Tobacco Enterprise Logistics Performance Evaluation Based on Principal Component Analysis

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Objectives: Tobacco logistics matters greatly in the development of the tobacco industry. Logistics performance evaluation is a sub-part of tobacco enterprise management performance evaluation. The in-depth study of logistics performance evaluation can form a more comprehensive enterprise management performance evaluation system, and provide logistics management tools such as control, diagnosis and coordination for enterprise logistics management. Methods: In this paper, a tobacco enterprise logistics performance evaluation index system is constructed from six aspects, including transportation, warehousing, inventory management, informatization, customer service and finance. A tobacco enterprise logistics performance evaluation method based on principal component analysis is put forward. Results: Through calculation, the comprehensive evaluation value of tobacco logistics performance of enterprises X in each year is obtained. The enterprise logistics performance is the worst in 2016. The enterprise logistics performance is the best in 2019. It indicates that the logistics level and ability of tobacco enterprises are improving year by year. Conclusion: Seen from the example, the principal component analysis method can be used to properly evaluate the logistics performance level of tobacco enterprises, and provide objective and quantitative reference data for tobacco enterprises to improve their logistics performance level and benefits.

Key words: tobacco enterprise; logistics performance evaluation; principal component analysis
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The tobacco industry is important to the national economy. As the core element of the tobacco industry, tobacco logistics is regarded as the backbone in the development of the tobacco industry. In recent years, with the introduction of tobacco regulatory policies and the increasing competition in the tobacco market,[1,2] logistics performance evaluation (LPE) has become the focus of the tobacco industry. With the input and output of tobacco enterprises, logistics activities have penetrated into various business activities of enterprises. Tobacco enterprise logistics performance refers to the operating efficiency and performance of tobacco enterprise logistics activities in a certain operating period. Studying LPE in depth can enrich and perfect the research and application of enterprise management performance evaluation and form a more

comprehensive enterprise management performance evaluation system. LPE is the basic work of tobacco enterprise logistics management. The research on logistics performance evaluation index system (LPEIS) of tobacco enterprise can provide logistics management means such as control and coordination for enterprise logistics management, and enterprise logistics key performance index can be applied to the comparison of logistics management efficiency and benefit of different enterprises in the same industry, thus providing the goal and basis for tobacco enterprises to improve logistics management.

It is necessary to analyze and evaluate the logistics performance of tobacco enterprises comprehensively, objectively and accurately, so that enterprises can find their own advantages and disadvantages in time. Besides, we can correctly judge the management level of tobacco enterprises, and help to explore their own potential and enhance their management ability, thus improving their overall efficiency. Therefore, how to evaluate the logistics performance of tobacco enterprises in a comprehensive, objective and accurate manner has become an urgent issue that enterprises have to cope with. In this paper, firstly, the LPEIS of tobacco enterprise is established, and on this basis, the principal component analysis (PCA) method is used to evaluate the tobacco enterprise logistics performance.

METHODS

Establishing LPEIS of Tobacco Enterprise

It is of great significance to create a set of LPEIS of tobacco enterprise to judge and evaluate the performance of enterprise logistics, so as to provide reference for tobacco enterprises to improve the current logistics system. To ensure the effectiveness and scientificity of the evaluation index system (EIS), the following principles should be followed when establishing the system.

Objectivity of the EIS. First of all, the established index system should minimize possible influence of subjective factors on the evaluation process and results; secondly, in the process of setting up the index system, it is required to have a global concept and be impartial.

Systematicness of the EIS. The established index system should have systematic thought and include all aspects involved in enterprise logistics performance to make them a system.

Operability of the EIS The whole logistics performance evaluation system is a complex systematic project, and the establishment of each index must consider all kinds of data needed for evaluation, the availability of data and the difficulty of data collection.

When evaluating logistics performance, we should first consider the purpose of evaluation. According to different evaluation purposes, the applicable objects of LPE index can be the whole logistics system, logistics subsystems such as supply logistics, production logistics, sales logistics and recycling logistics, logistics functions such as transportation, warehousing, inventory management, production planning and control, and even specific logistics activities in each function, thus forming different logistics performance evaluation systems.

The research on LPE mainly establishes the EIS from the perspectives of logistics function, process and system.[3-14]

In this paper, the LPEIS of tobacco enterprise is divided into six components, such as transportation, warehousing, inventory management, information level, customer service and finance.

(1) Transportation performance evaluation index

The function of transportation is to overcome the difference in space and time between the production and demand of products. The main function of transportation is to transfer products from the place of origin to the designated place, and the main purpose of transportation is to complete the transportation task of goods with the least time and cost. In a word, transportation is an important function and activity of tobacco logistics, which mainly completes the movement of physical objects from the place of supply to the place of demand. Therefore, the transportation performance evaluation is helpful to the transportation efficiency and economic benefits.

Generally speaking, the EIS of transportation performance consists of transportation cost, transportation efficiency, transportation quality and so on. The following table gives specific quantitative index (Table 1).

Table 1
Transportation Performance Evaluation Index

Evaluation Elements	Evaluating Index	Measurement Method
Transportation cost	Freight per ton-kilometer	Transportation cost/Ton kilometers
Transportation efficiency	Vehicle loading efficiency	Actual loading capacity/Loading capacity
	Utilization rate of transportation capacity	Vehicle input number/Total number of vehicles
Transportation quality	On-time transportation rate	On-time transportation times/Total transportation times
	Damage rate of cargo	Cargo damage number /Total number of cargoes

(2) Warehousing performance evaluation index

Warehousing is an activity to preserve goods, control their quantity and quality. It is a subsystem of tobacco logistics system, which plays the role of buffer, adjustment and balance in logistics system. The purpose of warehousing is to overcome the time difference between product production and consumption, and make materials produce time effect and realize their use value. Through warehousing, goods can be brought into play in the most effective time period, and the time value and use value of goods can be created.

Warehousing is the node in the tobacco logistics operation process. Generally speaking, the EIS of warehousing performance consists of warehousing cost, warehousing efficiency and warehousing quality. The following table gives specific quantitative index (Table 2).

Table 2
Warehousing Performance Evaluation Index

Evaluation Elements	Evaluating Index	Measurement Method
Warehousing cost	Proportion of warehousing cost	Annual warehousing cost/Total annual reserves
Warehousing efficiency	Utilization rate of warehouse area	Actual utilization area/Available area
	Utilization rate of warehouse capacity	Actual utilization volume/Available volume
	Utilization rate of equipment	Actual working time of equipment/ Rated working time of equipment
Warehousing quality	Intact rate of cargo	Number of intact cargo/Total number of cargoes
	Error rate of cargo	Number of wrongly distributed cargoes/Total number of cargoes in stock

(3) Inventory management performance evaluation index

Inventory management refers to the management of commodity quantity in the process of tobacco logistics. Good inventory management can speed up the turnover of funds, improve the utilization rate of funds and increase the benefit of investment.

Generally speaking, the EIS of inventory management performance is composed of inventory management cost, inventory management efficiency, inventory management quality, etc. The following table gives specific quantitative index (Table 3).

Table 3
Inventory Management Performance Evaluation Index

Evaluation Elements	Evaluating Index	Measurement Method
Inventory management cost	Percentage of inventory funds	Inventory funds/Gross output value
Inventory management efficiency	Inventory turnover days	Monthly outbound/Average daily inventory
	Supply plan implemented rate	Number of plans implemented/Total number of plans

(4) Informatization performance evaluation index

Information is the internal link of tobacco logistics system and the bridge between logistics system and the outside. Information runs through logistics activities all the time, and informatization plays an increasingly important role in modern tobacco enterprise logistics system. Improving the level of logistics informatization and providing timely and accurate logistics information are important ways for tobacco enterprises to gain competitive advantage.

The EIS of informatization performance is composed of informatization cost, informatization efficiency, etc. The following table gives specific quantitative index (Table 4).

Table 4
Informatization Performance Evaluation Index

Evaluation Elements	Evaluating Index	Measurement Method
Informatization cost	Proportion of investment in informatization	Current investment in informatization/Current investment in fixed assets
Informatization efficiency	Information accuracy	Accurate number of information activities/Total number of information activities
	Information timeliness rate	Number of timely information activities/Total number of information activities
Informatization level	Network coverage	Number of departments covered by network/Total number of departments

(5) Financial performance evaluation index

Theoretically speaking, logistics activities can be reflected through the financial statements of tobacco enterprises. However, because the costs of logistics activities are scattered in many departments, it is difficult to evaluate the performance of the whole tobacco logistics system only through financial statements. Therefore, the EIS of financial performance can be established through easily obtained financial data. The following table gives specific quantitative index (Table 5).

Table 5
Financial Performance Evaluation Index

Evaluation Elements	Evaluating Index	Measurement Method
Operating capacity	Total asset turnover	Total sales revenue/Total assets
Profitability	Net profit margin	Net profit/Gross revenue
Solvency	Asset liability ratio	Liabilities/Total assets

(6) Customer service performance evaluation index

It is the ultimate goal of a tobacco enterprise to provided good products and services to customers, which is supported and guarantee by the logistics activities of the tobacco enterprise. Accepting customer orders is an important part of enterprise logistics work, and the service for orders is an important part of logistics service. The ability of tobacco enterprises to response to and process customer orders reflect the logistics performance level to a certain extent. Therefore, the EIS of customer service performance consists of customer service level and customer service efficiency. The following table gives specific quantitative index (Table 6).

Table 6
Customer Service Performance Evaluation Index

Evaluation Elements	Evaluating Index	Measurement Method
Customer service level	Out of stock rate	Out of stock/Shipment
Customer service efficiency	On-time delivery rate	On-time delivery times/Total delivery times
	Correct delivery rate	Correct delivery times/Total delivery times
	Average delivery time	Order receipt time-official delivery time

Evaluation Model Based on PCA of Tobacco Enterprise Logistics Performance

PCA is a significant statistical method, explores how to transform multi-index problems into much fewer comprehensive indexes, which turns problems with high-dimensional space into those with low-dimensional space, resulting in simpler and more intuitive problems. Moreover, these comprehensive indexes are not interrelated and are able to provide most of the information of the original indexes.

The basic concept of PCA may be summarized like this: with the help of an orthogonal transformation, the original random variables related to components are turned into new variables unrelated to components. From an algebraic point of view, the covariance matrix of original variables is transformed into a diagonal one. And in the perspective of geometry, the original variable system is turned into a different orthogonal system, pointing to the orthogonal direction with most divergent sample points, and thus the multidimensional variable system is reduced in terms of dimensions.[15]

Evaluation steps of principal component analysis are demonstrated below.

(1) Standardized data processing

Each index in the evaluation has different dimensions and orders of magnitude, so it cannot be compared together directly. It is necessary to standardize the numerical value of the index to eliminate the difference in dimension and order of magnitude. The most common method is standardization transformation.

Collecting n samples of p -dimensional random variable x, Construct sample matrix X

$$X = \begin{bmatrix} x_1^T \\ x_2^T \\ \dots \\ x_n^T \end{bmatrix} = \begin{bmatrix} x_{11}x_{12}\dots x_{1p} \\ x_{21}x_{22}\dots x_{2p} \\ \dots\dots\dots \\ x_{n1}x_{n2}\dots x_{np} \end{bmatrix} \quad (1)$$

The elements in the sample matrix X are transformed to obtain matrix Y.

$$Y = \left(y_{ij}\right)_{n\times p} \quad (2)$$

To positive index, $y_{ij} = x_{ij}$

To negative index, $y_{ij} = -x_{ij}$

The method for standardized transformation of data is as follows.

$$z_{ij} = \frac{y_{ij} - \overline{y_j}}{s_j} \quad (3)$$

$$\overline{y_j} = \frac{\sum_{i=1}^{n} y_{ij}}{n} \quad (4)$$

$$s_j^2 = \frac{\sum_{i=1}^{n} (y_{ij} - \overline{y_j})^2}{n-1} \quad (5)$$

$i = 1,2,3,\dots,n$

$j = 1,2,3,\dots,p$

(2) Calculate the sample correlation coefficient matrix R

$$R = \left[r_{ij}\right]_{p\times p} = \frac{Z^T Z}{n-1} \quad (6)$$

(3) Solve eigenvalues of characteristic equation

Let $\left|R - \lambda I_p\right| = 0$, solve p eigenvalues:

$\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p \geq 0$

(4) Determine the number of principal components

m principal components are selected, and the value of m is determined according to the cumulative contribution rate. In the principal component analysis method, the contribution rate of the index is a_k. when the cumulative contribution rate Q is greater than 0.85, the number of principal components to be determined.

$$a_k = \frac{\lambda_k}{\sum_{j=1}^{p} \lambda_j} \quad (7)$$

$$Q = \frac{\sum_{j=1}^{m} \lambda_j}{\sum_{j=1}^{p} \lambda_j} \quad (8)$$

(5) Calculate principal component

Solving the equations to obtain the feature vectors L_i, transform the standardized index variables into the principal component F_{ik}.

$$RL = \lambda_j L \quad (9)$$

$$L_i = \left(l_{i1}, l_{i2}, \ldots, l_{ip}\right)^T \quad (10)$$

$$F_{ik} = \sum_{i=1}^{p} l_{jk} z_{ij} \quad (11)$$

$k = 1,2,\ldots,m$

$i = 1,2,\ldots,n$

(6) Calculate the comprehensive evaluation value F_i

$$F_i = \sum_{k=1}^{m} a_k F_{ik} \quad (12)$$

$k = 1,2,\ldots,m$

$i = 1,2,\ldots,n$

Data Analysis

In this paper, a tobacco enterprise X is taken as the research object. According to the LPEIS of tobacco enterprise established in front part, by collecting and sorting out relevant data, the relevant data of the tobacco enterprise logistics performance from 2016 to 2019 are obtained (Table 7).

Table 7
Logistics Performance Data of Enterprise X

Evaluating Index	2016	2017	2018	2019
Freight per ton-kilometer/yuan (x_1)	0.23	0.39	0.32	0.28
Damage rate of cargo/% (x_2)	0.10	0.12	0.14	0.44
Proportion of warehousing cost/% (x_3)	1.30	2.60	2.34	2.86
Error rate of cargo/% (x_4)	0.10	0.13	0.16	0.15
Percentage of inventory funds/% (x_5)	2.50	5.25	3.75	4.75
Inventory turnover days/day (x_6)	1.00	1.30	2.10	1.60
Proportion of investment in informatization/% (x_7)	2.10	3.12	1.54	1.98
Asset liability ratio/% (x_8)	1.05	2.10	2.57	2.70
Out of stock rate/% (x_9)	2.21	3.45	3.07	2.40
Average delivery time/day (x_{10})	10.00	9.50	9.20	11.30
Vehicle loading efficiency/% (x_{11})	85.00	43.35	49.30	46.75
Utilization rate of transportation capacity/% (x_{12})	95.00	65.55	76.00	63.65
On-time transportation rate/% (x_{13})	97.00	87.30	79.54	65.96
Utilization rate of warehouse area/% (x_{14})	85.00	51.00	62.90	72.25
Utilization rate of warehouse capacity/% (x_{15})	60.00	53.40	40.80	47.40
Utilization rate of equipment/% (x_{16})	65.00	58.50	57.85	38.35
Intact rate of cargo/% (x_{17})	99.00	76.32	57.42	89.10
Supply plan implemented rate/% (x_{18})	90.00	79.20	61.20	85.50
Information accuracy/% (x_{19})	95.00	93.60	94.30	92.70
Information timeliness rate/% (x_{20})	90.10	89.70	87.50	85.40
Network coverage/% (x_{21})	30.00	19.50	24.30	15.60
Total asset turnover/% (x_{22})	20.00	16.50	17.25	15.10
Net profit margin/% (x_{23})	10.10	9.30	8.50	9.00
On-time delivery rate/% (x_{24})	95.00	93.50	92.30	89.10
Correct delivery rate/% (x_{25})	96.00	94.50	95.30	90.10

According to the data in front part, SPSS software is used to analyze the data and calculate the eigenvalue and contribution rate of principal components (Table 8). The first three principal components when the cumulative contribution rate is greater than 85% are taken, which can represent 100% of the information of the nine indexes and are used to explain the selected principal components. The factor loads of three principal components are obtained, and the factor load matrix is as follows (Table 9).

From the calculation results of factor load matrix in last section, the principal component model can be obtained.

Z_1=-0.504X_1-0.702X_2-0.956X_3-0.902X_4+0.717X_5+…+0.898X_{21}+0.967X_{22}+0.844X_{23}+0.873X_{24}+0.734X_{25}

Z_2=0.710X_1-0.709X_2+0.145X_3+0.202X_4+0.336X_5+…+0.214X_{21}+0.115X_{22}-0.351X_{23}+0.467X_{24}+0.659X_{25}

Z_3=0.492X_1-0.069X_2+0.253X_3-0.381X_4+0.610X_5+…+0.385X_{21}-0.227X_{22}+0.406X_{23}+0.139X_{24}-0.163X_{25}

Table 8
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative	Total	% of Variance	Cumulative
1	14.283	57.134	%	14.283	57.134	%
			57.134			57.134
2	6.510	26.039	83.173	6.510	26.039	83.173
3	4.207	16.827	100.000	4.207	16.827	100.000

Table 9
Component Matrix(a)

Evaluation Index	Component		
	1	2	3
X_1	-.504	.710	.492
X_2	-.702	-.709	-.069
X_3	-.956	.145	.253
X_4	-.902	.202	-.381
X_5	-.717	.336	.610
X_6	-.701	.338	-.628
X_7	.077	.227	.971
X_8	-.982	.078	-.171
X_9	-.387	.860	.332
X_{10}	-.295	-.947	.125
X_{11}	.926	-.310	-.215
X_{12}	.924	-.051	-.378
X_{13}	.921	.274	.277
X_{14}	.572	-.709	-.412
X_{15}	.786	-.277	.553
X_{16}	.805	.593	-.024
X_{17}	.320	-.832	.454
X_{18}	.424	-.741	.522
X_{19}	.867	.351	-.353
X_{20}	.808	.465	.363
X_{21}	.898	.214	-.385
X_{22}	.967	.115	-.227
X_{23}	.844	-.351	.406
X_{24}	.873	.467	.139
X_{25}	.734	.659	-.163

From the factor load matrix, the following conclusions can be drawn.

Principal component Z_1 is mainly explained by X_3, X_8 and X_{22}, and the factor loads of these indexes are far greater than other indexes. Therefore, the first principal component expressed by Z_1 has a large load on indexes such as proportion of warehousing cost, asset liability ratio and total asset turnover rate. It mainly reflects the financial and capital operation status of enterprises.

Principal component Z_2 is mainly a comprehensive reflection of X_9, X_{10} and X_{17}. The factor loads of these indexes are far greater than other indexes. Therefore, Z_2 indicates that the load on indexes such as out of stock rate, average delivery time and Intact rate of cargo is relatively large. This principal component mainly reflects the ability of enterprises in order service and warehouse management.

Principal component Z_3 mainly reflects the information of X_6 and X_7, and the factor loads of these two indexes are far greater than other indexes. Therefore, the third principal component expressed by Z_3 has a greater load on indexes such as inventory turnover days and proportion of investment in informatization. It mainly reflects the enterprise's ability in inventory management and informatization.

RESULTS

According to the eigenvalue and contribution rate of principal components in last section, the comprehensive evaluation index F of tobacco enterprise logistics performance is calculated and constructed. F is the linear combination of principal components Z_1, Z_2 and Z_3.

$F=0.57134Z_1+0.26039Z_2+0.16872Z_3$

Through calculation, the comprehensive evaluation value of tobacco logistics performance of enterprises in each year is obtained (Table 10).

From Table 10, it can be seen that the annual rank of tobacco enterprise logistics performances. The enterprise logistics performance is the worst in 2016. The enterprise logistics performance is the best in 2019. It indicates that the logistics level and ability of enterprises are improving year by year.

Table 10
Annual Rank of Tobacco Enterprise Logistics Performances

Z_1	2016	2017	2018	2019
Z_1	11.74	12.03	11.67	12.47
Z_2	-12.51	-11.87	-10.89	-10.30
Z_3	-5.23	-5.61	-5.32	-5.41
F	1.27	1.32	1.43	1.78

CONCLUSION

In this paper, the LPEIS of tobacco enterprise is established from six aspects, including transportation, warehousing, inventory management, informatization, customer service and finance. The LPE method based on principal component analysis is put forward. By using PCA, various factors affecting enterprise logistics performance are analyzed. In the process of transforming the original variables into main components, weights reflecting principal components and information content contained in index are formed, and finally comprehensive evaluation results of tobacco enterprise logistics performance are obtained. Seen from the example, the principal component analysis method can be used to properly evaluate the logistics performance level of tobacco enterprises, and provide objective and quantitative reference data for tobacco enterprises to improve their logistics performance level and benefits.

Conflicts of Interest Disclosure Statement

The authors declare this research is not funded by any organization related to tobacco production.

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