A performance evaluation model of supply Chain based on extension correlation function

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Received 1 September 2014, www.tsi.lv

Abstract

Performance evaluation of supply chain is complex and of uncertainty, and is influenced by factors of multiple levels. Directing at the features mentioned above, this paper studied the performance evaluation of supply chain of multiple attributes, and put forward a performance evaluation model and algorithm of supply chain based on extension correlation function. Via analysis of relative factors in the process of performance evaluation of supply chain, the model gave out an index system of performance evaluation of supply chain and by standardization of different evaluation indexes, it built an improved extension correlation function between evaluation indexes of enterprise supply chain performance and the ideal range of supply chain performance. Thus, the comprehensive weighted extension goodness between enterprise supply chain performance and the ideal range of supply chain performance could be obtained. According to the value of comprehensive weighted extension goodness, the supply chain with the optimal implementation effect could be selected, so as to offer effective support for the follow-up implementation of supply chain. Finally, in order to offer a scientific method for improving the supply chain and the enterprise competitiveness, the model and algorithm was tested an actual case.

Keywords: supply chain, performance evaluation, extension correlation function, model

1 Introduction

Supply chain management is an operation model forming and developing in fierce competition with the aim to improve the core competitiveness. Along with the rapid development of computer science and technology and IT science and technology, in today's commercial environment that tends to be disordered and dynamic, traditional supply chain is evolving to a dynamic supply chain of higher agility. It will make the supply chain structure more diversified, and the relationship among enterprises as supply chain members more complex. Thus, the performance evaluation of supply chain will be more complex with multiple levels of influence factors [1-3]. To evaluate and measure the performance of supply chains and management effects, relative indexes need to be chosen. However, if the organization performance is only evaluated from return of investment (ROI), the static measurement of organization performance based on financial accounting and management can no longer effectively evaluate the performance of supply chain. By far, researches directing at supply chain performance mainly concentrate on logistics, information flow, capital flow, and systematically analysis on supply chain performance is few. What's more, most of performance evaluation models of supply chain only considered single performance index. The indexes considered includes inventory level, cost, date of delivery, etc. And generally, those models only provide ideal decision-making and operation method, and do not provide discussion on measurement of concrete supply chain performance. And aspects including choices of indexes and construction of evaluation methods call for further study [4-6]. By far, there have been many decision-making and evaluation methods of complex system. In different system, different decision-making and evaluation methods focus on different aspects in solving problems. Some studies on those methods have made corresponding achievements [7-10]. For performance evaluation system of supply chain, there are multiple and complex factors that influence the performance value of supply chain and some indexes can only be described with qualitative fuzzy description rather than accurate quantitative value. Thus, the process of performance evaluation of supply chain is a process of decision-making analysis of complex system with incomplete information. Thus, this paper studied the performance evaluation of chain supply based on extension theory [11-14]. A normative evaluation index system of supply chain performance was established. It can analyse the supply chain performance of enterprise comprehensively based on extension correlation function, which made the modelling and analysing of supply chain more comprehensive, accurate and effective. Overall, with this model, the management of supply chain can be more targeted, which can provide a strong support for enterprise development.

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2 Construction of evaluation index system of supply chain

2.1 BASIS CHARACTERISTICS OF EVALUATION INDEXES OF SUPPLY CHAIN PERFORMANCE

Different scholars have different consideration in determination of evaluation index of supply chain. For example, at present, the typical ROF model analyses supply chain performance from the aspects of resources, output, flexibility, etc.; SCOR model evaluates the supply chain performance based on four management process, namely material supply, manufacturing, transportation and planning; Lummus R R model analyses performance evaluation of supply chain form supply, transformation, transportation and requirement management. It can be observed that these models improve and supplement traditional performance evaluation of supply chain from different perspectives. However, by far there are still some limitations in performance evaluation of supply chain. For example, there are few studies focusing on the performance evaluation of the whole supply chain, and most of the studies only focused on the chosen of indexes but did not evaluate and analyse the whole supply chain, and performance evaluation of supply chain based on the operation flow is not reflected. Thus, choice of evaluation indexes of performance evaluation of supply chain in the new circumstance needs to be focused on the connection between enterprises in the chain and the interior and exterior environment of supply chains. What's more, the relationship and integrally of members in the whole chain and the consistency of operation of members should be emphasized, and meanwhile, the potential relationship among business process, pecuniary condition and market condition should be reflected. Thus, choice of evaluation indexed of supply chain performance should follow some basic rules including comprehensiveness that the evaluation indexes of supply chain reflect the operating condition of the whole supply chain. Systematises that the evaluation indexes of supply chain reflect the integration and coordination of the operation of the whole supply chain, importance that the evaluation indexes chosen should be key performance indicator in performance evaluation of supply chain.

2.2 EVALUATION INDEX SYSTEM OF SUPPLY CHAIN PERFORMANCE

Directing at some problems in choice of evaluation indexes for existing performance evaluation of chain supply, by combining relative principles in choice of evaluation indexes of supply chain performance, this study provided an improved evaluation index system of supply chain performance from the perspectives of market, finance and operation flow. Its structure is presented in Figure1.

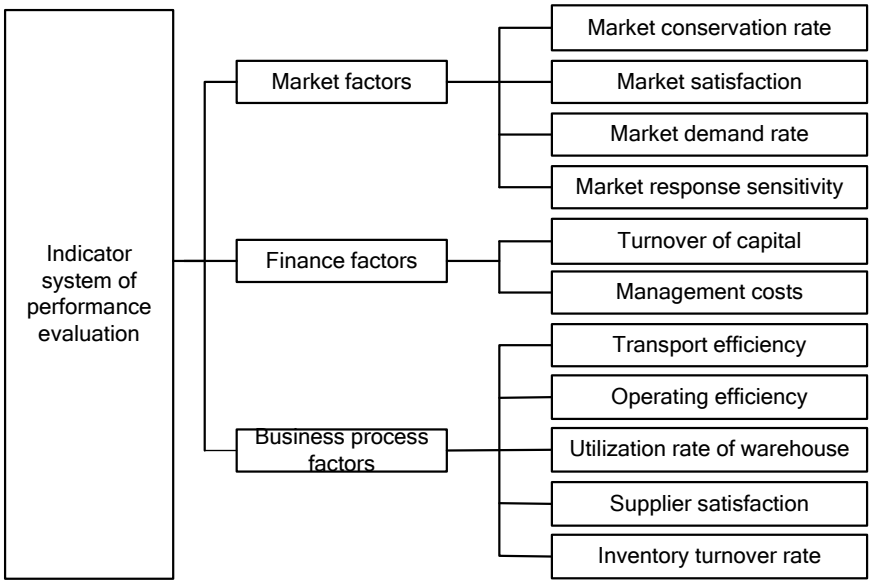

FIGURE 1 Evaluation index system of supply chain performance

3 Performance evaluation model and algorithm of supply chain based on extension correlation function

3.1 STANDARDIZATION OF EVALUATION INDEXES OF SUPPLY CHAIN PERFORMANCE

In the process of choosing evaluation indexes of supply chain performance, some indexes are not a certain value, so these indexes are fuzzy; some indexes are positive indexes while some are negative indexes. Thus, these indexes of multiple levels, attributes and categories need to be standardized. Thus, directing at qualitative and quantitative measurement, this paper puts forward the process of standardization presented as below.

If the evaluation index of supply chain performance p_i is a positive index, its value $v_i(p)=\left[v_i^a(p), v_i^b(p)\right]$. The corresponding standardized index is:

$$v_i^*(p)=\left[v_i^{*a}(p),v_i^{*b}(p)\right]= \left[v_i^a(p)/\max_{1\le j\le m}\left(v_{ij}^b(p)\right),v_i^b(p)/\max_{1\le j\le m}\left(v_{ij}^b(p)\right)\right], \quad (1)$$

where: $\left[v_i^a(p)/\max_{1\le j\le m}\left(v_{ij}^b(p)\right),v_i^b(p)/\max_{1\le j\le m}\left(v_{ij}^b(p)\right)\right]$ is the maximum value in the interval of evaluation index of supply performance p_i.

If the evaluation index of supply chain performance p_i is a negative index, its value $v_i(p)=\left[v_i^a(p),v_i^b(p)\right]$, the corresponding standardized index is:

$$v_i^*(p)=\left[v_i^{*a}(p),v_i^{*b}(p)\right]= \left[\min_{1\le j\le m}\left(v_{ij}^b(p)\right)/v_i^a(p),\min_{1\le j\le m}\left(v_{ij}^b(p)\right)/v_i^b(p)\right], \quad (2)$$

where: $\left[\min_{1\le j\le m}\left(v_{ij}^b(p)\right)/v_i^a(p),\min_{1\le j\le m}\left(v_{ij}^b(p)\right)/v_i^b(p)\right]$ is the maximum value in the interval of evaluation index of supply performance p_i.

If the evaluation index of supply chain performance p_i is a fuzzy quantitative description, fuzzy evaluation and corresponding fuzzy membership should be applied. The values and indexes are presented in Table1.

TABLE 1 The membership degree of fuzzy evaluation of evaluation indexes of supply chain performance

Degree of fuzzy membership	State level of index
0.1	Vary bad
0.3	Bad
0.5	Fair
0.7	Good
0.9	Very good
0.2,0.4,0.6,0.8	Between the neighbouring state levels mentioned above

By standardization of evaluation indexed of supply chain mentioned above, the discrepancy between different indexes was removed and the measuring standard was unified. In this way, the performance evaluation of supply chain can be more accurate.

3.2 CALCULATION MODEL OF EXTENSION CORRELATION OF SUPPLY CHAIN PERFORMANCE

Extenics is a subject of intelligent design that studies the rule and method of contradictory issues among or within things with formalized model. This subject, with characteristics of formalization, logicalization and mathematization, has corresponding achievements of engineering application in many fields and has formed extension engineering extension direction. This paper provides an extension correlation calculation model of supply chain performance by improving the classical extension distance.

If the corresponding positive ideal domain $v_i^{o*}(p)$ of standardized evaluation index of supply chain performance p_i is:

$$v_i^{o*}(p)=\left[v_i^{o*a}(p),v_i^{o*b}(p)\right]= \left[\max_{1\le j\le m}\left(v_{ij}^{*a}(p)\right),\max_{1\le j\le m}\left(v_{ij}^{*b}(p)\right)\right]. \quad (3)$$

Then the corresponding negative ideal domain $v_i^{N*}(p)$ of standardized evaluation index of supply chain performance p_i is:

$$v_i^{N*}(p)=\left[v_i^{N*a}(p),v_i^{N*b}(p)\right]= \left[\min_{1\le j\le m}\left(v_{ij}^{*a}(p)\right),\min_{1\le j\le m}\left(v_{ij}^{*b}(p)\right)\right]. \quad (4)$$

When the standardized evaluation index of supply chain performance p_i is an accurate value, namely $v_i(p)=v_i^a(p)=v_i^b(p)$, the extension distance ρ_{ij}^O of the evaluation phase of supply chain performance j between evaluation index of supply performance p_i and positive ideal domain $v_i^{o*}(p)$ is:

$$\rho_{ij}^O=\left|v_i(p)-\frac{v_i^{o*a}(p)+v_i^{o*b}(p)}{2}\right|-\frac{v_i^{o*b}(p)-v_i^{o*a}(p)}{2}. \quad (5)$$

The extension distance ρ_{ij}^N of the evaluation phase of supply chain performance j between evaluation index of supply performance p_i and negative ideal domain $v_i^{o*}(p)$ is:

$$\rho_{ij}^N=\left|v_{ij}(p)-\frac{v_i^{N*a}(p)+v_i^{N*b}(p)}{2}\right|-\frac{v_i^{N*b}(p)-v_i^{N*a}(p)}{2}. \quad (6)$$

If the standardized evaluation index of supply chain performance p_i is fuzzy value, namely $v_i(p)=\left[v_i^a(p),v_i^b(p)\right]$, the extension distance ρ_{ij}^O of the evaluation phase of supply chain performance j between evaluation index of supply performance p_i and positive ideal domain $v_i^{o*}(p)$ is:

$$\rho_{ij}^O=\frac{\left(\left|v_{ij}^a(p)-\frac{v_i^{o*a}(p)+v_i^{o*b}(p)}{2}\right|+\left|v_{ij}^b(p)-\frac{v_i^{o*a}(p)+v_i^{o*b}(p)}{2}\right|+v_i^{o*a}(p)-v_i^{o*b}(p)\right)}{2}. \quad (7)$$

The extension distance ρ_{ij}^{N} of the evaluation phase of supply chain performance j between evaluation index of supply performance p_i and negative ideal domain $v_i^{o*}(p)$ is:

$$\rho_{ij}^{N}=\frac{\left(\left|v_{ij}^{a}(p)-\frac{v_i^{N*a}(p)+v_i^{N*b}(p)}{2}\right|+\left|v_{ij}^{b}(p)-\frac{v_i^{N*a}(p)+v_i^{N*b}(p)}{2}\right|+v_i^{N*a}(p)-v_i^{N*b}(p)\right)}{2}. \tag{8}$$

When all the extension distances are obtained, the extension correlation function K_j^{O} between evaluation phase of supply chain performance j and ideal positive domain $v_i^{o*}(p)$ and the extension correlation K_j^{N} between evaluation phase of supply chain performance j and negative ideal domain $v_i^{o*}(p)$ are respectively:

$$K_j^{O}=\begin{cases}\rho_{ij}^{O}/\max\limits_{0\le j\le 1}\left|\rho_{ij}^{O}\right| & \max\limits_{0\le j\le 1}\left|\rho_{ij}^{O}\right|\neq 0\\ 0 & \max\limits_{0\le j\le 1}\left|\rho_{ij}^{O}\right|=0\end{cases}, \tag{9}$$

$$K_j^{N}=\begin{cases}\rho_{ij}^{N}/\max\limits_{0\le j\le 1}\left|\rho_{ij}^{N}\right| & \max\limits_{0\le j\le 1}\left|\rho_{ij}^{N}\right|\neq 0\\ 0 & \max\limits_{0\le j\le 1}\left|\rho_{ij}^{N}\right|=0\end{cases}. \tag{10}$$

Thus, the extension correlation ψ_j^{O} between evaluation phase of supply chain performance j and positive ideal domain $v_i^{o*}(p)$, and the extension correlation $\psi_j^{N}\psi_j^{O}$ between evaluation phase of supply chain performance j and negative ideal domain $v_i^{N*}(p)$ are respectively:

$$\begin{cases}\psi_j^{O}=\sum\limits_{i=1}^{n}\left(w_i*K_j^{O}\right)\\ \psi_j^{N}=\sum\limits_{i=1}^{n}\left(w_i*K_j^{N}\right)\end{cases}. \tag{11}$$

3.3 REALIZATION OF PERFORMANCE EVALUATION AND ALGORITHM OF SUPPLY CHAIN BASED ON EXTENSION CORRELATION FUNCTION

If the extension correlation of the evaluation phrase of supply chain performance j subordinate to the positive ideal domain of evaluation performance of supply chain $v_i^{o*}(p)$ is $\psi_j\left(0\le\psi_j\le 1\right)$, the extension correlation of the evaluation phrase of supply chain performance j subordinate to the negative ideal domain of evaluation performance of supply chain $v_i^{N*}(p)$ is $1-\psi_j$. In order to determine the extension correlation ψ_j, the objective function was established according to the advantages and disadvantages of positioning implementation plan:

$$F\left(\psi_j\right)=\min\left\{\left(\psi_j*\psi_j^{N}\right)^2+\left(\left(1-\psi_j\right)*\psi_j^{O}\right)^2\right\}. \tag{12}$$

The extension correlation ψ_j can be obtained according to extremum principle:

$$\psi_j=1/\left(1+\left(\psi_j^{N}/\psi_j^{O}\right)^2\right). \tag{13}$$

According to what mentioned above, the implementation steps of evaluation model and algorithm of supply chain based on extension correlation function is as below:

Step 1: According to the principles of choosing evaluation index of supply chain performance, establish an evaluation index system of supply chain performance of multiple levels and attributes by consulting relative design specialist.

Step 2: Based on interrelated thesis about standardization of evaluation indexes of supply chain performance mentioned in Section 2.1, standardize positive evaluation indexes according to Equation (1), negative evaluation indexed according to Equation (2) and fuzzy evaluation indexes according to Figure 1.

Step 3: Build positive ideal domain and negative ideal domain of different types of evaluation indexes under the evaluation index system of supply chain performance by Equations (3) and (4)

Step 4: Obtain the extension distance between different evaluation indexes of supply chain performance and the positive ideal domain according to Equations (5) and (7).

Step 5: Obtain the extension distance between different evaluation indexes of supply chain performance and the negative ideal domain according to Equations (5) and (7).

Step 6: Obtain the extension correlation function between performance evaluation of supply chain and positive ideal domain of evaluation index of supply chain performance according to Equation (9), and the extension correlation function between performance evaluation of supply chain and negative ideal domain of evaluation index of supply chain performance according to Equation (10).

Step 7: Considering the weight of different evaluation index of supply chain performance, obtain the extension correlation between performance evaluation of supply chain and positive ideal domain of evaluation index of supply chain performance, and the extension correlation between performance evaluation of supply chain and negative ideal domain of evaluation index of supply chain performance based on Equation (11).

Step 8: Obtain the comprehensive correlation of performance evaluation of supply chain of all the evaluation indexed according to Equation (12).

Step 9: Analyse the performance evaluation of supply chain according to the value of comprehensive extension correlation.

4 Case studies

In this paper, a supply chain in which a brand clothing enterprise is the core was chosen as the major research subject to explain and analyse the model and algorithm in this paper. This clothing enterprise is a collective operation enterprise with production-supply-marketing integration. It has a wholesome system of production, selling and designing, and also relevant raw material suppliers, distribution alliance business and third party logistic service provider. The market operating area of the enterprise is wide, and the business cooperation with other sections is stable. Thus, the supply chain with this enterprise as its core is formed. Relative data of this enterprise from 2011 to 2012 was collected. Moreover, by the evaluation index system of supply chain performance and corresponding calculation model and algorithm, different evaluation indexes of supply chain performance was standardized. Results are presented in Table 2.

TABLE 2 evaluation indexes of supply chain performance and standardized data

Evaluation index	**Index type**	**2011**		**2012**	
		Original data	*Standardized data*	*Original data*	*Standardized data*
Market retention rate	Positive index	0.78	1.000	0.72	0.923
Market satisfaction	Positive index	0.85-0.88	0.966-1.000	0.78-0.80	0.886-0.909
Market demand rate	Positive index	0.12-0.15	0.750-0.938	0.13-0.16	0.813-1.000
Market reaction sensitivity	Positive index	0.80	1.000	0.80	1.000
Rate of capital turnover	Positive index	0.61	0.938	0.65	1.000
Management cost	Negative index	560	1.000	620	0.903
Transport efficiency	Positive index	0.68-0.71	0.958-1.000	0.63-0.65	0.887-0.915
Operating efficiency	Positive index	0.57-0.59	0.934-0.967	0.58-0.61	0.951-1.000
Utilization rate of warehouse	Positive index	0.78	0.951	0.82	1.000
Supplier cooperation satisfaction	Positive index	0.66	1.000	0.54	0.818
Inventory turnover rate	Positive index	0.85	1.000	0.83	0.976

According to the Table of extension distance of evaluation index of supply chain performance, the extension distance between evaluation index of supply chain performance and positive ideal domain and the extension distance between evaluation index of supply chain performance and negative ideal domain can be obtained respectively. Results are presented in Table 3.

TABLE 3 Extension domain of evaluation index of supply chain performance

Evaluation index	**2011**		**2012**	
	Extension distance of positive ideal domain	*Extension distance of negative ideal domain*	*Extension distance of positive ideal domain*	*Extension distance of negative ideal domain*
Market retention rate	0	0.077	0.077	0
Market satisfaction	0	0.074	0.069	0
Market demand rate	0.094	0.063	0.063	0.094
Market reaction sensitivity	0	0	0	0
Rate of capital turnover	0.062	0	0	0.062
Management cost	0	0.097	0.097	0
Transport efficiency	0	0.054	0.047	0
Operating efficiency	0.017	0.015	0.008	0.040
Utilization rate of warehouse	0.049	0	0	0.049
Supplier cooperation satisfaction	0	0.182	0.182	0
Inventory turnover rate	0	0.024	0.024	0

According to the extension correlation function of evaluation index of supply chain performance, the extension correlation function between evaluation index of supply chain performance and positive ideal domain and the extension correlation function between evaluation index of supply chain performance and negative ideal domain can be obtained. The results are presented in Table 4.

Thus, the comprehensive extension correlation of performance evaluation of supply chain of this enterprise is 0.485 in 2011 and 0.651 in 2012. According to the evaluation analysis above, the supply chain capacity of the supply chain with brand clothing enterprise presented a tendency of rapid decline in 2011-2012. It shows that this enterprise should put more resources into the evaluation indexes that presented a decline tendency in the evaluation index system of supply chain performance to stop the decline.

TABLE 4 Extension correlation function of evaluation index of supply chain performance

Evaluation index	2011		2012	
	Extension correlation function of positive ideal domain	*Extension correlation function of negative ideal domain*	*Extension correlation function of positive ideal domain*	*Extension correlation function of negative ideal domain*
Market retention rate	0	1.000	1.000	0
Market satisfaction	0	1.000	0.932	0
Market demand rate	1.000	0.670	0.670	1.000
Market reaction sensitivity	0	0	0	0
Rate of capital turnover	1.000	0	0	1.000
Management cost	0	1.000	1.000	0
Transport efficiency	0	1.000	0.870	0
Operating efficiency	1.000	0.375	0.471	1.000
Utilization rate of warehouse	1.000	0	0	1.000
Supplier cooperation satisfaction	0	1.000	1.000	0
Inventory turnover rate	0	1.000	1.000	0

5 Conclusions

This paper studied the performance evaluation of supply chain of complexity, multiple attributes and multiple levels of influence factors and relative problems in decision-making. Based on it, this study provided an improved performance evaluation model and algorithm, which is based on extension correlation function. The paper firstly analysed the relative constraints in the implementation process of performance evaluation of supply chain. Based on it, corresponding evaluation index system of supply chain performance was established. Then the ideal domains of different types of evaluation indexes under this evaluation index system was constructed, and the extension distance between the improved evaluation index of supply chain performance and the ideal domain of each evaluation index of supply chain performance. And based on it, the comprehensive extension correlation of supply chain performance was constructed. In this way, supply chain performance can be evaluated effectively. This model is simple in calculation with high resolving capacity and its performance and operation is quite simple. Thus, it can provide support for computer-assisted performance evaluation of supply chain.

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