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Research on Green Supply Chain Performance Evaluation of Manufacturing Enterprises

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Abstract

This study addresses the environmental and resource challenges by constructing a green supply chain performance evaluation index system for a Chinese manufacturing enterprise (Company M). Based on the balanced scorecard theory and relevant literature, the system includes five first-level indicators (financial value, customer service, supply chain process, development and innovation, low-carbon environmental protection) and 21 second-level indicators. The entropy weight method and grey relational analysis are applied to evaluate Company M's green supply chain performance from 2013 to 2021. Results show that the performance fluctuates but generally improves, indicating potential for further enhancement. Relevant suggestions are proposed to optimize Company M's green supply chain performance.

Keywords

green supply chain, performance evaluation, gray scale analysis method, entropy value method

1. Introduction

1.1 Research Background

In recent years, environmental issues have become increasingly severe on a global scale, and environmental regulations have been tightened accordingly. How to break through the inherent drawbacks of traditional supply chains, free them from the dilemma of "vicious" development, and enable them to better adapt to the environment to achieve harmonious development among the environment, economy, and society is an urgent problem to be solved. Against this backdrop, the concept of sustainable development emerged. The theme of sustainable development was proposed at the United Nations Conference on the Human Environment held in Stockholm. The introduction of the concept of sustainable development has triggered a new economic transformation, driving the economies of countries around the world towards green development. It is under such circumstances that the green supply chain came into being. The green supply chain integrates environmental, economic, and social factors, and adjusts the traditional supply chain system from the perspective of the environment, thereby maximizing the matching of interests among the three and achieving a win-win situation.

In the past, China's economic development direction has long remained in the traditional extensive model. However, China has gradually realized this reality and has taken effective countermeasures. In 2007, relevant departments issued the *National Policy on Climate Change*, marking China's first complete, systematic, and effective policy for mitigating climate impacts. During the 2021 National People's Congress and Chinese People's Political Consultative Conference sessions, China first included "carbon neutrality" in the government work report. In July, China launched its first national carbon emission trading market, signaling an unprecedented level of China's capacity for global greenhouse gas emission reduction. In the carbon emission market, manufacturing enterprises are a very critical presence.

Manufacturing is vital to national development. It not only drives national economic growth but also plays a positive role in reducing energy consumption and pollution. As the secondary industry, its energy consumption and pollutant emissions account for two-thirds, and it also occupies one-third of the national total of energy and pollutants. As the world's largest manufacturing country, China is advancing the development of a strong manufacturing nation and rapidly expanding its market. However, as a latecomer in industrialization, China's industrial electrification level is relatively backward, and many manufacturing enterprises still use outdated and environmentally unfriendly methods such as industrial boilers and industrial coal kilns for production, causing a large amount of pollution. In recent years, with the increasing awareness of environmental protection and the intensification of market competition, the focus has shifted from price and quality to environmentally friendly products. This competition not only requires an advantage in price but also demands performance in environmental protection, energy saving, renewability, and sustainable development. Therefore, to maintain a leading position in the market, manufacturing enterprises need to strengthen energy conservation and environmental protection and implement green supply chain management. Adopting green supply chain management practices not only reflects the responsibility of the manufacturing industry but also protects the environment, enhances economic benefits, and ensures that China's manufacturing industry maintains a leading position in the global market. Company M is a leader in the manufacturing industry, ranking in the Fortune Global 500 for several consecutive years, with over 400 million users worldwide, and has been actively exploring the construction of a green supply chain. It is representative in the domestic manufacturing industry. Based on the above background, this paper selects Company M, a representative manufacturing enterprise, as the research object and conducts a performance evaluation study of its green supply chain.

1.2 Research Significance and Objectives

As a significant area of economic growth, the manufacturing industry is confronted with severe environmental pollution and energy consumption issues. Therefore, this paper focuses on the performance of green supply chains in manufacturing enterprises. Based on the production characteristics and development status of manufacturing enterprises, this study constructs an evaluation index system.

Subsequently, taking Company M as an example, this paper conducts an empirical analysis and provides suggestions for Company M according to the results of the empirical analysis, in order to help it solve problems and improve its green supply chain construction. This research holds certain theoretical significance.

Moreover, it has reference value for existing studies on the performance evaluation of green supply chains. As a systematic and interdisciplinary concept, the influence of the green supply chain has transcended the utilization of material resources. Its impact is not limited to the use of material resources but permeates various behaviors, influencing people's behavioral habits, economic development, and well-being. However, at present, there is no consensus on the performance evaluation index system for green supply chains, and there are numerous research entry points for its performance evaluation system. Therefore, this paper proposes a green supply chain performance evaluation system based on manufacturing enterprises, with the expectation of better promoting the development of green supply chains. In addition, a comprehensive assessment of corporate performance will also have a positive impact on the theoretical construction of green supply chains, promoting their continuous progress. By conducting green supply chain performance evaluations, not only can the development of enterprises be effectively guided, but also an effective reference can be provided for enterprises, thereby effectively promoting the implementation of green supply chain management strategies.

2. Literature Review

In the field of green supply chain research, global studies on the theory of green supply chains mainly include green procurement, the selection of green suppliers, green supply chain decision-making, green supply chain practices, cost management of green supply chains, and research on the operation of green supply chains in specific industries. These theoretical studies have provided us with a new environment for sustainable development and are conducive to the achievement of sustainable development.

Webb (1994) first introduced the concept of "green procurement" and elaborated on the concept of "green supply chain". Subsequently, researchers from a renowned university in the United States, during a study on environmentally responsible manufacturing, first introduced the concept of "green supply chain" into academia, thus pioneering a new research field. Narasimhan and Carter (2001), from the perspective of procurement, elaborated on the concept of green supply chain and discussed the environmentally related activities involved in the supply chain. The realization of green supply chain is attributed to the work done by the procurement department in reducing waste, recycling, reuse, and finding alternative materials. Zsidisin and Siferd (2001) defined green supply chain management as the management policies, actions taken, and relationships formed by enterprises in the supply chain. The various relationships generated in the design, material procurement, production, distribution, use, reuse, and the products and services of the company are accordingly. Helen Walker (2008) et al. analyzed the driving forces and barriers for enterprises to implement green supply chain management strategies and proposed types of driving forces, including customers, management level, corporate culture, organizational structure, competitors, and public opinion. Stefan A (2009) used cost management theory to analyze and study the cost influencing factors in the textile and apparel supply chain. It was concluded that in the process of green supply chain management, costs are mainly divided into three categories: direct costs, activity-based costs, and transaction costs. Combined with case studies, some suggestions and strategies for cost management were proposed. According to Uygun (2016), when making green supply chain decisions, multiple factors should be comprehensively considered. Based on the fuzzy multi-objective decision-making model, the fuzzy ANP method is used to determine weights, and the fuzzy TOPSIS method is employed to conduct a comprehensive evaluation and ranking of the green supply chain performance of the studied enterprises. Hassan et al. (2013) found in their research on the relationship between green supply chain management practices and corporate performance that quantitative research alone cannot fully reveal the connection between the two. Therefore, qualitative research is needed to supplement it, which can analyze the possible reasons for supporting or not supporting green supply chain management practices. Rebecca et al. (2021) discovered that the organic combination of internal and external green SCM can significantly improve the operational and financial conditions of third-party logistics providers. Through fuzzy set qualitative comparative analysis, survey data from 232 TPLs supported this conclusion. Amini Habibeh (2022), based on the traditional supply chain performance evaluation theory, introduced a low-carbon perspective, used a comprehensive optimization method to screen indicators, and simulated indicator weights using expert ranking and coefficient of variation-based subjective and objective methods.

Kannan G (2008) analyzed the main reasons affecting the performance of corporate environmental work from three aspects and pointed out the main factors influencing the performance of corporate environmental work. Based on this, a method for evaluating the environmental management performance of suppliers based on green supply chain was established. Amy H.I. Lee (2009) used the Delphi method to analyze the differences between traditional supply chains and green supply chains, established a multi-level evaluation index system, and on this basis, proposed a new method for evaluating green supplier performance using a fuzzy extended multi-level evaluation method. In addition, Stepan Vchon (2006), Ottar Michelsen (2007), and others have also evaluated the performance of green suppliers. Lee S-Y, Rhee S-K (2007) used network analysis to evaluate the strategy of green supply chain management.

In recent years, with the increasing attention to green supply chains worldwide, various academic institutions, professionals, and policymakers have actively engaged in this field. While significant progress has been made in research, the development in this area remains relatively limited due to the lack of a comprehensive theoretical framework. As society evolves, the performance evaluation of green supply chains has garnered increasing attention. It holds substantial theoretical value and provides businesses with valuable references. Although numerous scholars have attempted to explore the performance of green supply chains from multiple perspectives and have achieved certain results, there are still many areas that remain underdeveloped. Therefore, this paper aims to conduct an in-depth investigation into the performance evaluation of green supply chains to offer more references for businesses.

3. Construction of the Performance Evaluation Index System for Green Supply Chains

At present, the concepts of green, low-carbon, and environmental protection are gradually taking root in people's hearts. It has become a social consensus for enterprises to focus on energy conservation and emission reduction while carrying out production and operation activities. China has also gradually introduced strict carbon reduction policies. Enterprises' original neglect of the environment will lead to the impact on economic benefits and the loss of social reputation. With the development of the times, the traditional supply chain performance evaluation model can no longer meet the needs of today's society. In order to meet the growing demand for low-carbon and environmental protection, we need to reshape and improve the supply chain performance evaluation model, and incorporate environmental protection and sustainability into consideration, so as to promote the establishment and operation of the green supply chain. In order to ensure the effectiveness of green supply chain decision-making and its impact on the economy, environment, and social development of enterprises, it is necessary to construct a comprehensive evaluation index system that includes various environmental factors and has scientific, objective, and operable characteristics, so as to effectively supervise the decision-making results.

3.1 Basis for the Construction of the Performance Evaluation Index System for Green Supply Chains

The Balanced Scorecard (BSC) is a novel performance management system that comprehensively considers the implementation and management of strategy. Dr. Robert S. Kaplan, a distinguished academic from Harvard Business School, and David P. Norton, a global leader from the Norton Company, jointly propelled the development of the Balanced Scorecard. It shifts managers' focus towards long-term development rather than merely concentrating on current performance, and it can also promptly identify potential issues and conduct effective analyses.

However, this new approach to financial performance evaluation also has some drawbacks. For instance, it focuses solely on current performance, lacking consideration for the long term. Through the application of the Balanced Scorecard, we can address the shortcomings of traditional methods. From a strategic perspective, we can analyze four distinct dimensions: financial, customer, internal processes, and learning and growth. These dimensions are crucial for understanding the key impacts on corporate performance and providing support for sustainable corporate growth.

By utilizing the Balanced Scorecard, we can maintain a balance while achieving multiple objectives, including but not limited to: sustaining long-term development, maintaining stable growth, preserving competitive advantages, and ensuring continuous improvement. Adopting the Balanced Scorecard approach enables us to better assess the overall operations of a company, thereby facilitating continuous corporate improvement. Therefore, we have selected this method as the evaluation criterion and have incorporated four different perspectives within the evaluation framework. However, the traditional Balanced Scorecard theory lacks a crucial performance evaluation of green and low-carbon indicators in the context of green supply chains. The Green Supply Chain Balanced Scorecard theory fills this gap.

The Green Supply Chain Balanced Scorecard method is based on the traditional Balanced Scorecard theory. It integrates the concept of the Balanced Scorecard with the performance evaluation of green supply chains, establishing an evaluation index system that incorporates “green” and “low-carbon” elements into the traditional Balanced Scorecard framework. This method emphasizes “green” principles and integrates the “green” philosophy throughout the entire supply chain process. It is a performance evaluation method designed to achieve a balanced state between the economic and environmental benefits of supply chain node enterprises, short-term goals and long-term strategies, and internal processes and external environments. Given its alignment with the research objectives of this paper, the Green Supply Chain Balanced Scorecard has been chosen as the theoretical foundation of this study.

3.2 Construction of the Performance Evaluation Index System for Green Supply Chains

Based on the five principles of comprehensiveness, scientificity, significance, independence, and feasibility mentioned earlier in this chapter for selecting evaluation indicators, and in conjunction with the theoretical basis of the Green Supply Chain Balanced Scorecard, this study constructs the performance evaluation index system for the green supply chains of manufacturing enterprises from five dimensions: financial value, customer service, supply chain processes, development and innovation, and low-carbon environmental protection. These five dimensions serve as the first-level indicators of the performance evaluation system.

In determining the second-level indicators, it is necessary to build on the first-level indicators that already have a theoretical basis. While considering whether they meet the principles of indicator selection, it is also essential to consider their compatibility with manufacturing enterprises. The construction of a complete evaluation index system involves four steps: First, define the scope of evaluation; second, through in-depth research and analysis, select the best indicators; third, carefully examine and eliminate indicators that do not meet the requirements; finally, establish a comprehensive evaluation index framework.

This paper employs mathematical and statistical methods to select 20 core journals related to the performance evaluation of green supply chains. The performance evaluation index system for green supply chains is regarded as a set, with each indicator considered as an element. Assuming that the total number of occurrences of the i-th evaluation indicator Ai in the literature is Bi, we set $ci=Bi/20$. Indicators with larger ci values are retained. Taking financial value indicators as an example, 12 second-level evaluation indicators were preselected from the relevant literature to construct a second-level structured evaluation index system, as shown in Table 1 below.

Table 1. Pre-selection of Indicators for Evaluating the Financial Value of Green Supply Chains

First-level indicators	Second-level indicators	c value
Financial values	Total Asset Turnover Ratio	0.65
	Gearing Ratio	0.75
	Return on Net Assets	0.75
	Green Procurement Cost	0.35

Total Supply Chain Operating Cost	0.50
Sales Growth Rate	0.55
Return on Total Assets	0.5
Green Supply Chain Total Cost of Ownership	0.45
Sales Margin	0.60
Current Ratio	0.45
Net Profit Ratio	0.25
Internal Rate of Return	0.25

In accordance with the actual circumstances, this paper has eliminated indicators with a c value less than 0.5. Taking into account the realities of the manufacturing industry and the availability of data, two indicators were removed, thereby constructing the evaluation index system for the financial value of the green supply chain. Similarly, employing the same data processing methodology, and following the aforementioned approach to determine the indicators at each level, a comprehensive performance evaluation index system for the green supply chain was established. The specifics are presented in Table 2 below:

Table 2. Green Supply Chain Performance Evaluation Indicator System for Manufacturing Industry

First-level indicators	Second-level indicators
Financial Value	Total Assets Turnover Ratio
	Return on Net Assets
	Gearing Ratio
	Sales Growth Rate
	Sales Profit Margin
Customer Service	Customer Complaint Rate
	Customer satisfaction rate
	Market share of main products

Supply Chain Processes	Inventory Turnover
	Full Business Cycle
	Product Quality Conformity
	Inventory turnover days
Development & Innovation	Share of scientific researchers
	Number of Employee Training
	Percentage of R&D investment
	Number of patented technology growth
Low Carbon Environmental Protection	Comprehensive Energy Consumption of 10,000 Yuan GDP
	Total greenhouse gas emissions
	Total Sewage Discharge
	Total Electricity Consumption
	Total Energy Consumption

4. Performance Evaluation Model for Green Supply Chains

4.1 Grey Relational Analysis Performance Evaluation Model

In the performance evaluation of green supply chains in manufacturing enterprises, although there are many models and methods available for measurement, obtaining objective and scientific evaluation results requires reducing the subjectivity in weight assignment. To ensure the reliability of the data, this paper employs Grey Relational Analysis (GRA), which can more accurately reflect the associations between various indicators, thereby making the evaluation results more accurate and credible. Based on the entropy method, this paper constructs a complete evaluation model using Grey Relational Analysis to assess the performance of green supply chains in manufacturing enterprises in a more scientific manner, with the expectation of achieving better management outcomes.

A system is an entity composed of multiple interconnected and interdependent components, and its existence is characterized by randomness and uncertainty. Relational degree is a method for measuring the correlation between things or factors. It provides a quantitative means to describe a process or occurrence of an event, essentially conducting a quantitative analysis of the event. If the trends of change in things or factors are highly consistent, it can be concluded that the correlation between them is strong;

conversely, if the trends are inconsistent, the correlation is weak. Compared with other comprehensive evaluation methods, Grey Relational Analysis requires less data, has lower data requirements, and is based on a simple principle that is easy to understand and master. Meanwhile, this study employs the entropy method, which is more objective, to calculate the weights of indicators. Entropy is a measure of quantitative uncertainty; the lower the uncertainty of the sample, the smaller the entropy value, and vice versa. Based on this, according to the differences in the uncertainty of indicators, the weights of each performance evaluation indicator are calculated using the tool of information entropy and incorporated into the evaluation system to provide a basis for performance evaluation.

The Grey Relational Analysis model constructed in this thesis identifies an ideal optimal sample from nine years of data from Company M. This optimal sample consists of the maximum values of positive indicators and the minimum values of negative indicators, which serve as the reference sequence. By calculating the relational degrees between each sample sequence and the reference sequence, the model makes a comprehensive comparison and ranking of the evaluated objects, and the overall situation of the relational degrees is used to make the evaluation.

(1) Determination of the Reference Sequence

Let there be *m* objects to be evaluated, each with *p* evaluation indicators. Based on the economic significance of each evaluation indicator, the optimal value of each indicator is selected from the *m* objects to form the reference sequence:

$$x_0 = \{x_{01}, x_{02}, \ldots, x_{0p}\}，\ i=1,2,\ldots,m.$$

(2) Dimensionless Data Processing

Due to the influence of different dimensions and orders of magnitude of the evaluation indicators, comparability among the indicators is not feasible. Therefore, it is necessary to perform dimensionless processing on the actual values of each indicator. That is:

$$x_{ij} = \frac{x_{ij}}{x_{0j}} (i = 1,2, \ldots, m; j = 1,2, \ldots, p)$$

(3) Calculation of correlation coefficients

First, the absolute difference sequence between each evaluated object sequence and the optimal reference sequence has to be calculated. The formula is as follows：$\Delta_{ij}= \left|x_{ij} - 1\right| (i = 1,2, \ldots, m; j = 1,2, \ldots, p)$，On this basis, according to the formula:$\Delta(max) = maxmax\Delta_{ij}(k)$，$\Delta(min) = minmin\Delta_{ij}(k)$，the maximum difference $\Delta(max)$ and the minimum difference Δ(min) between the two levels can be obtained. Subsequently, the relational coefficient between the *i*-th evaluated object and the optimal reference sequence can be calculated:

$$\zeta_{ij} = \frac{\Delta(min) + \rho\Delta(max)}{\Delta_{ij} = \rho\Delta(max)}$$

Herein, ρ denotes the distinguishing coefficient, which takes a value within the interval [0,1]. In practical applications, it is generally set that ρ = 0.5

(4) Calculation of Indicator Weights Using the Entropy Method

Let there be *M* objects to be evaluated, with *N* evaluation indicators for each object. The indicator values for each evaluated object are represented by a vector, thereby obtaining the original evaluation matrix as follows:

$$X = (x_{ij})_{M\times N} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1N} \\ x_{21} & x_{22} & \cdots & x_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ x_{M1} & x_{M2} & \cdots & x_{MN} \end{bmatrix}$$

In the first step, data normalization is conducted. For negative indicators, where a smaller value is preferable, the specific processing is carried out according to the following formula:

$$k_{ij} = \frac{max\{X_{ij}\} - X_{ij}}{max\{X_{ij}\} - min\{X_{ij}\}}$$

For positive indicators, where a larger value is preferable, the specific processing is carried out according to the following formula:

$$k_{ij} = \frac{X_{ij} - min\{X_{ij}\}}{max\{X_{ij}\} - min\{X_{ij}\}}$$

After the aforementioned standardization, the normalized matrix of the new indicators is obtained as follows:

$$X_y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1N} \\ y_{21} & y_{22} & \cdots & y_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ y_{M1} & y_{M2} & \cdots & y_{MN} \end{bmatrix}$$

In the second step, after data normalization, the entropy e_j and weight ω_j for each indicator are calculated, with the specific process as follows:

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{M} x_{ij}}$$

Secondly, the entropy e of the j th indicator is calculated, using the following formula:

$$e_j = -\frac{1}{\ln(M)}\sum_{i=1}^{M} p_{ij}\ln(p_{ij})$$

Which $\frac{1}{\ln(M)} > 0$， $e_j > 0$.

Subsequently, the differentiation coefficient of the j-th indicator is calculated, with the formula presented as follows:

$$g_j = 1 - e_j$$

Finally, the weight of the j-th indicator is calculated. The entropy method is employed to determine the weight of each individual indicator, where ω_j represents the weight of the j-th indicator, with the formula given as:

$$\omega_j = \frac{g_j}{\sum_{j=1}^{N} g_j}$$

(5) The grey relational degree E_i is obtained, and the results are sorted accordingly, with the formula presented as follows:

$$E_i = \sum_{k=1}^{m} \omega_j(k)\, \zeta_{ij}(k) \ \ (k = 1,2, \dots, m)$$

5. Case Study Analysis of the Performance Evaluation of M Company's Green Supply Chain

5.1 Company Profile

Company M is a global publicly-listed manufacturing enterprise primarily engaged in the production and manufacturing of home appliances and their supporting products. It operates in the production and operation of household electrical appliances, electric motors, and their components. It is a manufacturing technology group involved in the import and export, wholesale, and processing of home appliances, raw materials for home appliances, and spare parts, as well as in the business of robots and automation systems. The core products include the manufacturing of home appliances and the service business of robots and automation systems. Over the past five years, the company has invested nearly 50 billion yuan in research and development funds. It has been listed in the Fortune Global 500 for several consecutive years and has more than 400 million users worldwide.

5.2 Data Dimensionless Processing

Prior to conducting the evaluation, given that the indicators vary in terms of content, form, range of values, and units, it is essential to first apply a formula to perform dimensionless processing on each indicator. Data dimensionless processing refers to the standardization and normalization of indicator data through specific mathematical methods, transforming the originally disparate indicators into a relatively unified evaluation value to eliminate the impact of different dimensions among the indicators. Dimensionless processing of the indicator data renders the performance evaluation in this paper more scientific and valuable. After obtaining the dimensionless data, the entropy method is employed to determine the weights of the indicators. The entropy weight method can avoid the interference of subjective human factors in the determination of indicator weights, ensuring the objectivity of the evaluation process and results. Following the dimensionless processing of the original indicator data and the calculation of the entropy weight indicator weights, the data is weighted and subjected to grey relational analysis to obtain the grey relational coefficient matrix.

5.3 Calculation of Grey Relational Degree

The grey relational degree for each year is calculated through grey relational analysis, and the results are ranked accordingly, as shown in Table 3:

Table 3. Table of Grey Relational Degree Ranking for Performance Evaluation Indicators of Company

Years	Relevance	Ranking
2013	0.846	1
2014	0.793	2
2015	0.784	3
2016	0.766	6
2017	0.768	4
2018	0.763	7
2019	0.745	9
2020	0.754	8
2021	0.767	5

The relational degree refers to the similarity between each evaluation item and the “reference value” (parent sequence). It is obtained through the average connection between these evaluation items and the “reference value” (parent sequence). This relational degree ranges between 0 and 1. The greater the relational degree, the closer the connection between the evaluation item and the “reference value” (parent sequence), and thus, the higher the evaluation. Finally, based on the magnitude of the relational coefficients, the evaluation items are ranked to determine their relative merits. In this thesis, the parent sequence is the ideal reference value for the performance of M Company’s green supply chain. The relational degree is used to evaluate and rank the performance of M Company’s green supply chain over nine years. The relational degree value lies between 0 and 1; the higher this value, the stronger the correlation with the “reference value” (parent sequence), which implies a higher evaluation. As can be seen from the table above: for the nine evaluation items, the performance evaluation of M Company’s green supply chain in 2013 is the highest (relational degree: 0.846), followed by 2014 (relational degree: 0.793), while the year with the lowest performance evaluation is 2019.

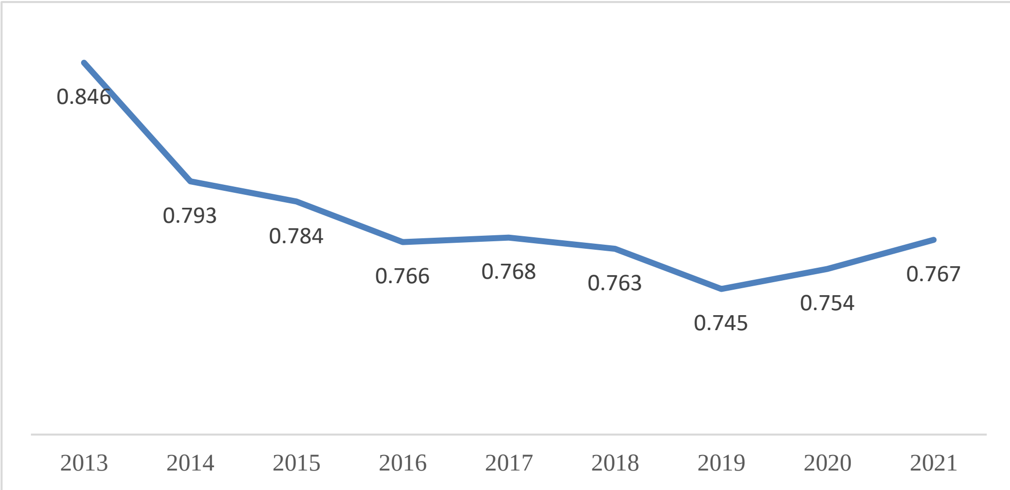

Figure 1. Line Chart of Grey Relational Degree Trend for M Company from 2013 to 2021

As can be observed from the figures and tables, the performance evaluation of M Company's green supply chain from 2013 to 2021 demonstrates an overall trend of initially decreasing and then increasing. This trend is closely related to the corporate strategies implemented by M Company and the broader macroeconomic environment in China.

5.4 Analysis of Evaluation Results

From the model calculations presented above, we can derive the overall performance evaluation of M Company's green supply chain from 2013 to 2021. Similarly, the grey relational degree can be calculated for the first-level indicators within each criterion layer of M Company's green supply chain performance evaluation index system, resulting in Figure 2.

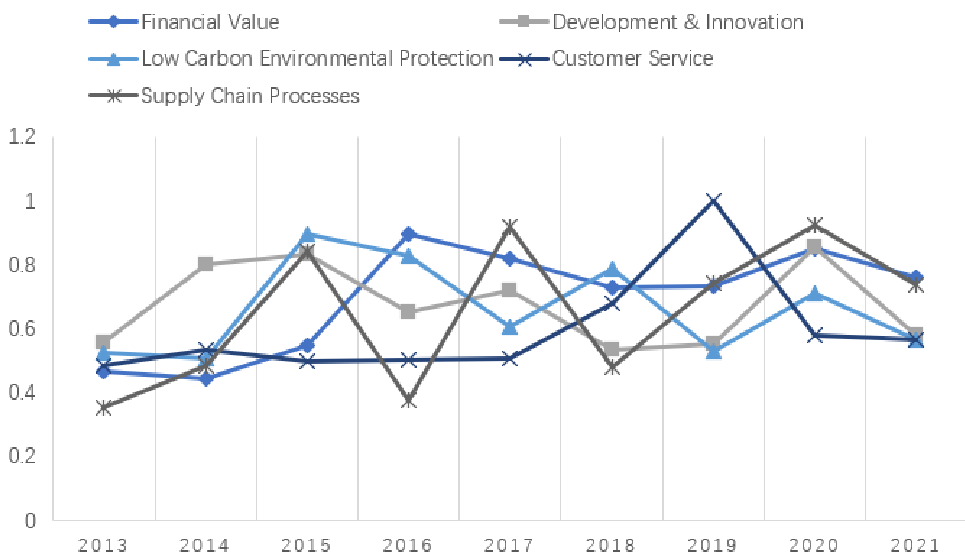

Figure 2. Graph of Correlation Coefficients of Level 1 Indicators of Performance Evaluation of Company M

As can be observed from the aforementioned figures and tables, in the performance evaluation of M Company's green supply chain, all five first-level indicators exhibit fluctuations. However, when comparing the final year, 2021, with the initial year, 2013, there is an overall upward trend. Moreover, starting from 2020 and 2021, the five first-level indicators begin to show a gradual convergence in their changing patterns. In contrast, during the earlier period from 2013 to 2019, each first-level indicator displayed distinct variations.

5.5 Research Implications

After conducting the performance evaluation of M Company's green supply chain, it is evident that the company's emphasis on green supply chain construction is still relatively low. Although M Company has begun to gradually increase its focus, the late start has resulted in an unsatisfactory overall performance at the current stage. Of course, the late start is a common issue among Chinese manufacturing enterprises and is not unique to M Company. Combining the case analysis in this chapter with the current status of M Company's green supply chain construction, this paper proposes three recommendations to assist manufacturing enterprises, represented by M Company, in the construction of their green supply chain systems.

(1) Increase Financial Investment. Implementing a green supply chain is not an easy task. It requires enhancing and perfecting the overall level of green practices within M Company. This includes equipping advanced production equipment and facilities, improving production technologies, and strengthening innovation capabilities. These processes necessitate adequate funding. Therefore, M Company should increase its investment in energy conservation and emission reduction to ensure sufficient financial resources for production activities.

(2) Enhance Green Management and Innovation Capabilities. In terms of management, M Company needs to establish a concept of green development and create an atmosphere of green growth within the enterprise. Managers should have a forward-looking vision and be willing to innovate in management practices. The concept of green development should be integrated into the stages of setting goals and designing products.

(3) Strengthen Supply Chain Stability. From the fluctuations in M Company's supply chain process indicators, it is evident that this indicator experiences significant annual changes, with variations notably higher than those of the other four indicators. This is due to the lack of stability in the company's supply chain. Therefore, M Company should take measures to enhance the stability of its supply chain. For example, it could invest in key upstream and downstream supplier nodes to ensure timely supply. Additionally, when selecting suppliers for long-term cooperation, M Company should establish a set of evaluation criteria or systems tailored to its needs for choosing green suppliers. This will enable the company to assess and evaluate suppliers, ultimately selecting the best green suppliers.

6. Conclusion of the Study

Through an in-depth analysis of the actual situation of Company M, this study has constructed a targeted performance evaluation index system for the green supply chain of manufacturing enterprises. By integrating multiple methods, including the entropy method and grey relational analysis, this research not only effectively evaluates the performance of the green supply chain but also provides a scientific basis for the sustainable development of manufacturing enterprises. Specifically, based on the constructed evaluation system, this paper conducts a performance evaluation and analysis of Company M. On the basis of the designed performance evaluation index system for manufacturing enterprises, the performance evaluation index data of Company M were collected. Utilizing the green supply chain performance evaluation model constructed based on the entropy method and grey relational analysis, the performance indicators of Company M were calculated and analyzed, thereby yielding corresponding evaluation results that provide strong support for the company's strategic decision-making.

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