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Research on Maturity of Port Operation System based on Super-SBM

Han Hu

School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Bengbu, Anhui, 233030, China

Abstract

In view of the system maturity measurement problem, this paper uses data visualization, control variables and other methods to establish an index system to measure the maturity of system, a system evaluation model based on coupling coordination degree, and a system effiency improvement model based on Super-SBM, etc. selecting data from four companies, using software such as DEA-SOLVER and MATLAB to carry out empirical analysis. It obtains the maturity level of every company's system, and make recommendations for companies with low maturity.

Keywords

System Maturity; Super- SBM Model; PSR Model; Comprehensive Assessment.

1. Introduction

Data is a strategic asset for most companies. Companies need to extract business value from this data, and it can be difficult. Therefore, it is of great significance for enterprises and companies to establish a mature data and analysis system to protect data resources.

Driven by uncertain external factors, the completeness and maturity of data and analysis systems are becoming more and more important. At the same time, the maturity of data and analysis system determines the level of business performance, which needs to be evaluated and evaluated. Based on the evaluation results, it is worth studying and thinking to change and improve the system, optimize the analysis ability of the system, develop the maximum potential of the system, so as to obtain competitive advantages and improve the company's income.

Port performance evaluation is always a hot topic. It is found that some scholars have studied port performance evaluation and put forward their own views. Let's describe it briefly.

In *The* Symbiotic *Performance Evaluation of Port Clusters Based on FCE*[1], Liu Wei evaluates the symbiosis performance of port cluster enterprises by using fuzzy comprehensive evaluation method (FCE). On the basis of the evaluation, the factors affecting the performance of port cluster are discussed according to the characteristics of port cluster development and the evaluation results. Finally, the author puts forward some suggestions and views on how to promote the development of port performance. However, due to the consideration of less aspects, the lack of a certain practical and persuasive.

In *Performance evaluation of container port collecting and distributing system based on combination weighting method*[2], Hu Yujie established a unified performance evaluation index system for three container port layout modes based on comprehensive weighted method, and dealt with and verified the problems by combining entropy method and analytic hierarchy process. But the research object is single, there are certain limitations.

Most literatures have carried out innovative research on port performance evaluation, but lack of systematic management of port data. However, a complete data analysis system is the basis of performance evaluation, so we put forward the concept of data analysis system and the corresponding evaluation model, and put forward the confidence degree of the system and relevant suggestions.

2. System Maturity Model based on PSR Model

2.1. Model Preparation

First, we need to find the relevant indicators to evaluate the system maturity. Through the analysis of the enterprise, we can get the following indicator system. including personnel, technology, processes, et al., are shown in Table 1 for details.

Table 1. System KPI screening results

Classification	Specific indicators	Unit
People	staff numbers	person
	work experience	year
	educational levels	—
	induction training numbers	times
Technology	R&D expenses	million
	program error rate	%
	customer satisfaction	%
	number of techniques	species
Process	data tracking rate	%
	number of data changes	times
	data retention period	year

In the process of constructing indicators to measure the maturity of system, we have obtained various indicators, but these indicators have the difference between positive indicators and negative indicators. The larger the index value of the positive index, the better, and the smaller the index value of the negative index, the better. Among the indicators we built to measure the maturity of the system, the positive indicators include the number of employees, work experience, educational level,induction training numbers,R&D expenses, customer satisfaction, number of techniques, data tracking rate, and data retention years. Negative indicators include the program error rate and the number of data changes.

In order to facilitate the subsequent use of the indicators, we preprocess the indicator data to eliminate the differences caused by different dimensions of the indicators.

For the positive indicator, use the formula:

$$X_{ij} = \frac{x_{ij} - \min\{x_j\}}{\max\{x_j\} - \min\{x_j\}}.$$

For the negative indicator, use the formula:

$$X_{ij} = \frac{\max\{x_j\} - x_{ij}}{\max\{x_j\} - \min\{x_j\}}.$$

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Among them, $\min\{x_j\}$: it refers to the minimum value of the j-items indicator data in each region ($j=1,2,3,\cdots,20$), $\max\{x_j\}$:it refers to the maximum value of the *j*-items indicator data in each region, x_{ij} : it is raw data for the indicator ($i=1,2,3,\cdots,31$), X_{ij} : it is the indicator data value after dimensionless processing.

2.2. Model Solution

Coupling refers to the phenomenon in which two or more systems interact and influence each other, and the degree of coupling is used to measure the degree to which systems or elements influence each other. First, calculate the comprehensive score value of the personnel layer, technical layer, and process layer:

$$Z_1 = \sum_{i=1}^{m} O_i \times Z'_{1i},$$

$$Z_2 = \sum_{i=1}^{n} P_i \times Z'_{2i},$$

$$Z_3 = \sum_{i=1}^{k} Q_i \times Z'_{3i}.$$

Then, calculate the degree of coupling U between system personnel, technology, and processes *U*:

$$U = \left[\frac{Z_1 Z_2 Z_3}{\frac{(Z_1 Z_2 Z_3)^3}{3}} \right]^{1/3}.$$

Among them, O_i represents respectively the corresponding weight of each indicator in the people system, P_i represents respectively the corresponding weight of each indicator in the technology system, Q_i represents respectively the corresponding weight of each indicator in the process system. Z'_{1i}, Z'_{2i}, and Z'_{3i} represent the dimensionless values of each indicator in people, technology, and process, respectively. And Z_1, Z_2, and Z_3 represent the comprehensive score of people, technology, and process, respectively. Finally, U represents the coupling function.

The degree of coupling can intuitively reflect the strength of the coupling between the personnel, technology, and processes of corporation's system. Coupling has a value between 0 and 1 (excluding 0 and 1). The U closer it is to 1, the greater the coupling between the systems, and vice versa. When $U \in (0, 0.3]$, it is a low-level coupling; when $U \in (0.3, 0.5]$, it is an antagonistic stage. When $U \in (0.5, 0.8]$, it is a running-in stage. When $U \in (0.8, 1]$, it is a high coupling, indicating that the subsystem is in a benign resonance coupling and orderly development state.

Next, referring to the coupling coordination degree model, we obtain the comprehensive evaluation index *C*:

$$C = \frac{1}{3} \times Z_1 + \frac{1}{3} \times Z_2 + \frac{1}{3} \times Z_3$$

Finally, build a system maturity model D:

$$D = \sqrt{UC}$$

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2.3. Empirical Analysis of the Same Type of Enterprises

we demonstrate the model with a port-type company data indicator. We selected the data of shanghai international port group, Nanjing Port limited company, Qingdao Port International limited company, and Guangzhou Port Group Co. LTD in 2020 as the research basis, and the data are all from the Shanghai Stock Exchange.

For convenience of description, we abbreviate the names of the four enterprises. We abbreviate shanghai international port group as SPIG , Nanjing Port limited company as NP Co., LTD , Qingdao Port International limited company as QPI Co., LTD and Guangzhou Port Group Co. LTD as GPG Co., LTD.

We measure the maturity level of each enterprise's system, and bring the data into the system maturity evaluation model. The results are shown in Table 3.

Table 2. System maturity level of each company

enterprise	System Maturity
SPIG	0.6193
NP Co., LTD	0.1897
QPI Co., LTD	0.4634
GPG Co., LTD	0.5773

It can be seen that the system maturity shows that among the four seaport enterprises, the systems of Shanghai Port Group, Qingdao Port International Co., Ltd., and Guangzhou Port Group Co., Ltd. are all at medium maturity, while the system maturity of Nanjing Port Co., Ltd. is relatively low.

3. System Efficiency Model based on Super-Sbm

3.1. Model Solution

The traditional CCR model and BCC model assume that the scale return of production technology is constant, or although the scale return of production technology is variable, it is assumed that all evaluated objects are in the optimal production scale stage. But in actual production, many production units are not in the optimal scale of production. Moreover, when the traditional BCC model and CCR model have many input indicators and output indicators, they cannot compare and distinguish the differences in efficiency levels, and the accuracy cannot be guaranteed.

We use the system maturity evaluation model to determine the maturity of system. After the maturity level is determined, system is further improved with the Super-SBM model, so as to propose amendments to the system and improve the efficiency of the system. The specific process of Super-SBM is shown in Figure 1.

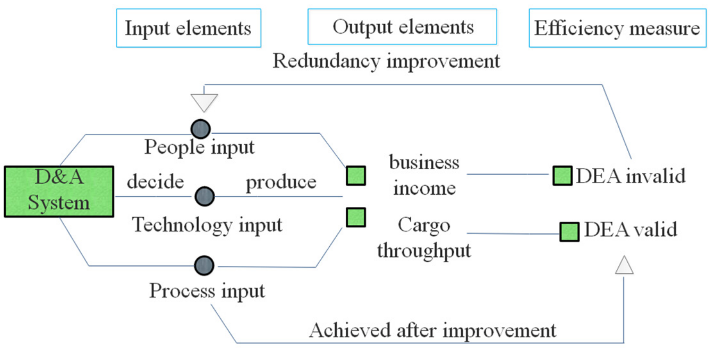

Figure 1. Schematic diagram of the Super-SBM model process

We use indicators that measure the maturity of system as input indicators, and cargo throughput and annual revenue as output indicators. The following explains the cargo throughput and annual revenue:

(i) Cargo throughput: refers to the weight of the cargo that enters from the waterway and exits from the port area and is loaded and unloaded during the reporting period. It includes packages, materials, supplies, fuel, mail, luggage, et al. It is an important indicator for port companies.

(ii) Annual income: refers to all legal income obtained from the country in a year.

3.2. Model Establishment

Suppose there are n evaluation decision-making units, and each decision-making unit has m kinds of "input" and t kinds of "output" resources. The specific calculation formula is as follows:

$$\min\rho = \frac{1+\frac{1}{m}\sum_{i=1}^{m} s_i / x_{i0}}{1-\frac{1}{q_1+q_2}\left(\sum_{r=1}^{q_1} s_r / y_{r0} + \sum_{t=1}^{q_2} s_t / b_{t0}\right)},$$

$$s.t.\begin{cases} \sum_{j=1, j\neq j_0}^{n} x_j\lambda_j - s^- \leqslant x_0(i=1,\cdots,m) \\ \sum_{j=1, j\neq j_0}^{n} y_j\lambda_j + s^+ \leqslant y_0(r=1,\cdots,q_1) \\ \sum_{j=1, j\neq j_0}^{n} b_j\lambda_j - s^{b-} \leqslant b_0(r=1,\cdots,q_2) \\ 1-\frac{1}{q_1+q_2}\left(\sum_{r=1}^{q_1} s_r/y_{r0}+\sum_{t=1}^{q_2} s_t/b_{t0}\right) > 0 \\ \lambda_j, s_i, s_r, s_t \geqslant 0(j=1,\cdots,n,j\neq j_0) \end{cases},$$

We use DEA-SOLVER software to solve the results and get the conclusion. Conclusion: By modifying the relevant slack variables and projecting the relevant evaluation objects to the production frontier, the DEA is effective, that is, providing specific improvement space for the relevant performance indicators for the company, so that the company can maximize the potential of its data assets.

The DEA efficiency values of each company are shown in Table 3.

Table 3. DEA efficiency value of SBM model of each company

enterprise	SBM Score
SPIG	1.9119
NP Co., LTD	0.8925
QPI Co., LTD	1
GPG Co., LTD	1.4054

There is room for further improvement. Based on investment-oriented Super-SBM system improvement model, three seaport enterprises are valid DEA, and the order of scores is Shanghai Port International Co., Ltd., Guangzhou Port Group Co., Ltd., Qingdao Port Group, Nanjing Port Co., Ltd., which shows that the model we designed can effectively evaluate the system maturity of the seaport industry, and is of great help in measuring its effectiveness. The visualization results are shown in Figure 2.

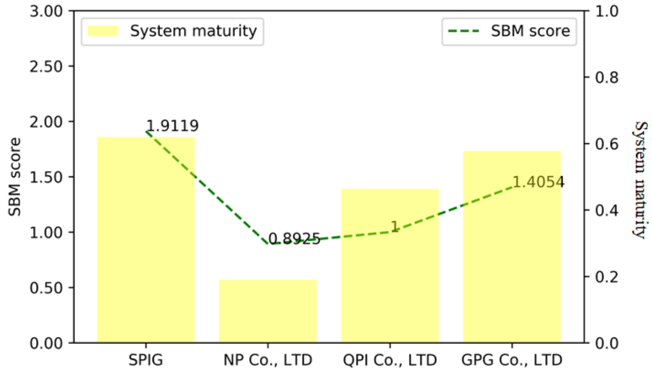

Figure 2. SBM score-System maturity visual display

4. Conclusion

From the four port enterprises studied, it can be seen that the port enterprises in economically developed regions such as Shanghai and Guangzhou have a high degree of maturity, while Nanjing, as an inland city, has a low degree of maturity. From the results of super SBM, the input-output efficiency of Shanghai port and Guangzhou port is high and needs to be maintained. However, the DEA results of Nanjing port are not effective, so the input and output in the above index system need to be started separately, Analyze the problems and further improve port operation efficiency

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