Supply Chain Dynamic Performance Measurement Based on BSC and SVM

Yan Hong[1], Yang Zhong-Hua[2]

[1] School of Management, Wuhan University of Science and Technology, Wuhan430081,HuBei, China

[2] School of Management, Wuhan University of Science and Technology, Wuhan430081,HuBei, China

Abstract

Now individual contest among enterprises has been turning into collective contest among supply chains. Supply chain management (SCM) has been a major component of competitive strategy to enhance organizational productivity and profitability. In recent years, organizational performance measurement and metrics have received much attention from researchers and practitioners. The foundation of proper supply chain performance assessment system is the basis of its effective operation and management. Most of the traditional supply chain performance evaluation is a static evaluation, while the actual supply chain is a dynamic system, therefore need to adapt with ways to carry out the evaluation. In order to meet the needs of the dynamic alliance's overall performance evaluation, this paper extended the traditional four Balanced Scorecard dimension into five. On this basis, established the five Balanced Scorecard dimension of supply chain, and also established a three-layered of quantitative index system according to this model. Measured then each performance index's value by using the theory of Fuzzy Analytic Hierarchy Process, meanwhile reduced the number of input of the Support Vector Machine (SVM) by using classification method, finally, got performance evaluation's result by using the weighted Least Squares Support Vector Machine (LS-SVM), which provides the basis for rational analysis and decision-making of the supply chain.

Keywords: *Supply Chain Performance, Balanced Scorecard, FAHP, LS- SVM.*

1. Introduction

With the rapid development of economic globalization, knowledge-based, information technology, the competition between enterprises is not a single enterprise in a certain time, a certain space, the competition for certain end markets, customer one-on-one competition, but become a kind of competition based on product development, design, manufacturing, distribution, distribution, sales and service competition across time and space, has been developed into a competition between the supply chain management. Not only as one of the core supply chain performance evaluation of supply chain management is the focus of supply chain management, supply chain management difficulties. Many scholars in-depth study on the performance of the supply chain, and achieved good results.

The need of performance measurement systems at different levels of decision-making, either in the industry or service contexts, is undoubtedly not something new. Kaplan and Norton (1992) have proposed the Balanced Scorecard, as a means to evaluate corporate performance from four different perspectives: the financial, the internal business process, the customer, and the learning and growth [1]. Their Balanced Scorecard is designed to complement "financial measures of past performance with their measures of the drivers of future performance". The name of their concept reflects an intention to keep score of a set of items that maintain a balance "between short long term objectives, between financial and non-financial measures, between lagging and leading indicators, and between internal and external performance perspectives". Since the Balanced Scorecard theory, the industry has a lot of research. In the September 1993 issue of the "Harvard Business Review, Kaplan and Norton published" Putting the Balanced Scorecard to Word "article, the Balanced Scorecard applied to RockWater, Apple and AMD three companies case [2]. Kaplan and Norton proposed a strategic map, marking the Balanced Scorecard performance management system from one jumped as a strategic management tool [3]. A balanced performance evaluation of supply chain such as, Balanced Scorecard not only helps organizations in faster and wider progress monitoring of their operations but can also help them in improving their internal and external functions of business such as engineering and design applications, production, quality improvement, materials management, quick response, gaining lost market shares, proper implementation of business strategies. Therefore, it is clear that for effective supply chain management, measurement goals must consider the overall scenario and the metrics to be used. These should represent a balanced approach and should be classified at strategic, tactical, and operational

levels, and be financial and non-financial measures, as well. Lambert, Cooper and Pagh successful supply chain management requires cross-functional integration, the main challenge is how to successfully integrate. Brewer and Speh proposed the implementation of supply chain performance evaluation method based on Balanced Scorecard and Analytic Hierarchy Process (AHP) [5].

Throughout BSC-based performance evaluation of the status quo, you can see traditional Balanced Scorecard theory ignored supplier factors both internal and external balance of the supply chain system, its inadequacies. Especially in the assessment of the performance of the supply chain based on dynamic alliance, often through the analysis of the value chain of suppliers to help companies take strategic improvement actions to promote the value chain of suppliers and recycling, so you can save production costs and reduce enterprise procurement costs. In view of the lack of traditional Balanced Scorecard theory in the performance evaluation system of dynamic alliance, first extend the traditional thinking balanced scorecard for the five-dimensional dynamic balanced scorecard that the dynamic alliance downstream member satisfaction, alliance within the enterprise supply chain business processes, supplier satisfaction, the economic benefits of the supply chain, supply chain innovation and development capabilities.

Then a dynamic alliance's supply chain performance evaluation, for example, establish a dynamic performance evaluation of supply chain decision-making table, and attribute reduction and value reduction of decision table using Support Vector Machine (SVM), which has been forecast performance evaluation results of the decision-making the rule set. Finally, weighted Least Squares Support Vector Machine (LS-SVM) forecasting overall performance assessment results provide the basis for rational analysis and decision-making of the supply chain.

2. Dynamic evaluation of supply chain performance architecture design

2.1 Five-dimensional BSC Mode

Balanced Scorecard was originally defined as the corporate performance measurement tool. Early 1990s, Kaplan and Norton (1992) have proposed Balanced Scorecard, as a means to evaluate corporate performance from four different perspectives: the financial, the internal business process, the customer, and the learning and growth [1][2][3]. Their Balanced Scorecard is designed to complement “financial measures of past performance with their measures of the drivers of future performance”. The emergence of Balanced ScoreCard, changed the status of the pre-financial indicators to dominate the world, the performance indicators extreme imbalance. Four indicators together, constitute the internal and external, results-driven factors, a variety of balanced long-term and short-term, qualitative and quantitative, based on the evaluation of the three-dimensional, forward-looking enterprise performance management. Subsequently, Brewer and Speh made application Balanced Scorecard explore supply chain performance assessment, and explore basic manifestation of a new supply chain performance assessment tools - supply chain performance evaluation, and proposed as a basis for kind of new supply chain performance assessment tool - Supply Chain Balanced Scorecard, which established a framework for links between SCM and Balanced Scorecard [5]. Supply chain Balanced Scorecard to supply chain business processes as a starting point to corporate strategic objectives, performance indicators and corporate strategy linked, comprehensive assessment of business performance, to cultivate enterprise core competitiveness.

However, the traditional supply chain Balanced Scorecard approach in considering the balance of the supply chain system of internal and external factors ignored suppliers. In fact, the suppliers as an important link in the value chain in the production and operation is very important. Only when the vendor for enterprises on time, in ensuring quality and quantity to provide goods and materials required for enterprises to ensure the normal operation and for customers to provide products to meet their needs. In particular, in the performance evaluation of supply chain, supplier value chain analysis can help enterprises improve strategies to promote the recycling value chain of suppliers, in order to save production costs and reduce procurement costs. On the other hand, the supply chain performance evaluation is unique in that is different from the single enterprise evaluation: assessing the indicators of the operating performance of the entire supply chain not only need to assess the operational performance of the node enterprises, but also to consider the operational performance of the node enterprises its upper node enterprise or the entire dynamic alliance. Therefore, reasonable assessment of business process, scientific and objective assessment of the situation of the entire supply chain operations, real-time, dynamic characteristics need to be considered. Accordingly, we believe that creating a Balanced Scorecard framework of supply chain performance evaluation system should be integrated the dynamic alliance downstream member satisfaction alliance within the enterprise supply chain business processes, supplier satisfaction, the economic benefits of supply chain, supply chain five aspects of innovation and development ability. Add Balanced Scorecard classic four dimensions based on the dimensions of suppliers, the formation of the five-dimensional balanced scorecard for

supply chain dynamic alliance structure, as shown in Figure 1.

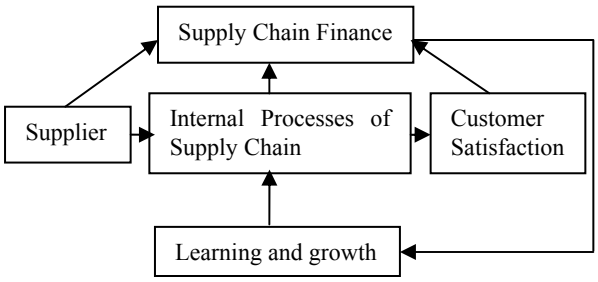

Figure 1: Five-dimensional BSC model of Supply Chain

Balanced Scorecard framework of dynamic alliance of supply chain performance evaluation system includes five aspects as following:

（1）Supplier. This is the part of the traditional supply chain balanced scorecard ignored. The selection and evaluation of supplier is particularly important in dynamic alliance. Therefore, in the framework of the proposed model, the supplier is an important dimension in the Dynamic Balanced Scorecard. Shift from competition to cooperation, to achieve a win-win situation between the manufacturer and supplier to supplier relationships through the assessment of selection and improvement of supplier relationships.

（2）Internal business processes. Internal business process measures which we concern are those internal processes the greatest impact on customer satisfaction and achieve organizational financial goals. Balanced Scorecard method introduced innovative processes to internal business processes, from the point of view of the supply chain considerations, it require companies to create new products and services to meet the current and future target customers demand. These processes can create value in the future to promote the future of corporate financial performance.

（3）Customer satisfaction. Supply Chain Balanced Scorecard is more concerned about the performance of the supply chain in the level of customers and market segments, and clarify how to meet customer needs in order to effectively achieve the financial goals of the entire dynamic alliance. Customer value based on customer perception and therefore requires an assessment of the origin on the customer, including the level of service and customer satisfaction

（4）Learning and growth. Balanced Scorecard goal is revealed in these three aspects of the existing capacity of the system, and the gap between the high performance required capacities. To close these gaps, companies must invest to enable employees to acquire new skills, and straighten out the program and the day-to-day work of the organization. To close these gaps, companies must invest to enable employees to acquire new skills, and straighten out the program and the day-to-day work of the organization.

（5）Supply Chain Finance. On the financial side, the Balanced Scorecard not only to assess the traditional enterprise financial ratios, return on investment, cash flow, profit and other indicators, but also concerned about the financial condition of the entire supply chain indicators. Financial performance measurement method to reveal the overall strategy of the alliance and its implementation and enforcement are to contribute to the improvement of the supply chain.

2.2 The Selection of Indicators and Metrics of Supply Chain Performance Evaluation

Supply chain performance evaluation indicators selection of hot and difficult in the current performance evaluation study. Different research institutions and personnel have different views on supply chain performance index system. We believe that the selection of indicators should be in a number of ways to achieve a balance, so as to build a good performance evaluation system. A good performance indicator system includes not only reflect the short-term and long-term goals, the level of internal and external indicators, including the balance between leading indicators and lagging indicators, quantitative indicators and qualitative indicators. This paper extends the traditional Balanced Scorecard theory, the formation of a five-dimensional Balanced Scorecard. The indicators measuring dynamic alliance upstream suppliers, including on-time delivery rate, production flexibility and other indicators. We select time delivery rate, the rate of qualified products and supply chain flexibility and other indicators to reflect the performance of the supply chain in supplier dimension. On-time delivery rate is one of the most important indicators of the Alliance selection of suppliers, the high and low values reflect the supplier delivery performance, supplier performance considerations. Product qualification rate refers to the number of products of acceptable quality percentage of total product output, and it reflects the quality level of the suppliers of goods. For flexible indicators, Supply Chain Council defines it as the ability to respond to supply chain. On-time delivery rate is one of the most important indicators of the supply chain alliance selection of suppliers, the high and low values reflect the supplier delivery performance, supplier performance considerations. Product qualification rate refers to the number of products of acceptable quality percentage of total product output, which reflects the quality level of the suppliers of goods. For the other four dimensions, we refer to the standardized indicators SCOR model based on the operation of the internal processes. According to the

characteristics of dynamic alliance in the supply chain, the paper selected 15 classic sample indicators to build a performance evaluation system. As shown in Table 1.

Table 1 Supply Chain Balanced Scorecard performance assessment indicators and metrics

Dimension	KPIs	Metrics
Financial	Profitability(F1)	Net profit / total revenue (%)
	Asset turnover(F2)	Total sales / total net assets (%)
	Inventory turnover rate(F3)	Average proportion of cost of goods sold / inventory
	Cash turnaround time(F4)	Supply of inventory days + receivables aging - payables aging
Customer	Customer Satisfaction(C1)	Fuzzy Evaluation
	The expansion of the market rate(C2)	(Current market share - previous period market share) / previous period market share
	Market share(C3)	The total number of sales / industry sales (%)
Business processes	Response time(P1)	The time required to meet sudden demand
	The level of information systems (P2)	The level of information systems
	Technological advance(P3)	Fuzzy Evaluation
	Total cost of quality(P4)	The total cost of quality cost / product
	Reliability(P5)	Fuzzy Evaluation
Learning and growth.	Quality SystemL1(L1)	Fuzzy Evaluation
	Employee Satisfaction(L2)	Fuzzy Evaluation
	Profit growth(L3)	(Profit for the period - the previous period profit) / Profit
	New product development cycle(L4)	Statistical average
Suppliers	On-time delivery rate(S1)	The number of on-time delivery / delivery (%)
	Flexible(S2)	Fuzzy Evaluation
	The rate of qualified products(S3)	The number of acceptable quality / total number

3. The dynamic evaluation method based on Fuzzy Analytic Hierarchy Process and LS-SVM forecast

3.1 Fuzzy Analytic Hierarchy Process

Fuzzy Analytic Hierarchy Process (FAHP) is a fuzzy comprehensive evaluation method and analytic hierarchy process evaluation method, it contains the evaluation of the complex system of multiple indicators (or factors, evaluation factors) objects total evaluation. A wide range of applications in the evaluation system, performance assessment, and system optimization, is a combination of qualitative and quantitative evaluation model, usually is the first to determine the factors set chromatography analysis, and then judge the effect of fuzzy comprehensive evaluation to determine.

1）Determining the weights

The key of FAHP lies in the establishment of judgment matrix. The importance of a factor than the other factors to be quantified, get fuzzy complementary judgment matrix $A=(a_{ij})_{n\times n}$. Commonly used in Table 1 shown in the 0.1 to 0.9 scale their relative importance of the number of scale the a_i's weight value fuzzy complementary judgment matrix A and w_i is

$$w_i=\frac{\sum_{i=1}^{n}a_{ij}+\frac{n}{2}-1}{n(n-1)} \quad i=1,2,...,n \qquad (1)$$

Formula (1) contains the excellent characteristics of fuzzy consistency judgment matrix and its judgment information, a small amount of calculation and easy computer programming.

Table 2 0.1 to 0.9 scale law and its meaning

Scale	Definition
0.5	Two factors compared equally important.
0.6	Comparison of two factors, one factor is slightly important than the other factors.
0.7	Comparison of two factors, one factor is obviously important than the other factors.
0.8	Comparison of two factors, one factor is much more important than the other factors.
0.9	Comparison of two factors, one factor is extremely important than the other factors.
0.1,0.2,0.3,0.4	If factors a_i and a_j compared to get a_{ij}, then the factor a_i and a_j comparison phase determines $a_{ij}=1-a_{ji}$.

Set up $w=\left(w_1,w_2,...w_n\right)^T$ sort of fuzzy complementary judgment matrix $A=\left(a_{ij}\right)_{n\times n}$ vector, if $a_{ij}=w_i-w_j+0.5$, then $A=\left(a_{ij}\right)_{n\times n}$ for the of fuzzy consistency of judgment matrix, Which is w_i exactly the same sort of judgment matrix vector weights for each index weight value.

2）Data processing and calculation

Table 1 performance indicators, both quantitative also include qualitative, its dimension is also different for each indicator should be dimensionless, convert it to a number in [0, 1], it has comparable. Qualitative indicators are generally obtained by fuzzy assessment methods, and in both cases the normalization process with quantitative indicators:

Normalized for positive indicators (index value is the bigger the better, such as market share), can be carried out in accordance with the equation (2):

$$v'=\left(x-x_{\min}\right)/\left(x_{\max}-x_{\min}\right) \quad (2)$$

Normalized for reverse indicators (the smaller the index value the better, for example, response time), can be carried out in accordance with the equation (3):

$$v'=\left(x_{\max}-x\right)/\left(x_{\max}-x_{\min}\right) \quad (3)$$

Finally, the comprehensive evaluation value of the supply chain five-dimensional Balanced Scorecard can be obtained through the formula $R_i=\sum_{i=k-1}^{n} w_{ik}\times X_{ik}$ (Where n each one indicator the two indicators number, X_{ik}, for each index values obtained after pretreatment.), so as to achieve the drop dimension and simplify the calculation.

3.2 Predict the performance of the weighted least squares support vector machine

Conditions of the supply chain, each node enterprise operation strategy dynamically adjust its operational behavior of a random change in trend is non-linear model of time. Support Vector Machine (SVM) can solve the nonlinear law of supply chain performance evaluation and the problem of inadequate samples, to be able to predict the overall performance of the supply chain of the future at a certain moment.

The realization of the Support Vector Machine (SVM) is mapped to high dimensional feature space through some kind of selected nonlinear mapping (kernel function) the input vector construct optimal separating Hyperplane in this space. Least Squares Support Vector Machine (LS-SVM) inherited the Support Vector Machine (SVM)structural risk minimization criterion and use of nuclear function converted to high-dimensional feature space to solve ideological, and the Support Vector Machine (SVM) converted into solving linear quadratic programming equations to avoid insensitive loss function greatly reduces the computational complexity. Weighted Least Squares Support Vector Machine (WLS-SVM) weighted them according to the degree of importance of the different samples, to eliminate sample different impact, has important implications on the predicted results. Therefore, using the Weighted Least Squares Support Vector Machine WLS-SVM [10] to predict and analyze the performance of the supply chain, the process is shown in Figure 2.

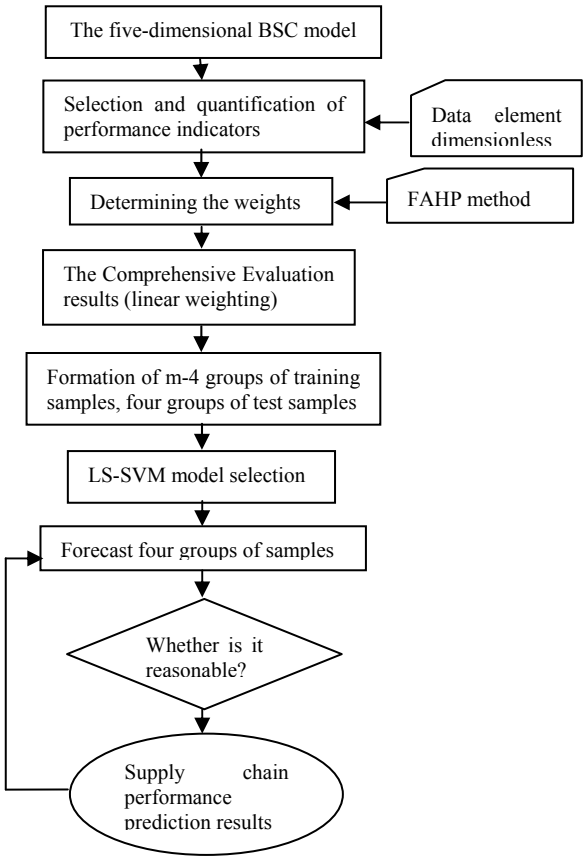

Figure 2: The flow chart of supply chain performance prediction

4. Case study

In this paper, a dynamic supply chain, for example, in the above five-dimensional balanced scorecard supply chain performance evaluation. Based on historical experience and fuzzy complementary judgment matrix of establishing rules to get the judgment matrix as follows:

$$A=\begin{bmatrix} 0.5 & 0.6 & 0.6 & 0.8 & 0.9 \\ 0.4 & 0.5 & 0.6 & 0.6 & 0.7 \\ 0.4 & 0.4 & 0.5 & 0.6 & 0.7 \\ 0.2 & 0.4 & 0.4 & 0.5 & 0.6 \\ 0.1 & 0.3 & 0.3 & 0.4 & 0.5 \end{bmatrix}$$

The use of (1) Extended Performance Balanced Scorecard five weights can be obtained: W_F=0.3, W_C=0.22, W_P=0.22, W_L=0.22, W_S=0.22.

Similarly weights can be obtained for each two indicators：

W_{Fi}=(0.37,0.28,0.16,0.19);

W_{Ci}=(0.43,0.21,0.43);

W_{Pi}=(0.22,0.19,0.16,0.15,0.27);

W_{Li}=(0.17,0.23,0.28,0.32);

WSi=(0.48,0.18,0.34).

In the past two years, the monthly value of dynamic supply chain performance indicators can be obtained after pretreatment of the support vector machine prediction sample value, the first 20 sets of data for the training sample, after four sets of test samples, output Y is actual monthly supply chain performance situation, the result is divided into four grades of the G_1、G_2、G_3、G_4 respectively correspond to the excellent performance in the differential state, and the corresponding value of 0.9,0.8,0.7,0.6, such as shown in table 3.

Table 3 Supply Chain Performance Indicators Quantization

F	C	B	L	S	P
0.185	0.072	0.132	0.107	0.085	0.7(G_3)
0.111	0.106	0.168	0.063	0.095	0.7(G_3)
0.218	0.132	0.191	0.104	0.101	0.9(G_1)
0.248	0.114	0.201	0.112	0.102	0.9(G_1)
0.174	0.101	0.127	0.129	0.093	0.8(G_2)
0.112	0.174	0.110	0.108	0.075	0.7(G_3)
0.127	0.157	0.111	0.050	0.055	0.7(G_3)
0.080	0.044	0.066	0.067	0.079	0.6(G_4)
⋮	⋮	⋮	⋮	⋮	⋮

RBF Radial Basis weighted support vector machines in the selection of the kernel function for high precision radial basis parameters δ = 0.45, to take balance factor C = 500, the fitting precision ε = 0.01, tuning constants γ = 500. Weighted through FAHP calculated Supply Chain Performance Balanced Scorecard five weights. Finally, the four groups of the predicted value and the actual value shown in Table 4.

Table 4 Supply Chain Performance Predictive Value of Contrast with the Actual Value

F	C	B	L	S	Predictive value	Actual value
0.14	0.183	0.125	0.078	0.062	0.783	G3(0.7)
0.201	0.095	0.184	0.117	0.100	0.868	G_2(0.7)
0.204	0.123	0.167	0.085	0.090	0.819	G_2(0.7)
0.135	0.156	0.127	0.162	0.067	0.714	G_3(0.7)

As can be seen from Table 3, the results of the following four groups of test data is 0.78313, 0.86805, 0.81998, 0.71378. The sets of data belongs to the interval [0.7, 0.8], the performance level is moderate. The other two sets of data belong to the interval [0.7, 0.9], the performance level is good. This is entirely consistent with the actual situation. And this also proves the effectiveness of the weighted least squares support vector machine model of dynamic supply chain performance prediction.

Finally, we input the performance evaluation of five aspects the value (0.19876, 0.14254, 0.16734, 0.09242, 0.08194), and call the above model to obtain a prediction value is 0.87392. That forecast next month to assess the performance is good. Therefore, by entering the Balanced Scorecard five values, call the dynamic evaluation model to predict supply chain performance assessment results and trends, and provides a basis for rational analysis and decision-making of the supply chain to develop, but also for the supply chain the performance evaluation provides a new idea.

5. Conclusion

Quantifiable indicators system to evaluate the performance of dynamic supply chain plays a central role in the day-to-day operations and management of the supply chain. In this paper, we consider a real-time and dynamic nature of the dynamic supply chain, and classic extended supply chain performance for the five-dimensional Balanced Scorecard Balanced Scorecard, to build a three-tier evaluation index system, and then apply the FAHP theory get the weight of the performance indicators input to support vector machine classification method dimensionality reduction, thereby reducing the amount of computation to increase the accuracy of the forecast. Finally, weighted least squares support vector machine prediction method of the future results of the assessment, and to provide a basis for rational analysis and decision-making of the supply chain.

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YanHong is currently an Instructor in the Information Management Department, School of Management, Wuhan University of Science and Technology (WUST), China. He received the Bachelor's degree in Computer Science from the Hubei University of Technology in 2000, and Master's degrees in Management Science and Engineering from Wuhan University in 2003. Her research interests include supply chain management, information system engineering and intelligent information systems.

Yang ZhongHua is currently an Associate Professor and tutor of graduate students in the Information Management Department, School of Management, Wuhan University of Science and Technology (WUST), China. He received the Bachelor's degree in Business management from the Hubei University of Technology in 1998, and Master's degrees in Computer Application Technology from Wuhan University of Technology in 2002. His research interests include information system engineering, decision support systems and intelligent information systems.