

Research on the Key Performance Evaluation Methods of Enterprises Using BSC and KPI Based on Analytic Hierarchy Process ---- Illustrated by the Case of Hangzhou Cigarette Factory

Yuexiong Gong ^{1,a, 1st}, Wei Ying ^{1,b, 2nd}, Yunxun Yu ^{1,c, 3rd}, XiaoZhong Zhou ^{1,d, 4th}, Xiaping Fan ^{1,e, 5th}

¹Hangzhou cigarette factory China Tobacco Zhejiang Industrial Co., Ltd Hangzhou, China

Abstract. Taking Hangzhou cigarette factory as an example, this paper establishes a key performance index system through integrating the balanced scorecard (BSC) and key performance index (KPI). The index system includes the first-level and 13 second-level indicators in four dimensions of finance, customers, internal processes, as well as learning and growth. Through Analytic Hierarchy Process (AHP) and fuzzy comprehensive evaluation method, it constructs an evaluation model of key corporate performance, finally achieves the actual performance levels of the enterprise, as well as puts forward the improvement suggestions. This evaluation method mainly includes the steps of determining the domain of evaluation factors at all levels, determining the evaluation level, determining fuzzy weight vectors of various indexes, establishing the fuzzy relation matrix and calculating comprehensive evaluation results. It has high accuracy in the process of performance evaluation, which has certain reference and guiding significance for improving the comprehensive competitiveness.

1 Introduction

Key performance management can be very vital to the development of enterprises, because the key performance management can fully stimulate the internal potentials of employees, realize the rational operation of the organization, and further achieve the development goals. Taking Hangzhou Cigarette Factory as an example, this paper applies the Balanced Scorecard (BSC) and Key Performance Index (KPI) into performance evaluation and builds a key performance index system. To further assess the key performance indexes of the enterprise throughout the year, an evaluation model based on the analytic hierarchy process and the fuzzy comprehensive evaluation method is constructed to accurately determine the current performance level. Thus, it can put forward the corresponding improvement suggestions.

2 Methods and basic theories

2.1 Balanced Scorecard (BSC)

The Balanced Scorecard (BSC) was jointly put forward by the American Norton Institute and Professor Kaplan of the Harvard University, and the relevant research was published in the *Harvard Review of Business* after the actual investigations on more than a dozen companies.

^agongyuexiong@zjtobacco.com, ^cyuyx@zjtobacco.com, ^dzhouxz@zjtobacco.com, ^efanxiaping@zjtobacco.com

^b*Corresponding author: yingwei@zjtobacco.com

They defined the balanced scorecard as an evaluation index system to drive the performance. As a strategy-oriented performance evaluation method, BSC emphasizes that performance evaluation indicators in enterprises must be closely linked with the strategies, meaning that performance evaluation indicators are decomposed from strategies. Through breaking the traditional financial performance evaluation methods, BSC transforms corporate strategies into specific and measurable indicators, including those traditional financial and other non-financial indicators. In detail, BSC examines the corporate performance mainly from four dimensions, that is finance, customers, internal processes, and learning and growth ^[1].

2.2 Key Performance Index (KPI)

Key performance index (KPI) refers to those key indicators being very important to business operations, which is the operable quantitative indicator by decomposing the strategic goals. Just like the Balanced Scorecard (BSC), KPI takes the company's strategic goals as the orientation. Before establishing the KPI system, however, it is very necessary to first understand the strategic goals of the company and further decompose the goals into key success factors, so that they can be decomposed into operable KPI. KPI can be fully compliance with this famous rule—Pareto's principle. According to this principle, 80% of corporate profits come

from 20% of key customers, 80% of the global wealth are owned by only 20% of people. In other words, 80% of corporate performance is determined by 20% of key behaviors. Through decomposing these 20% of behaviors into key performance indicators, it can target the focus of the entire performance evaluation [3].

3 Establishment of key performance index system

3.1 Establishment principle

Based on the characteristics of tobacco enterprises, the establishment of a performance evaluation index system should not only follow the SMART principle, but the systemic, feasible, hierarchic, quantified and general principles. The tobacco company itself is a system, so it is essential to make corresponding studies not only from the systematic financial indicators, but the non-financial indicators of business processes, customers and employees, in order to ensure the comprehensiveness and correctness of the evaluation. However, the number of selected indexes should be fully controlled to ensure the feasibility of the index system [2].

3.2 Strategic focus and key success factors of BSC's four dimensions

In recent years, the State Tobacco Monopoly Administration has put forward the five requirements of "targeted system, process management, information means, standardized foundation, and continuous improvement", and also issued the guiding opinions of "the first-class basic management, first-class system construction, first-class goal management, first-class innovation mechanism and first-class management team". Hangzhou Cigarette Factory actively follows the national development ideas and has proposed the high-quality development strategic goal of building a first-class cigarette manufacturing base. Under this environment, this paper further decomposes the strategic goals of the cigarette factory into the strategic focus and key success

factors from the four dimensions of BSC [4].

(1) Strategic focus and key success factors in the financial dimension

The strategic focus in the financial dimension is to reduce enterprises' operating costs and increase outputs.

The two key success factors decomposed by the strategic focus include the growth ability and cost reduction ability.

(2) Strategic focus and key success factors in the customer dimension

The strategic focus in the customer dimension is to meet the collaboration demands between customers and departments.

The two key success factors decomposed by the strategic focus include the customer satisfaction, and the quality of inter-departmental collaboration.

(3) Strategic focus and key success factors in the internal operation dimension

The strategic focus in the internal operation dimension is to improve the product quality and increase production efficiency.

The two key success factors decomposed by the strategic focus include the product quality and production efficiency.

(4) Strategic focus and key success factors in the learning and growth dimension

The strategic focus in the learning and growth dimension is to achieve the employees' growth and technological innovation.

The two key success factors decomposed by the strategic focus include the employee satisfaction and technological innovation ability [7].

3.3 Establishment of the key performance index system with the integration of BSC and KPI

Under the premise of controlling the number of 20 selected indexes, and following the Pareto's and SMART principles, this paper establishes the key performance index (KPI) of each key success factor from the four dimensions of BSC, and finally forms the key performance index system of the cigarette factory [7], which can be seen in Table 1.

Table 1 Key performance index system

First level index	Strategic focus	Key success factors	Second level index (KPI)
Finance	Increase output	Growth ability	Finished tobacco percentage
	Reduce production and operation costs	Cost reduction ability	Single controllable management cost
			Paper consumption amount per box
Customer	Meet customers' demands	Customer satisfaction	Complaint settlement rate of product quality
	Meet the inter-departmental collaboration demands	Quality of interdepartmental collaboration	Departmental collaboration satisfaction
Internal operation	Improve product quality	Product quality	Sigma level of production process
			Qualified rate of sampling inspection at three-level station
	Increase production efficiency	Efficiency increase ability	Labor productivity per employee
Downtime rate of tobacco			

			making equipment
			Operating efficiency of wrapping equipment
Learning and growth	Employees' growth	Employees' satisfaction	Qualified rate of training hours
	Technological innovation	Technological innovation ability	Proportion of middle and senior titles

4 Establishment of key performance evaluation model

In view of the complex, diverse and hierarchical index system features of tobacco companies, the method of integrating analytical hierarchy process (AHP) and fuzzy comprehensive evaluation method is used to evaluate the key performance levels. In detail, the AHP method is mainly used to determine the weight of the evaluation index, while the fuzzy comprehensive evaluation method is to comprehensively assess the performance of the cigarette factory.

4.1 Determine the domain of evaluation factors at all levels

To establish the key performance index system in enterprises, the first-level evaluation indicators used can be divided into finance, customers, internal processes, learning and growth, so the corresponding domain of evaluation factors can be $X = \{X_1, X_2, X_3, X_4\} = \{\text{finance, customer, internal process, learning and growth}\}$. There are four second-level indicators in the financial dimension, including the single controllable management cost, finished tobacco percentage, paper consumption amount per box, and comprehensive energy consumption of 10,000 cigarettes, while the evaluation factor domain $X_1: \{X_{11}, X_{12}, X_{13}, X_{14}\} = \{\text{single controllable management cost, finished tobacco percentage, paper consumption amount per box, and comprehensive energy consumption of 10,000 cigarettes}\}$. There are two second-level evaluation indexes under the customer dimension, including consumers' product quality satisfaction, departmental collaboration satisfaction, while the domain of evaluation factors $X_2 = \{X_{21}, X_{22}\} = \{\text{complaint settlement rate of product quality and departmental collaboration satisfaction}\}$. There are seven second-level evaluation indicators under the internal process dimension: labor productivity per employee, Sigma level of production process, qualified rate of sampling inspection at three-level station, downtime rate of tobacco making equipment and operating efficiency of wrapping equipment, while the evaluation factor domain $X_3 = \{X_{31}, X_{32}, X_{33}, X_{34}, X_{35}\} = \{\text{labor productivity per employee, Sigma level of production process, qualified rate of sampling inspection at three-level station, downtime rate of tobacco making equipment and operating efficiency of wrapping equipment}\}$. There are two second-level evaluation indicators under the internal process dimension $X_4 = \{X_{41}, X_{42}\} = \{\text{qualified rate of training hours and proportion of middle and senior titles}\}$ [8].

4.2 Determine the evaluation level

The key performance of the enterprises can be divided into 4 levels, and V represents the domain of evaluation level. $V = \{\text{excellent, good, average and poor}\}$, while the corresponding grades can be $E = \{90, 75, 60, 45\}$.

4.3 Analytic hierarchy process helps determine fuzzy weight vectors of various indexes

To determine the relative importance of each evaluation index, this paper specially selects five experts in the enterprise, relies on their investigation and consultation to know the relative importance. And on this basis, it further determines the judgment matrix for each level of index, and finally obtains fuzzy weight vectors of indicators at all levels.

(1) Analysis idea

The weights of indicators at all levels are determined by the analytic hierarchy process. The fuzzy weight vector of the first-level evaluation index is $W = (W_1, W_2, \dots, W_n)^T$, of which n means the n evaluation indicators in this system. The weight vector of the corresponding second-level evaluation index is $W_k = (W_{k1}, W_{k2}, \dots, W_{kn})^T$ of which k is an integer from 1-n. Then, the fuzzy weight vector of each evaluation index can be achieved.

(2) Fuzzy weight vector of indicators at all levels

With the investigation and analysis, this paper establishes a first-level index judgment matrix:

$$\begin{bmatrix} 1 & 1/3 & 1/2 & 4 \\ 3 & 1 & 1/2 & 4 \\ 2 & 2 & 1 & 4 \\ 1/4 & 1/4 & 1/4 & 1 \end{bmatrix}$$

Through the solution of the eigenvector and the maximum eigenvalue, as well as the consistency test, the paper obtains the fuzzy weight vector of the first-level index, and further uses W to indicate the evaluation factor set X [5].

$$W = (0.161, 0.465, 0.278, 0.096)^T$$

Then, we get the fuzzy weight vectors W_1, W_2, W_3 and W_4 of the four second-level indicators to evaluate the factor sets X_1, X_2, X_3 and X_4 .

$$W_1 = (0.337, 0.141, 0.240, 0.282)^T$$

$$W_2 = (0.800, 0.200)^T$$

$$W_3 = (0.237, 0.162, 0.118, 0.121, 0.362)^T$$

$$W_4 = (0.667, 0.333)^T$$

4.4 Establish the fuzzy relation matrix

After determining the weights of indicators at all levels, the paper makes a single-factor evaluation of each indicator to obtain the fuzzy relationship matrix of the four dimensions of finance, customers, internal processes, learning and growth, and then synthesizes the overall fuzzy relation matrix of the first-level indicators.

Based on the actual key performance indicators of a tobacco company in 2020, the data in Table 3.1 should be distributed to the five established corporate experts, and further make the evaluation according to the evaluation level, and $V = \{\text{excellent, good, average, poor}\}$. Finally, the paper summarizes the results from 5 experts to acquire the degree of membership of each evaluation index. The evaluation results can be shown in the table2^[6].

Table 2 Performance index data and evaluation results from experts

First-level index	Second-level index	2020 Index data	Grades			
			Excellent	Good	Average	Poor
Finance	Single controllable management cost	Unsuitable to make public	0	1	4	0
	Finished tobacco percentage	96.92%	0	2	3	0
	Paper consumption amount per box	Unsuitable to make public	0	1	3	1
	Comprehensive energy consumption of 10,000 cigarettes	Unsuitable to make public	2	1	2	0
Customer	Complaint settlement rate of product quality	Unsuitable to make public	2	3	0	0
	Departmental collaboration satisfaction	97%	1	2	2	0
Internal operation	Labor productivity per employee	Unsuitable to make public	5	0	0	0
	Sigma level of production process	Unsuitable to make public	2	2	1	0
	Qualified rate of sampling inspection at three-level station	99.91%	1	2	2	0
	Downtime rate of tobacco making equipment	0.13%	0	2	3	0
	Operating efficiency of wrapping equipment	Unsuitable to make public	0	0	3	2
Learning and growth	Qualified rate of training hours	99.77%	4	1	0	0
	Proportion of middle and senior titles	15%	0	1	3	1

According to Table 2, the fuzzy evaluation matrix of financial indicators is S_1 .

$$S_1 = \begin{bmatrix} 0 & 1/5 & 4/5 & 0 \\ 0 & 2/5 & 3/5 & 0 \\ 0 & 1/5 & 3/5 & 1/5 \\ 2/5 & 1/5 & 2/5 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0.2 & 0.8 & 0 \\ 0 & 0.4 & 0.6 & 0 \\ 0 & 0.2 & 0.6 & 0.2 \\ 0.4 & 0.2 & 0.4 & 0 \end{bmatrix}$$

According to $R_i = W_i^T \times S_i$, the fuzzy relationship matrix of financial indicators is:

$$R_1 = W_1^T \times S_1 = (0.337, 0.141, 0.240, 0.282)$$

$$\begin{bmatrix} 0 & 0.2 & 0.8 & 0 \\ 0 & 0.4 & 0.6 & 0 \\ 0 & 0.2 & 0.6 & 0.2 \\ 0.4 & 0.2 & 0.4 & 0 \end{bmatrix}$$

$$= (0.113, 0.228, 0.611, 0.048)$$

And this paper further obtains the simulated

relationship matrix of customers, internal operations, and learning and growth: R_2, R_3, R_4 .

$$R_2 = (0.360, 0.560, 0.080, 0)$$

$$R_3 = (0.326, 0.160, 0.369, 0.145)$$

$$R_4 = (0.533, 0.200, 0.200, 0.067)$$

Based on the above four dimensions of the fuzzy relationship matrix, the fuzzy relationship matrix of the first-level index should be expressed as:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \end{bmatrix} = \begin{bmatrix} 0.113 & 0.228 & 0.611 & 0.048 \\ 0.360 & 0.560 & 0.080 & 0 \\ 0.326 & 0.160 & 0.369 & 0.145 \\ 0.533 & 0.200 & 0.200 & 0.067 \end{bmatrix}$$

4.5 Calculation of comprehensive evaluation results

According to the formula $B = W^T R$, the overall evaluation result vector B:

$$B=(0.161, 0.465, 0.278, 0.096) \begin{bmatrix} 0.113 & 0.228 & 0.611 & 0.048 \\ 0.360 & 0.560 & 0.080 & 0 \\ 0.326 & 0.160 & 0.369 & 0.145 \\ 0.533 & 0.200 & 0.200 & 0.067 \end{bmatrix} = (0.327, 0.361, 0.257, 0.054)$$

Comprehensive evaluation score $N=BE^T=(0.327, 0.361, 0.257, 0.054)(90, 75, 60, 45)^T=74.416$

Thus, the evaluation scores for finance, customers, internal operations, and learning and growth can be N_1, N_2, N_3 and N_4 . The performance evaluation results of tobacco factory can be shown in Table 3 below.

Table 3 Performance evaluation results of Hangzhou Cigarette Factory

	Excellent	Good	Average	Poor	Evaluation result
Finance	0.113	0.228	0.611	0.048	66.090
Customer	0.360	0.560	0.08	0	66.090
Internal process	0.326	0.160	0.369	0.145	70.005
Learning and growth	0.533	0.200	0.200	0.067	77.985
Total	0.327	0.361	0.257	0.054	74.416

4.6 Evaluation results analysis

Based on the comprehensive evaluation score of 74.416, it can be seen that the performance in Hangzhou factory is at the middle and upper-level, and still has a certain gap with the strategic goal. Thus, there is still a larger room for improvement. From the global perspective, finance and internal processes are slightly inferior to customers and learning and growth, of which the former is only at the middle and upper-level. Among the financial indicators, single controllable management cost has the largest weight, and exerts the greatest impact on financial performance, which should be greatly improved in this regard. What's more, the operating efficiency of the wrapping equipment in the internal process indicator occupies a larger weight, and has the greatest impact on the internal process. In other words, its operating efficiency can determine the final internal performance indicators. Therefore, the enterprises still require to further solve the efficiency bottleneck of the equipment.

5 Conclusion

Taking Hangzhou cigarette factory as an example, this paper focuses on its characteristics and related theories at home and abroad to integrate the balanced score card (BSC) and key performance index (KPI) and build a corporate key performance indicator system, and further applies a comprehensive fuzzy comprehensive evaluation and analytic hierarchy process to help put forward the targeted improvement suggestions. This evaluation method has higher accuracy and consistent with the reality, which has certain guiding significance in the quantitative performance evaluation.

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