | X4     |
|------|-------------|--------|--------|--------|--------|
| U11  | 1.012       | 0.307  | 0.920  | 1.227  | 1.534  |
| U12  | 0.625       | 0.208  | 0.625  | 1.458  | 2.083  |
| U21  | 0.974       | 0.841  | 0.962  | 1.082  | 1.142  |
| U22  | 0.365       | 0.070  | 0.351  | 0.702  | 3.511  |
| U31  | 1.539       | 0.099  | 0.396  | 0.989  | 1.978  |
| U32  | 1.159       | 0.240  | 0.720  | 1.200  | 1.680  |
| U33  | 0.071       | 0.075  | 0.373  | 1.494  | 2.987  |
| U41  | 1.250       | 0.536  | 0.804  | 1.072  | 1.339  |
| U42  | 0.952       | 0.833  | 0.952  | 1.071  | 1.190  |
| U51  | 1.022       | 0.914  | 0.968  | 1.022  | 1.075  |
| U52  | 1.094       | 0.893  | 0.949  | 1.004  | 1.060  |
| U61  | 0.799       | 0.600  | 0.960  | 1.200  | 1.440  |
| U62  | 0.338       | 0.291  | 0.583  | 1.457  | 2.331  |
| U71  | 0.482       | 0.301  | 0.602  | 1.205  | 2.410  |
| U72  | 0.441       | 0.147  | 0.735  | 1.471  | 2.206  |
| U73  | 1.083       | 0.774  | 0.911  | 1.048  | 1.184  |
| U81  | 1.150       | 0.241  | 0.722  | 1.203  | 1.684  |
| U82  | 1.245       | 0.296  | 0.494  | 0.988  | 1.976  |
| U83  | 2.586       | 0.345  | 0.517  | 0.690  | 0.862  |

4.3. Calculate the correlation coefficient

The indexes value of Anqing Port X0 regard as the reference series to calculate the correlation coefficient, in turn, we calculate the degree of association between the indexes value of the status of Anqing Port development and each level of evaluation rank’s index value. The stage of development of Anqing Port lies on is determined by the degree of association. The correlation coefficient is showed in Table 5.

Table 5 Correlation coefficient

| Rank | X1     | X2     | X3     | X4     |
|------|--------|--------|--------|--------|
| \( \lambda_j(U_{11}) \) | 0.508  | 0.888  | 0.773  | 0.583  |
| \( \lambda_j(U_{12}) \) | 0.636  | 1.000  | 0.467  | 0.333  |
| \( \lambda_j(U_{21}) \) | 0.930  | 1.000  | 0.943  | 0.910  |
| \( \lambda_j(U_{22}) \) | 0.849  | 0.999  | 0.830  | 0.336  |
| \( \lambda_j(U_{31}) \) | 0.352  | 0.408  | 0.599  | 0.656  |
| \( \lambda_j(U_{32}) \) | 0.464  | 0.656  | 1.000  | 0.613  |
4.4. Entropy Method to calculate the weight of each index, showed in Table 6

| Secondary indexes | Weight | Secondary indexes | Weight | First layer indexes | Weight |
|-------------------|--------|-------------------|--------|---------------------|--------|
| U11               | 0.331  | U51               | 0.174  | U1                  | 0.129  |
| U12               | 0.669  | U52               | 0.007  | U2                  | 0.167  |
| U21               | 0.010  | U61               | 0.158  | U3                  | 0.076  |
| U22               | 0.990  | U62               | 0.835  | U4                  | 0.149  |
| U31               | 0.674  | U71               | 0.474  | U5                  | 0.147  |
| U32               | 0.326  | U72               | 0.503  | U6                  | 0.158  |
| U33               | 0.898  | U73               | 0.023  | U7                  | 0.136  |
| U41               | 0.102  | U81               | 0.381  | U8                  | 0.038  |
| U42               | 0.826  | U82               | 0.504  |                     |        |
|                   |        | U83               | 0.115  |                     |        |

4.5. Compound of multi-level degree of association, degree of association of each layer is showed in Table 7.

| Rank | Degree of association | X1  | X2  | X3  | X4  |
|------|-----------------------|-----|-----|-----|-----|
| R(U1)|                       | 0.594 | 0.963 | 0.568 | 0.416 |
| R(U2)|                       | 0.849 | 0.999 | 0.831 | 0.342 |
| R(U3)|                       | 0.389 | 0.489 | 0.730 | 0.642 |
| R(U4)|                       | 0.967 | 0.824 | 0.547 | 0.397 |
5. Comprehensive analysis of evaluation of level of Anqing Port development

Level of Anqing port development can be drawn at the starting stage which inclines to the backward stage due to the result of evaluation \( R(U) = (0.753, 0.864, 0.627, 0.413) \). According to the analysis of the results of evaluation of each layer of indexes; Anqing Port’s development has the following characteristics. Firstly, the infrastructure in Anqing port is relatively backward, and the scale of construction is smaller and difficult to form economies of scale. Although there are many port owners, it’s difficult to carry out a unified, standardized management because these port owners are small and moreover scattering. Secondly, low level of waterway, is difficult to meet the growing needs of social and economic development to the waterway transport. Although this can be obtained through expansion, reconstruction and other measures to improve the grade of waterway, this is limited room for improvement. During the "Eleventh Five-Year" period, Port and Shipping Authority of Anqing invested relatively less into waterway management, and conservation, so that the waterway conservation capacity is still quite limited of waterway conservation of Anqing Port is still quite limited. Thirdly, the evaluation of market demand and resource utilization of Anqing Port are both at a higher level than other aspects relatively, because the rich mineral resources, as well as bridge construction in Anqing enhances its influence on indirectly hinterland. Fourthly, Anqing Port is relatively lack of transportation management, especially inadequate optimization of transport structure. Anqing port is in a backward stage in container transport and specialized transport, and the majority of transport enterprises in Anqing Port are scattered, small, miscellaneous that makes standardized and united management hard to realize. Lastly, the information construction of Anqing Port is at a relatively leading level compared to other similar river ports. But due to the lack of uniform construction standards, level of information sharing is not high and it’s difficult to manage the information unified. Combined with <Anqing Port Overall Plan (2007)>, we can see the result is realistic.

6. Conclusions

This paper analyzes the importance of the port development strategic planning to the port’s development, and points out that the determination of the level of port development is the guidance to the strategic planning of development, and then establishes the index system for evaluation of level of port development based on Entropy Method. Due to space limitation, the paper only selects the evaluation indexes with wide attention to the current socio-economic environment relatively, which meets the requirement of port development and better, reflects the dynamic evaluation requirement of port development.

According to the data of evaluation index value attained from field surveys and collection about Anqing Port, the evaluation model established is applied to evaluate the current stage of level of Anqing port development. The result of evaluation is that the current stage of level of Anqing port lied in starting stage, which conforms to the reality of Anqing port development, and further demonstrates the index system of evaluation and evaluation model is of feasibility.

For the uncertainty and gray characteristics of evaluation system of level of port development, as well as the lack of theory, knowledge structure and time limited of the author, there are inevitably some inaccuracies in the process of selecting indexes, defining indexes, grading standards and data collection. The paper also has a lot of
inadequacies, and there are lots of problem needed to be explored, which need to be effectively addressed in future research.

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