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Research on Supply Chain Performance Evaluation Indicators

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Abstract

With the intensification of market competition and the trend of globalization, the competitive environment of enterprises has fundamentally changed. Modern business is no longer a competition between individual enterprises, but a competition between supply chains. The importance of supply chain management is becoming more and more prominent, and effective supply chain management can help enterprises gain and maintain competitive advantages. Existing research is not perfect in supply chain performance evaluation, and further research is needed in the selection of supply chain performance evaluation indexes. The purpose of this paper is to take supply chain performance evaluation as the research object, combine the supply chain operation reference model with the balanced scorecard, based on the principle of evaluating index selection, initially select evaluating indexes that can objectively reflect the performance of the supply chain, and then screen the evaluating indexes through the grey correlation analysis, with a view to finding evaluating indexes that can objectively reflect the performance of the supply chain.

Keywords

Supply Chain Management; Supply Chain Performance; Performance Evaluation; Evaluation Indicators; Gray Correlation Analysis.

1. Introduction

With the intensification of competition and the globalization of markets, the competitive environment in which enterprises operate has changed fundamentally. In the modern business environment, competition is no longer between individual enterprises, but between supply chains composed of multiple enterprises. Globalized competition has made supply chains more complex and diverse, with multinational enterprises working with suppliers, partners and customers across the globe to meet growing market demand. Such a competitive environment creates management challenges, including cultural differences, time zone differences, and logistics issues. Companies operate in highly competitive markets where customers demand higher quality, price and delivery times. Companies need to continuously improve supply chain efficiency and flexibility to cope with market pressures. In addition, companies look to supply chain management to reduce costs and increase profits. By reducing inventory, improving supply chain efficiency and optimizing production, companies can become more competitive and achieve higher profits.

Supply chain performance refers to the overall operational efficiency, effectiveness and quality of the supply chain, is a comprehensive evaluation of the supply chain business process, is a certain period of time supply chain management on the enterprise to produce the objective impact of the reflection, can be used to assess the implementation of enterprise supply chain management. Supply chain performance can also be considered as a set of indicators and metrics to assess and measure the operational efficiency and effectiveness of the supply chain

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system. By monitoring and managing supply chain performance, organizations can identify problems, improve processes, and achieve higher levels of customer satisfaction, cost control, and business growth. Supply chain performance can also be customized with metrics designed to meet the requirements of a particular industry, organization, or project. It is important to assess supply chain performance in the context of business objectives and strategy, focusing on overall performance rather than pursuing a single metric. By monitoring and improving supply chain performance, companies can realize increased operational efficiency, cost control, customer satisfaction, and competitive advantage in the marketplace.

Supply chain performance evaluation is the process of quantitative or qualitative assessment and measurement of the operation of the supply chain system, which refers to the analysis and evaluation of the supply chain as a whole and each link around the objectives of the supply chain. Evaluating the performance of the supply chain is an evaluation of the overall operational performance of the entire supply chain, the node enterprises of the supply chain, and the cooperative relationship between the node enterprises in the supply chain. It aims to determine the efficiency, effectiveness, and quality of the supply chain and provide feedback based on data and metrics for continuous improvement and optimization. The goal of supply chain performance evaluation is to measure and monitor the performance of each link in the supply chain, to identify bottlenecks and problems, and to provide a basis for strategy and decision making. By evaluating supply chain performance, companies can identify and solve problems, improve delivery, reduce costs, enhance customer satisfaction, and increase the competitiveness of the entire supply chain.

2. Literature References

FT.S. Chan in 2003 studied that supply chain performance evaluation plays an important role in the development of new strategic goals of companies to implement specific strategic intentions [1]. Christopher. M. in 2014 study pointed out the importance of supply chain in creating business value and competitive advantage [2]. Sodhi. M. S. in 2016 pointed out that supply chain performance evaluation has a positive role in risk management and explored the impact of different types of risk on performance evaluation [3]. Fang. C. in 2018 explored the impact of different supply chain performance evaluation indicators on sustainability, pointing out the importance of supply chain performance evaluation in promoting supply chain sustainability [4]. Houlihan J. B. in 1998 studied the main assessment indicators of supply chain performance evaluation from four aspects of supply chain management: demand, supply, process and delivery, providing a more complete basic structure of supply chain performance evaluation indicator system [5]. Tan K. C. proposed in 1999 to take the flexibility index as an important part of supply chain performance evaluation, and combined it with product quality, production time and product cost to become a new supply chain performance evaluation system [6]. Klapper L. S. in 1999 proposed a new performance measurement system including seven dimensions such as tangible external performance, reliability, responsiveness, capability, trustworthiness, security and accessibility. This study pointed out that customer service quality is the most important aspect of supply chain performance evaluation, which makes the supply chain performance evaluation system more complete and close to reality [7]. Beamon studied supply chain performance evaluation indicators from qualitative and quantitative perspectives in 1999 and summarized the indicators according to three major perspectives: resource, output, and flexibility [8]. Lapide L. in 2000 pointed out that when designing supply chain performance evaluation indexes, it is necessary to combine the existing environmental conditions to construct a supply chain performance evaluation system suitable for the contemporary era of rapid development of the Internet [9]. Gumasekaran in 2001 pointed out that when designing supply chain performance evaluation indicators, it is necessary to balance the financial and

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non-financial aspects, and divide these indicators into three different decision-making levels of strategic, tactical and operational oriented indicator structure [10]. Pohlen T. L. studied supply chain performance evaluation indexes from the perspective of demand elasticity in 2005, and pointed out that the ability to quickly respond and highly match the market demand should be the focus of supply chain performance evaluation [11]. Angerhofer B. J. in 2006 categorized supply chain performance evaluation indexes and classified supply chain performance evaluation into internal performance evaluation, external performance evaluation and comprehensive performance evaluation [12]. Bigliardi B. in 2010 studied supply chain performance evaluation indicators in terms of the degree of quantifiability and categorized supply chain performance evaluation indicators qualitatively and quantitatively according to the degree of quantifiability [13].

3. Preliminary Selection of Supply Chain Performance Evaluation Indicators

3.1. Supply Chain Operations Reference Model

The Supply Chain Operations Reference (SCOR) model is a cross-industry standard supply chain reference model and supply chain diagnostic tool published by the American Supply Chain Association. It comprehensively, accurately, and optimally provides standardized terminology and processes applicable to supply chains of all sizes and complexities.

SCOR defines the supply chain as five major processes: planning, purchasing, production, distribution, and returns, and cuts through the three levels of supply chain delineation, configuration, and process elements, respectively, describing the standardized definitions of each process, the measurement metrics corresponding to the performance of each process, and providing supply chain optimal implementation and human resource solutions. Utilizing SCOR allows companies to communicate supply chain issues internally and externally in the same language, objectively assess their performance, and clarify supply chain improvement goals and directions.

3.2. Balanced Score Card Methodology

The Balanced Score Card (BSC) approach is a performance management tool that is widely used in organizations and businesses to help them assess and improve all aspects of performance. The methodology provides a comprehensive and balanced view of performance by combining the strategic goals and KPIs of an organization, assessing performance across four dimensions: financial, customer, internal business process, and learning and growth. By linking these four dimensions, the balanced scorecard approach provides management with a comprehensive assessment framework that helps them set strategic goals, track performance, and promote overall business enhancement and continuous improvement.

3.3. Preliminary Selection of Indicators

In today's competitive market environment, effective evaluation and management of supply chain performance is crucial to the success of an organization. However, since the SCOR model only depicts the operational process of supply chain management rather than performance evaluation, and the original BSC model does not fit well enough with supply chain performance, in order to achieve a comprehensive supply chain performance analysis, this paper chooses to organically integrate the SCOR model with the BSC methodology in order to provide a comprehensive assessment in multiple dimensions, such as financials, customers, internal processes, and learning and growth. The integration of the SCOR model and the BSC approach can provide a more comprehensive and integrated perspective for supply chain performance analysis. This integration can help organizations better understand supply chain performance

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in different dimensions and develop improvement strategies based on the integrated metrics. The combined supply chain performance evaluation metrics are shown in Table 1.

Table 1. Supply chain performance evaluation metrics combining SCOR and BSC

Evaluation perspective	Evaluation indicator	Indicator abbreviation
Financial	Order fulfillment rate	OFR
	Sales expenditure rate	SER
	Asset turnover rate	ATR
	Total cost of supply chain management rate	TCR
Customer	Order completion rate	OCR
	Distribution performance rate	DPR
Internal control	Lead time for fulfilling orders	LTO
	Supply chain response time	SRT
	Inventory supply time	IST
	Cash flow time	CFT
Learning and growth	Value-added productivity	VAP

By integrating the SCOR model and the BSC methodology, organizations can obtain a more comprehensive, multi-dimensional assessment of supply chain performance. This integrated approach helps identify bottlenecks in the supply chain, unlock improvement potential, increase customer satisfaction, reduce costs, and improve efficiency to achieve sustained competitive advantage. Continuing to collect, monitor, and analyze this performance data will be key to continually improving supply chain performance to ensure that the supply chain is aligned with the organization's strategic goals, adapts to changing market demands, and achieves long-term success.

4. Screening of Supply Chain Performance Evaluation Indicators

4.1. Data Collection

In this paper, 100 listed companies in the manufacturing industry are selected as the object of study, and the following data are all from the 2022 annual financial reports of the 100 companies and the notes to their financial statements or calculated through the data in the financial reports, and in the text, we only show the data of 5 companies as an example, see Table 2.

Table 2. Experimental data

	G1	G2	G3	G4	G5
ROA	6.50%	6.94%	10.03%	10.20%	7.16%
DPR	98.68%	97.13%	94.53%	94.12%	91.56%
OCR	99.74%	99.76%	99.97%	99.97%	98.96%
OFR	95.12%	94.32%	89.91%	88.36%	86.99%
LTO	11.6	12.1	12.8	11.8	13.6
SRT	26.7	28.9	34	35.3	50.9
TCR	4.35%	5.48%	6.24%	5.66%	4.19%
SER	15.85%	16.78%	11.92%	12.35%	11.89%
VAP	1023445.73	1050991.94	842302.89	653036.19	587551.86
IST	91	73	39	39	46
CFT	147	128	93	92	103
ATR	1.07	1.13	1.56	2.06	2.8

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4.2. Determining the Analytical Sequence

Existing research has shown that good supply chain management can effectively improve the enterprise business continue, supply chain management and enterprise business performance is positively correlated, so in this paper, the use of enterprise business performance advantages and disadvantages to represent the supply chain performance, this paper chooses to return on total assets (ROA) as a measure of enterprise business performance indicators. In this paper, the ROA is selected as the parent sequence in the gray correlation analysis, which is the sequence used to reflect the performance of the enterprise, and is denoted as X. Distribution performance, order fulfillment rate, intact fulfillment rate, fulfillment of order lead time, supply chain response time, total cost of supply chain management, cost of goods sold rate, value-added productivity, days of supply of inventory, days of cash turnover, asset turnover, and so on, are chosen as the characteristics of the sequence. sequence, which is a sequence of data that may affect the performance of the firm, denoted as $x_1, x_2, x_3. x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}$.

4.3. Dimensionless Processing

Dimensionless processing refers to the removal of some or all of the units of an equation involving physical quantities by a suitable variable substitution for the purpose of simplifying the experiment or calculation. Based on the characteristics of the data in this study, this paper adopts the method of homogenization for the dimensionless treatment of the data, and solves the mean value of each series as shown in Table 3.

Table 3. Gray correlation analysis of the mean values of each series table

Indicator	Average value
ROA	7.25%
DPR	94.30%
OCR	99.66%
OFR	90.15%
LTO	11.97
SRT	37.06
TCR	5.49%
SER	12.83%
VAP	790748.34
IST	49.05
CFT	103.45
ATR	1.71

The results of homogenizing the data for each series are shown in Table 4.

Table 4. Gray correlation analysis of each series of homogenization processing table

	G1	G2	G3	G4	G5
ROA	0.897	0.9577	1.3841	1.4076	0.9881
DPR	1.0464	1.03	1.0024	0.9981	0.9709
OCR	1.0008	1.001	1.0031	1.0031	0.9929
OFR	1.0551	1.0462	0.9973	0.9801	0.9649
LTO	0.9691	1.0109	1.0693	0.9858	1.1362
SRT	0.7206	0.7799	0.9176	0.9526	1.3736
TCR	0.7929	0.9988	1.1373	1.0316	0.7637
SER	1.2351	1.3076	0.9289	0.9624	0.9265
VAP	1.2943	1.3291	1.0652	0.8258	0.743
IST	1.8552	1.4883	0.7951	0.7951	0.9378
CFT	1.421	1.2373	0.899	0.8893	0.9957
ATR	0.6257	0.6608	0.9123	1.2047	1.6374

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4.4. Solving for Gray Correlation Coefficient Values

4.4.1. Solving for the Difference Sequence

The formula for solving the difference series is as follows.

$$\Delta_i(k) = \left| X(k) - x_i(k) \right| \tag{1}$$

In equation (1), $X(k)$ represents the kth data in the parent sequence, the $x_i(k)$ represents the kth data in the feature sequence x_i, i takes 1, 2, 3, ... , 11, k takes 1, 2, 3, ... , 20.

4.4.2. Solving for the Bipolar Difference

The formula for solving the bipolar difference are as follow.

$$M = \max_i \max_k x\Delta_i(k) \tag{2}$$

$$m = \min_i \min_k \Delta_i(k) \tag{3}$$

In equations (2) and (3), M represents the bipolar maximum difference, m represents the bipolar minimum difference, i takes 1, 2, 3, ... , 11, k takes 1, 2, 3, ... , 20.

4.4.3. Solving for Correlation Coefficients

The formula for solving the correlation coefficient is as follows.

$$r_i(k) = \frac{m + \rho M}{\Delta_i(k) + \rho M} \tag{4}$$

In equation (4), $r_i(k)$ represents the correlation coefficient between the kth data in the feature sequence x_i and the kth data in the parent sequence, p represents the resolution factor (usually taken as 0.5) , i takes 1, 2, 3, ... , 11, k takes 1, 2, 3, ... , 20.

According to the above steps, the correlation coefficients between the parent sequence and each feature sequence are obtained as shown in Table 5.

Table 5. Correlation coefficient

	G1	G2	G3	G4	G5
ROA	0.8251	0.9097	0.6445	0.628	0.9818
DPR	0.8165	0.8905	0.6414	0.6179	0.9733
OCR	0.8728	0.9491	0.7384	0.648	0.7567
OFR	0.6721	0.6644	0.6027	0.6081	0.9229
LTO	0.91	0.9335	0.6879	0.621	0.8264
SRT	0.4748	0.5565	0.6155	0.6028	0.5757
TCR	0.4176	0.5652	0.5392	0.5294	0.9372
SER	0.7991	0.7978	0.5968	0.6029	0.6422
VAP	0.5683	0.7131	0.5873	0.571	0.9954
IST	0.6352	0.6508	0.685	0.5423	0.7398
CFT	0.7194	0.7005	0.594	0.7751	0.5147
ATR	0.8251	0.9097	0.6445	0.628	0.9818

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4.4.4. Solving for Gray Correlation Values

The formula for solving the gray correlation value between each feature sequence and the parent sequence is as follows.

$$r_i = \frac{1}{n}\sum_{k=1}^{n} r_i(k) \tag{5}$$

In Equation (5), r_i represents the gray correlation value between the feature sequence x_i and the parent sequence, i takes 1, 2, 3, ... , 11, k takes 1, 2, 3, ... , 20.

According to the formula for solving the gray correlation value, the gray correlation between each feature sequence can be obtained as shown in Table 6.

Table 6. Gray correlation table between the series

	ROA	TCR	LTO	DPR	OFR	SER	VAP	SRT	CFT	ATR	IST	OCR
ROA	1.00											
TCR	0.80	1.00										
LTO	0.76	0.75	1.00									
DPR	0.75	0.72	0.87	1.00								
OFR	0.75	0.71	0.87	0.87	1.00							
SER	0.72	0.76	0.70	0.72	0.72	1.00						
VAP	0.70	0.69	0.67	0.66	0.66	0.77	1.00					
SRT	0.70	0.67	0.72	0.68	0.67	0.63	0.60	1.00				
CFT	0.69	0.64	0.67	0.71	0.71	0.74	0.74	0.57	1.00			
ATR	0.68	0.60	0.61	0.57	0.57	0.54	0.56	0.77	0.48	1.00		
IST	0.62	0.61	0.56	0.55	0.55	0.74	0.75	0.55	0.67	0.50	1.00	
OCR	0.60	0.78	0.81	0.86	0.83	0.71	0.65	0.71	0.69	0.60	0.55	1.00

As shown in Table 6, the gray correlation between each feature sequence is lower than 0.9, i.e., there is no covariance between feature sequences. The gray correlation between each feature sequence and the parent sequence is shown in Table 7.

Table 7. Gray correlation ranking table

Indicator	Gray correlation value
TCR	0.8
LTO	0.756
DPR	0.753
OFR	0.749
SER	0.719
VAP	0.702
SRT	0.701
CFT	0.692
ATR	0.684
IST	0.622
OCR	0.596

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The bar chart of the gray correlation between each feature sequence and the parent sequence is shown in Figure 1.

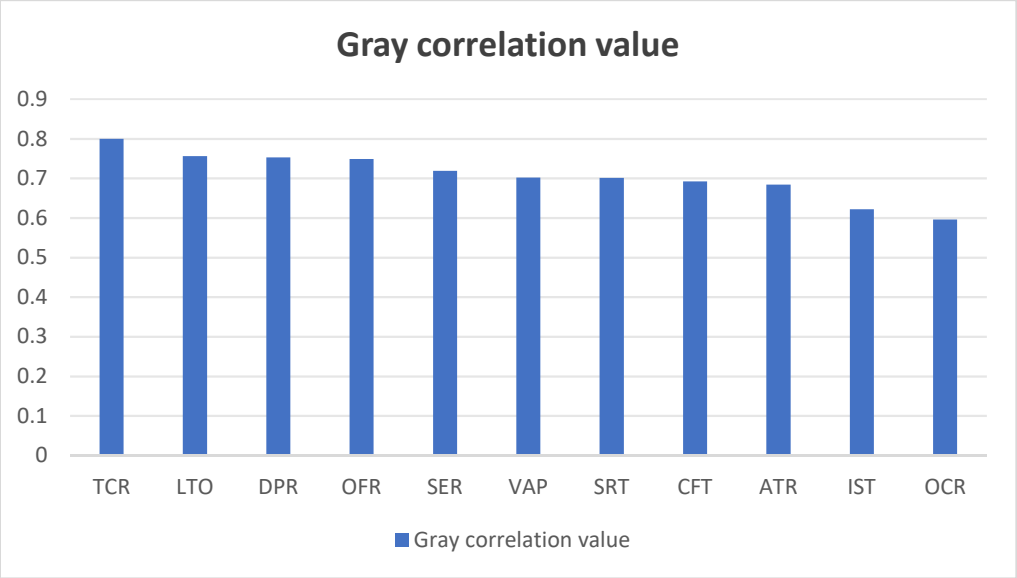

Figure 1. Bar chart of gray correlation

From the above figure and tables, it can be seen that among the 11 supply chain performance evaluation metrics identified in the previous section based on SCOR and BSC, the total cost ratio of supply chain management has the highest gray correlation with ROA, which in descending order of gray correlation is TCR, LTO, DPR, OFR, SER, VAP, SRT, CFT, ATR, IST, and OCR.Among the 11 evaluation metrics, seven of them are associated with the ROA with gray correlation value higher than 0.7 are 7 items such as TCR, LTO, DPR, OFR, SER, VAP, SRT, etc., while the remaining 4 items have gray correlation value lower than 0.7.According to the gray correlation analysis, it can be considered that 7 items such as TCR, LTO, DPR, OFR, SER, VAP, SRT, etc., have a high correlation with ROA, while the the remaining 4 items do not have high correlation with ROA. Based on this, the supply chain performance evaluation indexes determined in this paper are shown in Table 8.

Table 8. Supply chain performance evaluation indicators

Evaluation indicator	Indicator abbreviation
Total cost of supply chain management rate	TCR
Lead time for fulfilling orders	LTO
Distribution performance rate	DPR
Order fulfillment rate	OFR
Sales expenditure rate	SER
Value-added productivity	VAP
Supply chain response time	SRT
Cash flow time	CFT
Asset turnover rate	ATR
Inventory supply time	IST
Order completion rate	OCR

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5. Conclusion

In this paper, we initially screened 11 evaluation indicators of supply chain performance through SCOR and BSC, and then screened 11 evaluation indicators through gray correlation analysis model, and finally obtained 7 evaluation indicators with high correlation with supply chain performance, i.e. TCR, LTO, DPR, OFR, SER, VAP, and SRT. In summary, evaluating the supply chain performance needs to be carried out from different perspectives and the evaluation indicators should be selected reasonably. In the future research, we will continue to study the evaluation of supply chain performance and work to establish an objective and fair supply chain evaluation system.

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