Research on Sustainable Supplier Selection and Evaluation of Q Communications Equipment Company Based on AHP

Jiayi Wei[1(✉)], Ping Xing[2(✉)], and Hengwei Xu[3(✉)]

[1] School of Economics, Ocean University of China, Qingdao, China
18120011029@stu.ouc.edu.cn
[2] School of Automotive Studies, Tongji University, Shanghai, China
1336997012@qq.com
[3] College of Economics and Management, Nanjing Agricultural University, Nanjing, China
16119209@njau.edu.cn

Abstract. Due to the rapid development of 5G networks, telecommunication products, which cater to service diversity, emerge at this historic moment. For telecommunication industries, under the pressure of stricter environmental policy and increasing production demands, green supplier selection is becoming more and more prominent. Although some studies have researched green supplier selection, the evaluation system index system is still in constant improvement and differs in individual selection scenarios, and its application in telecommunication industries has not been sufficiently studied in the existing methods. Collaborative innovation and supplier information visualization have aroused attraction in recent year. This article newly considered the two indexes in green supply chain management by the analysis on a median-sized telecommunication enterprise Q. Through the AHP method, the comparison matrix was established by the experts' grading method. Based on the weight results of each index, the two new indexes ranked later compared with basic ones but are still worth considering in supplier selection. For median-sized enterprises like Q, detailed indexes may not work and be counterproductive instead.

Keywords: sustainable supplier selection · communications equipment company · AHP

1 Introduction

In green supply chain management, outward collaboration was proved to be of great importance for solving environmental concerns and seeking precious external resources [1]. Green supplier collaboration (GSC) has attracted more and more researchers on its performance in recent years, which is identified as the cooperation between the focal firm and its suppliers in joint planning for green initiatives [2]. The beneficial influence

J. Wei, P. Xing and H. Xu—Contributed equally.

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of GSC affects both financial and environmental performance via increasing the level of information sharing [3].

The rapid construction of 5G networks and the popularization of the Internet plus brought a growth trend of energy consumption to the telecommunication industry in China, while the government strengthens its supervision on energy consumption, which urges the telecommunication enterprises to shift to green ones [4]. Thus, it can be seen that GSC plays an increasingly significant role in telecommunication enterprises. Different from the traditional supplier selection problem, which is mostly aimed at maximizing the interests of enterprises, the green supplier selection focuses much on comprehensive consideration [5]. The choice of green suppliers can both reduce the generation of pollutants from the source and bring economic benefits and competitive advantages to the enterprise, which is crucial to the company's development [6, 7].

Two new influence factors in the green supply chain, collaborative innovation, and supplier information visualization have been recently well-concerning focuses. As the information and communication technologies blossomed and the globalization of the world economy increased, green supply chain collaborative innovation (GSCCI) is becoming increasingly popular in companies for adequately addressing the emerging challenge of protecting the deteriorating environment while satisfying the changing demand of consumers along the supply chain [8]. GSCCI is about the utilization of specific advantages of individual organizations in a holistic manner along the supply chain through the collaboration for jointly solving green management problems [9]. Collaborative innovation is the major driver to create value, enhance competitiveness and attract consumers in supply chains [10]. As for information visualization, which can help companies to search for reliable partners that can supply or consume material in matching quality and quantity to form a sustainable supply chain, it has great value as humans are used to visual thinking for solving problems [11, 12]. However, few existing pieces of research focus on the functions of both collaboration innovation and information visualization in the supplier evaluation index system, especially in the emerging telecommunication industries.

2 Literature Review

2.1 Existing Research Results

The traditional supplier selection mainly focuses on the current economic benefits, and the criteria include price, quality, delivery time and services provided by the supplier [13]. In 2014, Kannan et al. followed these four criteria in terms of the sustainability of economic benefits [14]. In practical application, the situation of suppliers themselves is often considered. For example, the BSC system comprehensively examines organizational performance from four dimensions: finance, customer, internal operation, and learning and growth [15]. PRTM index system covers the dimension of "assets" of suppliers.

From the perspective of TBL, the green practices of supply chain management (SCM) will have a profound impact on the social, environmental, and economic sustainability of the supply chain [16]. At present, the evaluation of the environmental performance of the manufacturing supply chain mostly starts from the environmental pollution and

its treatment, the utilization of resources and energy, and the recycling of products. In addition, studies on the selection of electronic equipment suppliers take "hazardous material management" as one of the important indicators.

The concepts of supply chain agility and supply chain resilience were put forward in 1995 and 2004, respectively. The former refers to the ability to quickly respond to market demand and make a response [17], while the latter refers to the ability to withstand and recover from destructive events [18]. How can suppliers achieve supply chain agility and resilience? The Global Supply Chain Management Association (GSCM) believes that agility depends on a firm's flexibility in development, procurement, manufacturing and logistics; Bai believes that resilience depends on the responsiveness, resilience, and adaptability of suppliers [19].

You et al. argue that the sustainable supply chain (SSC) must consider long-term issues - including innovation capacity and close collaboration between companies [20]. In recent years, many studies have taken supplier innovation and R&D investment as important indicators of supplier evaluation. However, since no enterprise has all the internal knowledge [21], the collaborative innovation capability of suppliers deserves as much attention as its innovation input. The game caused by lack of cooperation will make supply chain enterprises fall into "Prisoner's Dilemma". In the case of a centralized decision, the overall profit can be optimal [22]. To build trust and cooperation, research in recent years has identified the "information visualization capability" of suppliers -- information sharing among chain partners [23], and showing this capability through information sharing, information platform, and organizational communication [24].

2.2 Shortcomings of Existing Research

At present, the academic community generally believes that sustainable suppliers should be committed to the economic and environmental benefits of the supply chain and improve the innovation and competitiveness of the supply chain through cooperation and have good flexibility and responsiveness. The research of supplier selection in specific industries has gradually applied the above characteristics of suppliers into practice. However, existing studies still have obvious deficiencies in sustainable supplier selection practices, which are mainly reflected in the following aspects:

1. The methods of suppliers to realize SSC have been expanded in recent years, such as information visualization and collaborative innovation, etc. However, the existing supplier selection and evaluation models lag the latest research results and do not consider such characteristics of suppliers.
2. Due to the particularity of the communication equipment manufacturing supply chain, the focus of SSCM is different from that of the general manufacturing industry, such as innovation and research and development, management of hazardous substances, and the impact on people and communities [25, 26]. At present, the research of supplier selection for communication equipment manufacturing adopts the index system for general manufacturing, without considering the particularity of this industry.
3. Due to uncertainties, shorter and tougher business cycles and the many crises in the global supply network in recent years, especially the COVID-19 worldwide in 2020,

the resilience and agility of supply chains are more emphasized [27–29]. Therefore, the weights of "flexibility and responsiveness" obtained in previous studies may not conform to current managers' expectations, nor apply to future practices.

2.3 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a classical multi-objective decision-making method, which is widely used in the research of supplier selection. By determining the weight of each index, it plays a guiding role for the SCM of enterprises. Li's research on the selection of medical device suppliers established an evaluation model composed of 4 first-level criteria and 8 s-level criteria, determine the weight of each index by AHP method, and finally determined the feasibility and practicability of the model through examples [30]. Therefore, for the study of sustainable supplier selection, the AHP method is applicable (Table 1).

3 Empirical Analysis on the Selection of Sustainable Communication Manufacturing Suppliers Based on AHP Method

3.1 Q Corporate Case Background

Q enterprise is a small and medium-sized private communications technology company that produces and sells communications equipment. Founded in 2000, its products and solutions cover the fields of mobile, broadband, IP, optical networks, network energy, telecommunications value-added services and terminals. The business volume of the company has continued to maintain steady and healthy growth for more than a decade. Up to now, Q company has several independent research and development products, deeply supported by consumers, in the industry also has a certain popularity and good brand image.

Different from the general industry, the sustainable supplier selection index of the communication manufacturing industry is also different from that of the ordinary manufacturing industry. Therefore, this paper further considers the treatment of harmful substances in the selection of indicators. Combined with A HP method, qualitative and quantitative indicators are combined to select sustainable suppliers.

3.2 AHP Method to Construct the Weight of Calculation Index

3.2.1 Building a Comparison Matrix

Based on the given evaluation index system, a pairwise comparison matrix $A = (a_{ij})$ n*n. 3 Based on the principle of sustainable development, improve economic efficiency and meet customer needs. In the synthesis of experts' opinions and the development of the enterprise itself, the comparative results are set from six aspects: delivery capacity, service level, cost control, product quality, development potential, and social responsibility (Table 2).

Table 1. Supplier Indicator System

Delivery capacity (B1)	Duration of lead time (C1)
	Order completion rate (C2)
	Delivery on time (C3)
Level of service (B2)	Flexibility (C4)
	After-sales service level (C6)
	Ability to respond (C7)
Cost control (B3)	Fixed costs (C8)
	Operating costs (C9)
	Inventory turnover (C10)
Product quality (B4)	Incidence of quality accidents (C11)
	Certification of Product Quality (C12)
	Ability to respond (C13)
Development potential (B5)	Investment rate of scientific research and innovation funds (C14)
	Return on assets (C15)
	Knowledge management system (C16)
	Employee satisfaction (C17)
	Collaborative innovation (C18)
	Visualization of vendor information (C19)
Social responsibility (B6)	Energy resource use (C20)
	Hazardous substances management (C21)
	Enterprise Environmental Certification (C22)
	Impact on local communities (C23)
	Green Product Design Investment Rate (C24)
	Product recyclability (C25)

3.2.2 Consistency Testing of Indicators

The eigenvectors of each comparison matrix are obtained w and the corresponding maximum eigenvalue λ_{max}. The corresponding consistency index $CI = \frac{\lambda_{max}-n}{n-1}$ are obtained, the corresponding average random consistency index value is found RI, and the corresponding consistency ratio $CR = \frac{CI}{RI}$ is calculated to check whether the C R value is not greater than 0.1 (Tables 3, 4, 5 and 6).

Table 2. Summary of Comparison Matrices

S1	B 1	B 2	B 3	B 4	B 5	B 6
B 1	1	5	3	3	7	9
B 2	1/5	1	2	3	7	6
B 3	1/3	1/2	1	2	8	3
B 4	1/3	1/3	1/2	1	4	8
B 5	1/7	1/7	1/8	1/4	1	2
B 6	1/9	1/6	1/3	1/8	1/2	1

S2	C 1	C 2	C 3
C 1	1	1/5	1/7
C 2	5	1	1/3
C 3	7	3	1

S3	C 4	C 5	C 6
C 4	1	1/5	1/9
C 5	5	1	1/2
C 6	9	2	1

S4	C 7	C 8	C 9
C 7	1	1/5	1/7
C 8	5	1	1/3

C 9	7	3	1

S5	C 10	C 11	C 12
C 10	1	3	5
C 11	1/3	1	7
C 12	1/5	1/7	1

S6	C 13	C 14	C 15	C 16	C 17	C 18
C 13	1	2	5	7	4	5
C 14	1/2	1	3	3	3	4
C 15	1/5	1/3	1	2	5	3
C 16	1/7	1/3	1/2	1	4	3
C 17	1/4	1/3	1/5	1/4	1	2
C 18	1/5	1/4	1/3	1/3	1/2	1

S7	C 19	C 20	C 21	C 22	C 23	C 24
C 19	1	3	2	5	7	9
C 20	1/3	1	2	4	7	9
C 21	1/2	1/2	1	3	4	7
C 22	1/5	1/4	1/3	1	3	3
C 23	1/7	1/7	1/4	1/3	1	7
C 24	1/9	1/9	1/7	1/3	1/7	1

Table 3. Average Random Consistency Index RI for Different Orders

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Table 4. Results of Consistency Tests for Indicators

	CI	CR
S1	0.1201	0.0969
S2	0.0324	0.0559
S3	6.17E-04	0.0011
S4	0.0324	0.0559
S5	0.022	0.038
S6	0.1203	0.0971
S7	0.1109	0.0894

3.2.3 Total Weights of Indicators and Analysis of Results

Table 5. Indicators Weights at All Levels

	Primary indicator weights		Secondary node weight	Total weight
Delivery capacity	0.4372	Length of lead time	0.0719	0.031435
		Order completion rate	0.279	0.121979
		Delivery on time	0.6491	0.283787
Level of service	0.2158	Flexible	0.066	0.014243
		After-sales service level	0.3187	0.068775
		Response capacity	0.6153	0.132782
Cost control	0.1575	Fixed costs	0.0719	0.011324
		Operating costs	0.279	0.043943
		Inventory turnover	0.6491	0.102233

(*continued*)

Table 5. (*continued*)

	Primary indicator weights		Secondary node weight	Total weight
Product quality	0.1225	Incidence of quality accidents	0.6612	0.080997
		Product quality certification	0.2718	0.033296
		Customer Complaint Rate	0.067	0.008208
Development potential	0.0365	Investment rate of scientific research innovation funds	0.4199	0.015326
		Return on assets	0.232	0.008468
		Knowledge management system	0.1418	0.005176
		Employee satisfaction	0.103	0.00376
		Collaborative innovation	0.0583	0.002128
		Visualization of Supplier Information	0.0451	0.001646
Social responsibility	0.0305	Use of energy resources	0.3943	0.012026
		Hazardous substances management	0.2618	0.007985
		Enterprise Environmental Protection Certification	0.1773	0.005408
		Impact on local communities	0.0822	0.002507
		Investment in green product design	0.0602	0.001836
		Product recyclability	0.0242	0.000738

Table 6. Results in Descending Order of Weights

Delivery on time	0.283787
Response capacity	0.132782
Order completion rate	0.121979
Inventory turnover	0.102233
Incidence of quality accidents	0.080997
After-sales service level	0.068775
Operating costs	0.043943
Product quality certification	0.033296
Length of lead time	0.031435
Investment rate of scientific research innovation funds	0.015326
Flexible	0.014243
Use of energy resources	0.012026
Fixed costs	0.011324
Return on assets	0.008468
Customer Complaint Rate	0.008208
Hazardous substances management	0.007985
Enterprise Environmental Protection Certification	0.005408
Knowledge management system	0.005176
Employee satisfaction	0.003760
Impact on local communities	0.002507
Collaborative innovation	0.002128
Investment in green product design	0.001836
Visualization of Supplier Information	0.001646
Product recyclability	0.000738

4 Conclusions

According to the evaluation index system and the total weight ranking calculation, Q enterprises pay more attention to the on-time delivery rate, response-ability, order completion rate, and inventory turnover rate of suppliers in the process of selecting suppliers. This is more in line with the requirements of general enterprises to select suppliers, as well as the choice of suppliers to improve economic efficiency, to meet customer needs.

Among the indicators of sustainability principles, enterprises attach the most importance to the use of energy resources of suppliers, the management of harmful substances, and the environmental certification of enterprises. Their differences are not very large, which can prove that enterprises attach great importance to sustainable development, energy development and resource consumption. The high attention to the management

of harmful substances shows that enterprises have a high sense of social responsibility for environmental protection.

As a small and medium-sized communication manufacturing enterprise, Q enterprise has a relatively backward level of enterprise ability and development. In this case, it is the most fundamental and important to ensure the most basic on-time delivery rate and order completion rate. For the reason of attaching importance to the supplier's response-ability, on the one hand, it is necessary to attach importance to the supplier's service quality; on the other hand, it is necessary to reduce the risk of the Q enterprise itself contact the supplier in time once any problems arise.

Comparatively speaking, the collaborative innovation, the visualization of supplier information, the investment rate of green product design and the recyclability of products are relatively low in the ranking of supplier selection indicators of Q enterprises. The reasons are as follows: first, the small weight value does not mean that the index is not important, but the basic index with higher weight is not important enough, but it still belongs to the factors that need to be considered in the selection of suppliers. Secondly, the environmental background of Q enterprises is that most suppliers still stay in the low utilization of resources, and there are many problems in energy pollution. Even some interested suppliers still do not get the enterprise environmental certification license. Under the condition that the level of development is not advanced enough, it is most important to attach importance to the most basic green production index. Comparatively speaking, similar to green product design investment rate and the capacity product itself recyclability is not so important. Finally, it is difficult to make the supplier's information fully visual and transparent when negotiating with the supplier, unless the supplier is willing to become a strategic partner with the manufacturing enterprise.

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