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Research on the Application of Green Supply Chain Management: Based on SCOR Model

Xinye Fu[1,a] ,Chen Lin[2,b], Xinyi Ma[3,c,*]

[1]*School of Civil and Environmental Engineering, Nanyang Technological University, 50 Nanyang Ave, Singapore*

[2]*School of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Jiangjun Rd, Nanjing, China*

[3]*School of Business and Administration, Jimei University, Yinjiang Rd, Xiamen, China*

a. xfu012@e.ntu.edu.sg, b. 18206113303@nuaa.edu.cn, c. maxma@jmu.edu.cn

**corresponding author*

Abstract: This paper takes Apple Inc. as the research object and explores the green supply chain management issues based on the SCOR model. By combining the SCOR model through the theoretical framework and the characteristics of Apple's supply chain, management practice suggestions are made to reveal Apple's green performance in terms of environment, resources, and social responsibility. The study results show that Apple performs better in green procurement and marketing, but is slightly inferior in green recycling storage, and transportation. This provides valuable ideas for Apple's subsequent industrial sustainable development strategy, as well as lessons and references for other companies and industries, helping to promote the green development of the entire supply chain industry. In the future, it will be a key area to continue in-depth research on promoting and optimizing green supply chain practices in different industries and enterprises of different sizes.

Keywords: Green supply chain management, SCOR model, Apple Inc.

1. Introduction

Industrial civilization has promoted the rapid progress of human material life, but it has also brought about practical problems of environmental pollution. Nowadays, green development has become the consensus of economic growth in various countries, as well as for enterprises. Integrating green elements into traditional supply chain management ideas is a necessary measure for enterprises to achieve sustainable development. At present, the research on green development of enterprises mainly focuses on supply chain efficiency and cost management but ignores the monitoring and improvement of carbon emissions and sustainability in the supply chain[1]. Apple has been committed to promoting environmental protection measures in all aspects of its supply chain.

According to its latest environmental progress report, Apple's environmental protection projects have reduced carbon emissions in all ranges by more than 28 million tons in 2022. Since 2015, revenue has increased by more than 68 %, but total emissions have decreased by more than 45 %. Apple continues to expand the scope of emissions in the operating carbon footprint based on carbon neutrality in the company's operations. Now, home office, third-party cloud services, transmission and distribution losses, and the upstream impact of fuel have also achieved carbon neutrality.

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In terms of resource utilization, 20 % of the materials in Apple's products come from recycled or renewable resources; the plastic used in product packaging was only 4 %, which was significantly lower than 21 % in 2015. Three centers and 17 supplier plants have been accredited by the International Union for Sustainable Water Management standards; the waste conversion rate of the company's facilities has increased to as much as 71 %.

In a more advanced chemical process strategy, Apple conducted a toxicological assessment of more than 1,300 materials aimed at proactively eliminating potentially harmful substances in products; its IPC working group participated in the development and release of new IPC industry standards using safer cleaners; chemical composition data of more than 47,000 materials have been collected.

Taking Apple as the research object, this paper discusses the issue of green supply chain management based on the SCOR model, combs the SCOR model through the theoretical framework, and puts forward management practice suggestions combined with the characteristics of Apple's supply chain, to reveal Apple's green performance in environment, resources, and social responsibility. This study is helpful in providing new ideas and methods for enterprises and promoting the promotion of green supply chain management.

2. Literature Review

Currently, scholars at home and abroad have conducted research in various industries about the use of SCOR models in green supply chains.

Jianan Li used hierarchical analysis and fuzzy comprehensive assessment method to assess the existing supply chain greenness of GX Pharmaceuticals and focus on the analysis, to improve the links of the green supply chain and their interconnections and activities, and to put forward the safeguard measures such as constructing a green enterprise culture, strengthening the green supply chain cooperative relationship, and optimizing the logistics and distribution[2]. Qiyin Li[3] combined the SCOR model and expert questionnaire survey method, and designed the management model for the six links of design, procurement, logistics, production, distribution, and recycling respectively through the results of qualitative typing, and introduced the Six Sigma model and the six sigma management method to put forward the optimization plan of the green supply chain and the safeguard plan of Enterprise A. Arjun et al.[4] used a green supply chain management metrics system to discover the importance of employee management in agriculture in relation to environmental requirements and its significant impact on supply chain performance, which has implications for the development of performance measures for other similar companies. U Effendi et al.[5] used SCOR modeling and DEMATEL to conclude that improvements were made to PG Krebet Baru Company to prioritize making improvements in hazardous substance reduction, worker and environmental hygiene, product handling, and packaging reuse. Zahed Ghaderi et al.[6] used structural equation modeling for data analysis and explored the significant positive impact of green supply chain management (GSCM) internal and external measures on the reduction of environmental costs in hotels, leading to a significant impact of reducing environmental costs on green supply chain agility, resilience, and performance to have a direct impact. Vipul Jain et al.[7] combined the SCOR model with NGT and BWM approaches to construct an integrated performance management system and found that cost, quality, and green scores are the key factors for the sustainability of the e-waste supply chain. Masayu Rosyidah et al.[8] derived from the green SCOR model that green supply chain management can be enhanced in the palm oil industry in terms of sustainable cultivation, minimization of waste oil and GHG emissions, maximizing the use of new renewable energy sources and waste to improve the competitiveness of the firm.

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3. Steps and Process of the Study

3.1. Evaluation Methods Explored

Research on evaluation methods has gone through three main stages of development: qualitative methods, quantitative analysis, and a combination of qualitative and quantitative analysis. Quantitative analysis is easy to use, but because it is more subjective, the conclusions drawn are more abstract and less accurate than traditional quantitative analysis. Although qualitative methods are more accurate and reliable in analysing problems, they are cumbersome due to the arithmetic process and require a high degree of accuracy in the data processing. Therefore, a combination of qualitative and quantitative methods is currently used. The main assessment methods include Analysis of Hierarchy (AHP) an effective multi-principle assessment scheme invented by T.L. Saaty, an American operations research scientist, in the 1970s. Fuzzy Comprehensive Evaluation (FCE) is a comprehensive evaluation method for a target system containing a large number of fuzzy elements. Based on the characteristics of the above two methods, this paper combines the two methods and adopts fuzzy hierarchical analysis to study Apple's supply chain.

3.2. Hierarchy of Evaluation Objects and Determination of Relative Weights of Indicators

This paper adopts a hierarchical fuzzy evaluation method to study the greenness of Apple's supply chain. The specific steps are as follows.

(1) Hierarchy of evaluation audiences

By reviewing the information to establish Apple's green supply chain greenness assessment indicators, the detailed information is shown in Table 1 Apple's supply chain evaluation indicators.

Table 1: Apple's supply chain evaluation indicators.

Level 1 indicators	Level 2 indicators
A Green procurement	A_1 Vendor selection assessment
	A_2 Supplier quality management
	A_3 Vendor on-time delivery rate
	A_4 Supplier Environmental Qualifications
B Green storage and transport	B_1 Logistics information system
	B_2 Logistics tools
	B_3 Packaging rationality
	B_4 Storage environment
C Green Marketing	C_1 Consumer green identity
	C_2 Market share
	C_3 Consumer satisfaction
	C_4 Consumer loyalty
D Green Recycling	D_1 Level of returns processing
	D_2 Natural degradability of products
	D_3 Environmental friendliness of packaging
	D_4 Recyclability of phased-out products

(2) Determination of evaluation sets and score sets

According to the relevant national and industry technical standards, this paper sets the greenness evaluation set of Apple's green supply chain as the following five criteria: V={V1, V2, V3, V4, V5} = {poor, low, medium, good, excellent}. The corresponding branch vector, i.e., score set, is P=(20, 40, 60, 80, 100).

(3) Determination of relative weights of evaluation indicators

① Creating a weighting judgment matrix, details are shown in Table 2.

Table 2: Evaluation of the relative importance of indicators.

scale value	Meaning of Scale Values
1	Comparison of the two indicators, both of which are of equal importance
3	When comparing the two indicators, the former is slightly more important than the latter.
5	When comparing the two indicators, the former is significantly more important than the latter
7	Comparing the two indicators, the former is more strongly important than the latter
9	Comparison of the two indicators, with the former being extremely more important than the latter
2, 4, 6, 8	denote the intermediate values of adjacent judgments 1-3, 3-5, 5-7, 7-9 respectively

Construct the judgement matrix according to the scale:

$$R = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

(4) This judgement matrix satisfies: aij > 0; aij = 1/aji; aij = 1 (i = j)

② Calculation of relative weights from the judgment matrix.

Compute the geometric mean of the elements of each row of the judgment matrix.

$$G_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}}, i = 1,2,\cdots,n \tag{2}$$

Normalising G = (G1, G2, ··· , Gn) ^{T}

$$W_i = G/\sum_{i=1}^{n} G_i \tag{3}$$

Normalising G = (G1, G2, ··· , Gn) ^{T}

③ Calculate the consistency metrics of the judgment matrix and test its consistency.

Calculate the maximum eigenvalue

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(TW)_i}{nW_i} \tag{4}$$

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Calculation of the consistency indicator CI

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{5}$$

Calculation of the consistency ratio CR

$$CR = \frac{CI}{RI} \tag{6}$$

When CR < 0.1, the consistency of the judgment matrix is generally considered acceptable. When the judgment matrix is inconsistent (i.e., CR ≥ 0.1), the judgment matrix needs to be corrected to give satisfactory consistency. The sum of the weighting coefficients for each level is obtained by calculating the results. The results are shown in Table 3.

Table 3: Index calculation result.

Level 1 indicators	weighting at the first level	Level 2 indicators	Level 2 weights	Total secondary weights
A Green procurement	α	A_1 Vendor selection assessment	α1	α*α1
		A_2 Supplier quality management	α2	α*α2
		A_3 Vendor on-time delivery rate	α3	α*α3
		A_4 Supplier environmental qualifications	α4	α*α4
B Green storage and transport	β	B_1 Logistics information system	β1	β*β1
		B_2 Logistics tools	β2	β*β2
		B_3 Packaging rationality	β3	β*β3
		B_4 Storage environment	β4	β*β4
C Green Marketing	θ	C_1 Consumer green identity	θ1	θ*θ1
		C_2 Market share	θ2	θ*θ2
		C_3 Consumer satisfaction	θ3	θ*θ3
		C_4 Consumer loyalty	θ4	θ*θ4
D Green Recycling	ω	D_1 Level of returns processing	ω1	ω*ω1
		D_2 Natural degradability of products	ω2	ω*ω2
		D_3 Environmental friendliness of packaging	ω3	ω*ω3
		D_4 Recyclability of phased-out products	ω4	ω*ω4

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3.3. Fuzzy Relationship Matrix Establishment and Critique

Through the above evaluation analysis, the weights corresponding to each indicator are obtained, and the following will combine the knowledge of the fuzzy analysis method to provide a comprehensive evaluation of the greenness of Apple's green supply chain.Establishment of fuzzy relationship matrix as Table 4.

Table 4: Fuzzy relation matrix.

Level 1 indicators	Level 2 indicators	superior	very much	middle	lower (one's head)	differ from
A Green procurement	A_1 Vendor selection assessment	Γ1	Γ2	Γ3	Γ4	Γ5
	A_2 Supplier quality management	Γ6	Γ7	Γ8	Γ9	Γ10
	A_3 Vendor on-time delivery rate	Γ11	Γ12	Γ13	Γ14	Γ15
	A_4 Supplier Environmental Qualifications	Γ16	Γ17	Γ18	Γ19	Γ20
B Green storage and transport	B_1 Logistics information system	Γ21	Γ22	Γ23	Γ24	Γ25
	B_2 Logistics tools	Γ26	Γ27	Γ28	Γ29	Γ30
	B_3 Packaging rationality	Γ31	Γ32	Γ33	Γ34	Γ35
	B_4 Storage environment	Γ36	Γ37	Γ38	Γ39	Γ40
C Green Marketing	C_1 Consumer green identity	Γ41	Γ42	Γ43	Γ44	Γ45
	C_2 Market share	Γ46	Γ47	Γ48	Γ49	Γ50
	C_3 Consumer satisfaction	Γ51	Γ52	Γ53	Γ54	Γ55
	C_4 Consumer loyalty	Γ56	Γ57	Γ58	Γ59	Γ60
D Green Recycling	D_1 Level of returns processing	Γ61	Γ62	Γ63	Γ64	Γ65
	D_2 Natural degradability of products	Γ66	Γ67	Γ68	Γ69	Γ70
	D_3 Environmental friendliness of packaging	Γ71	Γ72	Γ73	Γ74	Γ75
	D_4 Recyclability of phased-out products	Γ76	Γ77	Γ78	Γ79	Γ80

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The weights W of each indicator obtained through the hierarchical analysis method and the fuzzy relationship matrix R of the evaluated object are synthesized to obtain the overall judgment vector of the indicators.

$$B = W \times R = (W_1, W_2, \cdots, W_n) \times \begin{bmatrix} r_{11} & \cdots & r_{1m} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{nm} \end{bmatrix} \tag{7}$$

To visualize the greenness of the enterprise's green supply chain, the greenness evaluation value is divided into grades. According to the description of evaluation indexes in the evaluation set, it will be used as the greenness grading standard, as shown in Table 5.

Table 5: Green rating.

Greenness Judgment level	superior	very much	middle	lower (one's head)	differ from
quantifiable numerical value	80-100	60-79	40-59	20-39	0-19

4. Analysis of the Results of the Study

The above calculation shows the score of Apple's green supply chain greenness evaluation from the four process segments of the individual scores that can be analyzed to suggest improvement measures for Apple's green supply chain.

Relative weight results and consistency test results calculated by judgment matrix, shown in Table 6 each part of Ahp evaluation results.

Table 6: Level 1 indicators evaluation results.

	A	B	C	D	Corresponding feature vector weights	Maximum characteristic root λMax	consistency test
A	1	4	3	1/2	0.36	4.20	$CI = \frac{\lambda_{max} - n}{n-1}$
B	1/4	1	2	1/2	0.16		0.07
C	1/3	1/2	1	1/4	0.09		$CR = \frac{CI}{RI}$
D	2	2	4	1	0.39		0.07
	a1	a2	a3	a4	Corresponding feature vector weights	Maximum characteristic root λMax	consistency test
a1	1	6	2	1/3	0.35	4.26	$CI = \frac{\lambda_{max} - n}{n-1}$
a2	1/6	1	1/4	1/4	0.06		0.09
a3	1/2	4	1	1/2	0.22		$CR = \frac{CI}{RI}$
a4	3	4	2	1	0.37		0.09

DOI: 10.54254/2754-1169/79/20241803

Table 6: (continued).

	b1	b2	b3	b4	Corresponding feature vector weights	Maximum characteristic root λMax	consistency test
b1	1	5	3	4	0.50	4.11	$CI = \frac{\lambda_{max} - n}{n - 1}$
b2	1/5	1	1/3	1/3	0.07		0.04
b3	1/3	3	1	2	0.25		$CR = \frac{CI}{RI}$
b4	1/4	3	1/2	1	0.18		0.04

	c1	c2	c3	c4	Corresponding feature vector weights	Maximum characteristic root λMax	consistency test
c1	1	4	3	5	0.52	4.12	$CI = \frac{\lambda_{max} - n}{n - 1}$
c2	1/4	1	2	3	0.25		0.04
c3	1/3	1/2	1	2	0.15		$CR = \frac{CI}{RI}$
c4	1/5	1/3	1/2	1	0.08		0.04

	d1	d2	d3	d4	Corresponding feature vector weights	Maximum characteristic root λMax	consistency test
d1	1	1/2	1/3	1/4	0.09	4.15	$CI = \frac{\lambda_{max} - n}{n - 1}$
d2	2	1	1/2	1/3	0.15		0.05
d3	3	2	1	1/4	0.26		$CR = \frac{CI}{RI}$
d4	4	3	4	1	0.50		0.06

The weights of the different indicators as well as the consistency indicators can be obtained by building a judgement matrix, and the weights obtained will help in the calculation of the subsequent fuzzy evaluation.

The sum of the results of the weighting coefficients of the indicators at each level is shown in Table 7.

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Table 7: Rating weight.

Level 1 indicators	weighting at the first level	Level 2 indicators	Level 2 weights	Total secondary weights
A Green procurement	0.36	A_1 Vendor selection assessment	0.35	0.126
		A_2 Supplier quality management	0.06	0.022
		A_3 Vendor on-time delivery rate	0.22	0.079
		A_4 Supplier environmental qualifications	0.37	0.133
B Green storage and transport	0.16	B_1 Logistics information system	0.50	0.080
		B_2 Logistics tools	0.07	0.011
		B_3 Packaging rationality	0.25	0.040
		B_4 Storage environment	0.18	0.029
C Green Marketing	0.09	C_1 Consumer green identity	0.52	0.047
		C_2 Market share	0.25	0.023
		C_3 Consumer satisfaction	0.15	0.014
		C_4 Consumer loyalty	0.08	0.007
D Green Recycling	0.39	D_1 Level of returns processing	0.09	0.035
		D_2 Natural degradability of products	0.16	0.062
		D_3 Environmental friendliness of packaging	0.26	0.101
		D_4 Recyclability of phased-out products	0.50	0.195

The results of the fuzzy relationship matrix are listed in Table 8.

Table 8: Results of fuzzy relation matrix calculation

Level 1 indicators	Level 2 indicators	supe rior	very much	mid dle	lower (one's head)	differ from
A Green procurement	A_1 Vendor selection assessment	0.17	0.31	0.35	0.12	0.05
	A_2 Supplier quality management	0.14	0.32	0.37	0.12	0.06
	A_3 Vendor on-time delivery rate	0.11	0.24	0.29	0.19	0.17
	A_4 Supplier Environmental Qualifications	0.16	0.36	0.27	0.18	0.03
B Green storage and transport	B_1 Logistics information system	0.17	0.35	0.22	0.19	0.07

DOI: 10.54254/2754-1169/79/20241803

Table 8: (continued).

	B_2 Logistics tools	0.17	0.32	0.22	0.21	0.08
	B_3 Packaging rationality	0.21	0.32	0.23	0.22	0.02
	B_4 Storage environment	0.17	0.35	0.19	0.21	0.08
C Green Marketing	C_1 Consumer green identity	0.24	0.44	0.18	0.14	0.04
	C_2 Market share	0.17	0.48	0.21	0.08	0.06
	C_3 Consumer satisfaction	0.18	0.45	0.24	0.07	0.06
	C_4 Consumer loyalty	0.11	0.45	0.33	0.08	0.03
D Green Recycling	D_1 Level of returns processing	0.19	0.26	0.45	0.06	0.04
	D_2 Natural degradability of products	0.15	0.27	0.48	0.08	0.02
	D_3 Environmental friendliness of packaging	0.22	0.18	0.44	0.12	0.04
	D_4 Recyclability of phased-out products	0.13	0.26	0.41	0.11	0.09

Table 9 (a) (b) indicates the score results of the fuzzy comprehensive evaluation and the score results of Apple’s supply chain.

Table 9 a: The score results of the fuzzy comprehensive evaluation.

B_1=	0.17	0.36	0.35	0.19	0.17	77.8
B_2=	0.21	0.35	0.21	0.22	0.07	71.8
B_3=	0.24	0.44	0.21	0.14	0.06	78.6
B_4=	0.21	0.26	0.41	0.12	0.09	73

Table 9 b: The score results of Apple’s supply chain.

R=	B_1=	0.14	0.29	0.28	0.15	0.14
	B_2=	0.20	0.33	0.20	0.21	0.06
	B_3=	0.22	0.40	0.19	0.13	0.06
	B_4=	0.19	0.24	0.38	0.11	0.08
B=	0.19	0.29	0.38	0.16	0.14	74.2

Through the fuzzy analysis method, we can conclude that the green procurement score is 77.8, the green storage and transportation score is 71.8, the green marketing score is 78.6, the green recycling score is 73, and the comprehensive score is 74.2. On the whole, its supply chain of Apple belongs to the middle to upper ranks of the industry in terms of green, and its green procurement and green marketing are higher while its green recycling and green storage and transportation scores are lower, which provides valuable ideas for the subsequent sustainable development strategy of the industry for Apple. This provides valuable ideas for Apple's subsequent industrial sustainable development strategy. Apple should continue to strengthen the recycling end of its supply chain, and in terms of warehousing, new green storage and transport technologies need to be developed.

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5. Conclusion

The evaluation results of Apple's supply chain greenness based on the SCOR model show that Apple has some advantages and practices in green supply chain management that are ahead of other enterprises. This proves that integrating green practices into the SCOR model can create a win-win situation for enterprises: not only improve supply chain efficiency but also reduce environmental impact. It highlights the importance of green supply chain management for enterprises, especially in the current urgent global demand for sustainable development. Apple's success story provides valuable lessons for other companies, demonstrating that strategic partnerships, investments in renewable energy, and product lifecycle management are critical to building sustainable supply chains.

In the future, continuing in-depth research on promoting and optimizing green supply chain practices in different industries and enterprises of different sizes will be a key area. In addition, enhancing cooperation and transparency in global supply chains and facilitating information sharing is also an important step towards more sustainable supply chain operations. Overall, this study highlights the potential of green supply chain management to enhance business competitiveness and drive environmental sustainability, and provides valuable guidance for future research and industry practice.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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