ISSN 2822-0412 (ONLINE)

SCSR
Supply chain and Sustainability Research

SCSR

SUPPLY CHAIN AND SUSTAINABILITY RESEARCH

VOL.3,No1;(Jan-Mar);2024

SOUTHEAST BANGKOK UNIVERSITY

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR

VOL.3, NO.1; JAN. – MAR.; 2024,

ISSN 2822-0412 (Online)

Supply Chain and Sustainability Research (SCSR) is an independently run non-profit journal dedicated to serve the worldwide scientific community through periodical of high-quality and high-impact scholarly, multi, and inter-disciplinary research that broadly resides in the arenas of supply chain and sustainability research. SCSR is committed to provide a platform that disseminates academic work, findings, and knowledge promptly, openly, and freely to all, and thus promote practical and public conversation and communication. By this, SCSR strives to be one of the important supply chain and sustainability journals in the world.

The Purpose: To support and encourage the writing of academic works. Disseminate academic works of faculty, academics and students both internally and externally as well as being a medium for education, research and dissemination of academic knowledge.

The goal is to serve as a hub for scholarly support, knowledge transfer, and dissemination. along with quality research The SCSR strives to publish insightful, innovative, and pertinent research that describes or may have an impact on management and/or innovation within the SCSR framework. Benefits to society, the community, and the country as a whole are frequently published in electronic journals by the SCSR. is diverse and interdisciplinary in character. The magazine accepts essays on all topics related to management as well as those relevant to innovation, regardless of discipline or subject area.

SCSR uses a “double-blind peer review system,” meaning that the authors do not know who the reviewers are, and the reviewers do not know who the authors are. All submitted manuscripts are to be reviewed by three expert reviewers per paper. Reviewers are chosen because of their expertise in the topic area and/or methodology used in the paper. Each article is judged based solely on its contribution, merits, and alignment with the journal’s mission. Should any revision be required, our instructions to authors are designed to move authors towards a successfully published article.

Periodicity: Four a year publication: 1) First Issue: January – December 2) Second Issue: April – June 3) Third Issue: July – September and 4) Four Issue: October – December.

Website: https://so08.tci-thaijo.org/index.php/SCSR/index

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ISSN 2822-0412 (Online)

Greetings from Editor-in-Chief: Supply Chain and Sustainability Review (SCSR)

The application of sustainability issues to supply chain management, logistics, transportation, and various optimization methods has been increasingly popular in recent years. One of the numerous issues that supply chain management encounters on an ongoing basis is operating in a sustainable manner. The goal of the SCSR is to investigate the use of sustainability in supply chain management, operation management, logistics, transportation, healthcare management, and fuzzy sets theory. The first issue of SCSR is to serve this purpose as how sustainable development must go hand in hand with logistics and supply chain management.

We invite academics from a variety of management-related disciplines to submit original, high-quality research papers that primarily address sustainability-management-related challenges and contribute to the SCSR's mission. The articles in the SCSR will emphasize both theoretical and empirical research. Literature reviews, conceptual theory development, qualitative survey research, such as case studies, and quantitative empirical methodologies may all be included in academic papers. SCSR rules must be adhered to by all submitted papers.

In view of current disruptions in global supply chains (e.g., chip crisis), the implications of supply chains for the climate and biodiversity discourse, new supply chain laws to increase social responsibility, and technological innovations (e.g., blockchain), supply chain management has become an imperative for global business.

In this issue, 6 research papers are presented.

(1) Southern China Airlines Service Quality Supply Chain and Customers' Satisfaction: A Practical Case Study

(2) Sustainable Finance Exploration: Analyzing the Impact of Environmental, Social, Governance (ESG) Information Disclosure in the Supply Chain

(3) Interplay Between Carbon Trading and Supply Chain Management: A Case Study of the Taiwan Carbon Exchange

(4) Exploring the Implementation of the 7Ps in Guangdong's MBA Education Programs: A Comprehensive Study

(5) An Academic Inquiry into ESG Strategy Communication and the Enhancement of Operational Control within the Supply Chain

(6) Hydrogen Energy Supply Chain: Production, Storage, and Applications – An Exploratory Study

In addition, we would like to inform you about our next issues (Volume 3 No.2,…) in 2024. Recent announcement of the call for papers is accessible on the SCSR website. This issue marks the debut of the

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SCSR and its birth. It is my pleasure to address you on this occasion. I would like to express a warm welcome to the SCSR readership on behalf of the SCSR Editorial Team. I would like to thank our authors, editors, and anonymous reviewers, who have all voluntarily contributed to the journal's success. Without your participation, this initial issue would not exist.

We look forward to receiving your contributions.

Jirasek Trimetsoothorn
Editor-in-Chief

Editorial Team

Editors

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VOL.3, NO.1; JAN. – MAR.; 2024, ISSN 2822-0412 (Online)

Southern China Airlines Service Quality Supply Chain and Customers' Satisfaction: A Practical Case Study

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Received: September 24, 2023 / Revised: November 4, 2023 / Accepted: March 26, 2024
Doi: 10.14456/scsr.2024.7

Abstract

The purposes of this research are: 1) To measure the service quality of China Southern Airlines. 2) To measure customers' satisfaction on flights with China Southern Airlines. 3) To explore the relationship between service quality and customer satisfaction for China Southern Airlines. The quantitative analysis method is applied in this research, based on the SERVQUAL model of perceived service quality theory, combined with the actual service quality of China Southern Airlines customers, according to five sub-dimensions (reliability, tangibility, assurance, responsiveness, and empathy). A sample size of 400 units of China Southern Airlines' customers was collected. The research instrument was a questionnaire with an overall reliability of 0.911 was found. The statistics used in data analysis included percentage, mean, standard deviation, and hypothesis testing Pearson's correlations.

The research results found that: 1) overall, the service quality of China Southern Airlines is valued at a good service (3.63 out of 5.00). In addition, the highest-rated aspect of service quality is reliability, followed by empathy. 2) This research indicates customers are generally satisfied with the service quality of Southern China Airlines (3.63 out of 5.00). 3) Finally, it is found that there is a significant relationship between SERVQUAL and customers' satisfaction with China Southern Airlines.

keywords: Service Quality, Satisfaction, Relationships, China Southern Airlines

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Introduction

Considering the aviation industry, it becomes evident that its fundamental nature is inherently service-oriented. One of the core missions of airlines is to provide services to passengers. Given that air travel is generally priced higher than other modes of transportation, people's expectations for service quality within the aviation industry are higher compared to other forms of travel. Therefore, in this sector, service can be regarded as a key factor contributing to the success of airlines. Some airlines might enjoy a stronger reputation in the market due to their service quality and passenger experience.

Measuring customer satisfaction in the airline industry is becoming ever more frequent and relevant due to the fact that the delivery of high-quality service is essential for airlines' survival and crucial to the competitiveness of the airline industry (Park et al., 2004).

Due to the quality of their services and the satisfaction of their customers, some airlines may have a better reputation in the market. Passengers' expectations for the caliber of public aviation services have increased as a result of the rapid development of public air transportation. The number of complaints regarding public aviation services is consistently on the rise as passenger awareness of their rights grows. As a result, there is constant pressure on the quality of these services. For domestic aviation enterprises, improving their core competitiveness in this new competitive climate becomes a critical challenge. Service quality has emerged as a crucial element in this competition due to its inclusion in the service industry (Li, 2019).

In the context of globalization, China Southern Airlines not only needs to maintain its leading position in the domestic market competition but also faces pressure from international aviation markets. This necessitates an even greater emphasis on improving its service quality to meet the demands of passengers from different regions. There are still some shortcomings in the passenger service operations of Chinese aviation companies when compared to internationally renowned airlines, despite the fact that domestic aviation companies in China are actively adjusting and optimizing their service systems based on passenger needs, leading to an evident improvement in service quality and passenger satisfaction compared to the past. There is a clear standardization of the customer experience, and different airlines find it difficult to distinguish their service brands. The system for evaluating service quality lacks scientific rigor and is unable to develop individualized service strategies that are differentiated based on the actual travel demands of passengers. The human touch is also lacking in service details, and service satisfaction is only slowly improving (Qin, 2021). Providing high-quality service is a crucial aspect for airlines to enhance passenger satisfaction and market competitiveness, necessitating the full attention of airline management.

Objectives

The purposes of this study are:

1) To measure the level of service quality of China Southern Airlines.

2) To measure the level of customer satisfaction on flights with China Southern Airlines.

3) To explore the relationship between service quality and customers' satisfaction with China Southern Airlines.

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Contributions

Researching and enhancing the quality of airline services has a positive impact on the company's operations, management, and employee teams. Particularly in the service-centric aviation industry, the quality of service is closely tied to the company's success. Improving the company's service quality management system can assist in better detection and management of potential issues, enhancing management efficiency and decision accuracy.

For the aviation industry, excellent service quality also signifies meeting consumer expectations and satisfaction, thereby enhancing the overall reputation of the industry and driving sales growth and market share expansion. Optimizing service quality contributes to market expansion. By providing exceptional service experiences, it not only increases passenger satisfaction but also stimulates sales growth and boosts market share.

The consumer satisfaction index can contribute to building a positive brand image, aiding the company in establishing trust and a favorable reputation. Positive brand image and high-quality service experience directly influence passengers' decisions in selecting an airline. Such decisions have a direct impact on enhancing market competitiveness and business growth.

Definitions

SERVQUAL is a widely recognized model for assessing service quality. It was developed by Parasuraman, Zeithaml, and Berry in 1985 and is often used in both the academic field and industry to measure and manage the quality of services (Parasuraman et al., 1985). This will address passenger service issues and enhance service quality.

In analyzing the passenger service issues of China Southern Airlines in this paper, research will also be developed based on the five dimensions of the SERVQUAL scale model:

“Tangibles” refers to the equipment and specific facilities used by airlines in carrying out their service activities. This dimension of service quality can be seen, touched, and felt by the customers.

“Reliability” primarily denotes the consistency of services provided by airlines, fulfilling service commitments accurately and on time. This dimension emphasizes very much on how the service system flows smoothly without interruption.

“Responsiveness” refers to the airline's ability to swiftly enhance service quality and level based on customer needs, providing timely service or accurate time estimates for service availability to ensure service efficiency, and how airline personnel respond to the needs of the passengers.

“Assurance” indicates that the services offered by the airline are trustworthy and come with a guarantee. The customers feel secure with the service of Airlines in terms of security, safety, comfort, and tertiary services.

“Empathy” indicates that the airline is capable of understanding customer needs and providing personalized services beyond customers’ satisfaction. Personalized services mean extra care, personally designed care and services customers receive with the flights.

Customer satisfaction can be viewed as an evaluation of the gap between actual experiences and expectations, encompassing both explicit, implied, or desired satisfaction or expectations. The concept of customer satisfaction first appeared in the field of marketing in the 1960s, introduced by Cardozo in 1965 (Cardozo, 1965). Howard and Sheth (1969) defined customer satisfaction as a "cognitive state of whether customers feel adequately compensated for the costs they have incurred."

Literature Review

The following literature will be investigated to ensure the research is adherent to theoretical models and constructs:

Service Quality

Evaluating service quality requires not only assessing consumers' judgments of the outcomes but also encompassing a comprehensive evaluation from the consumer's perspective throughout the service process. Gronroos (1982) proposed that service quality is determined by the alignment between customers' expected service and their actual service experience. Chen (2020) conducted a study on customer satisfaction with domestic airlines, emphasizing the impact of service quality on airlines. They argued that service quality directly affects consumer satisfaction and marketing quality. Airlines should focus on improving their service levels. Gronroos (1982) found in his research that marketing communication, word-of-mouth, image, and needs play a crucial role in shaping customers' service expectations, while the technical competence of service personnel and the functionality of service facilities are key factors influencing customers' service experiences.

Satisfaction

The concept of customer satisfaction first appeared in the field of marketing in the 1960s, introduced by Cardozo in 1965(Howard & Sheth, 1969). Howard and Sheth (1969) defined customer satisfaction as a "cognitive state of whether customers feel adequately compensated for the costs they have incurred." Westbrook and Reilly (1983) viewed customer satisfaction as an "affective response generated by the psychological impact of the product presentation and shopping environment during the purchase process." Kotler (1991) described customer satisfaction as a "feeling that arises when an individual compares the perceived effects of a product with their expectations." Hunt (1977) defined customer satisfaction as the "evaluation made when consumption experiences match or exceed expectations." Tse and Wilton (1988) considered customer satisfaction as the "evaluation of the difference between the expected quality formed before purchasing a product and the perceived quality after consumption."

SERVQUAL

The SERVQUAL (Service Quality) assessment framework is frequently used in evaluating service quality. The SERVQUAL model is currently the most widely applied theoretical model in the field of service quality research, providing a significant and insightful tool for studying service quality, and laying an important foundation for subsequent research, making it undoubtedly the preferred choice in our field of study on service quality. In 1985, Parasuraman, Zeithaml, and Berry (Parasuraman et al., 1985) built upon Gronroos' customer-perceived service quality model to redefine service quality. They proposed that the level of service quality is

essentially the gap between customers' expectations of service and their actual service experience. A smaller gap indicates higher service quality, while a larger gap suggests lower service quality.

Related Research

With the emergence of a service-oriented economic society, the aviation sector, which is a part of the service economy, would bring intense rivalry. Following the price war, the majority of domestic aviation companies have come to the realization that, in addition to enhancing service quality and understanding customer needs, they must also be dedicated to enhancing customer satisfaction. This is because, in the competitive landscape of the entire service industry, achieving these goals is essential for ensuring the long-term growth of their clientele (Wang, 2018).

Customer happiness is significantly impacted by the quality of airline services, according to research (Xiong, 2017). Additionally, she thinks that customer pleasure primarily hinges on the caliber of the airline's services and that passenger contentment with an airline directly influences the airline's ability to grow in a long-term, stable, and healthy manner. Enhancing the quality of service provided to customers can turn them into the company's most devoted patrons, which is a prerequisite for airlines' long-term growth.

According to Yu and Li (2010), consumer satisfaction is positively impacted by perceived value and the quality of aviation services, but negatively impacted by negative emotions. Simultaneously, good emotions influence perceived value, which in turn influences consumer satisfaction. The aforementioned findings demonstrate that customer happiness is significantly impacted by both consumer sentiment and the caliber of airline services.

Mao and Zhu (2010) conducted a quantitative analysis using satisfaction indicators to determine the effects of different variables on customer satisfaction. They found that the greatest influence on customer satisfaction is "perceived service quality" from the customer, followed by corporate image, which suggests new directions for strategic adjustments by airlines. guideline.

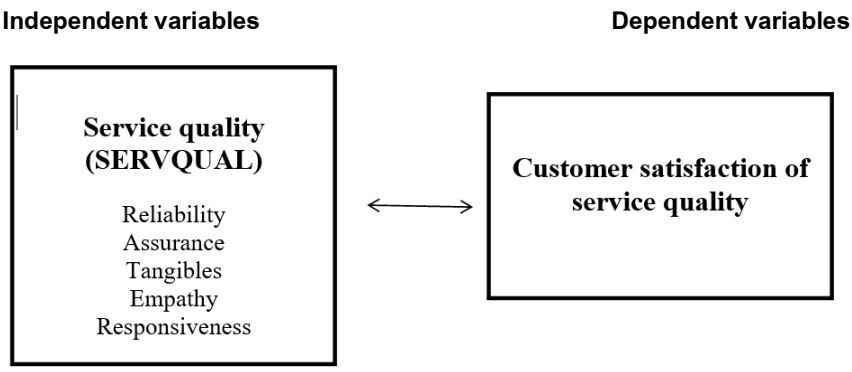

Figure 1 Conceptual framework

Research Methodology

The overall participants of this study were passengers who had flown with China Southern Airlines. A sample of 400 passengers who had flown with the airline at least once or multiple times within the past year was selected using a simple random sampling method.

Slovin's (1960) formula calculates the number of samples required when the population is too large to directly sample every member. As the following chart shows, once your population is large enough, boosting your sample size does little (or nothing) to increase accuracy

$$n = \frac{N}{1 + Ne^2}$$

N = Population Size

e = Margin of Error

n = Sample size

Set up Margin of Error, 95% confidence interval 5% margin of error; plug data into the formula, when the population size (N) is larger, the number of sample size (n) tends to be but does not exceed 400.

This study collected data through a questionnaire survey. The survey will be conducted by using the online survey platform "Questionnaire Star" and questionnaires will be randomly distributed to consumers who have traveled with China Southern Airlines during the past one year (June 2022 – June 2023).

Part 1: A questionnaire containing basic information about customers who had flown with China Southern Airlines at least once or multiple times within the past year. This section included questions about the respondent's gender, age, income, and other personal details.

Part 2: A questionnaire survey evaluating the service quality on the five dimensions (reliability, assurance, tangibles, empathy, and responsiveness) using a 5-point rating scale.

Part 3: A questionnaire survey assessing the extent to which customers are satisfied with the service quality of Southern China Airlines using a 5-point scale.

Scoring Satisfaction Level

Means Strongly Satisfied

Means Satisfied

Means Neutral

Means Less Satisfied

Means Least Satisfied

The author employed a computer package to analyze the data as follows:

Part 1 : personal information factors of the passenger.

Part 2: customer satisfaction in 5 dimensions including 1) Tangibles 2) Reliability 3) Responsiveness 4) Assurance and 5) Empathy analyzed by using Arithmetic mean value ( ) and Standard Deviation (S) value whose criteria are:

Average Satisfaction Level

1.00 - 1.80 Means Least Satisfied

1.81 - 2.40 Means Less Satisfied

2.41 - 3.40 Means Neutral

3.41 - 4.20 Means Satisfied

4.21 - 5.00 Means Strongly Satisfied

Part 3 : recommendations analyzed by using content analysis.

Data Analysis

Tabel 1 Reliability analysis of Service Quality

Variable	Cronbach's Alpha	N of Items
Tangible	.836	5
Reliability	.842	5
Responsibility	.843	5
Assurance	.824	5
Empathy	.842	5

Table 2 Reliability analysis of Satisfaction

Variable	Cronbach's Alpha	N of Items
Satisfaction	.911	10

Generally, a Cronbach's Alpha value above 0.7 is considered acceptable for research purposes, so all your variables seem to have good internal consistency. The reliability value is greater than 0.7, so this questionnaire has high reliability.

Table 3 Descriptive statistics

	$\bar{x}$	S.D.
SERVQUAL	3.63	.804
Satisfaction	3.62	.821

The Arithmetic mean value of SERVQUAL is 3.63 and the Standard Deviation is 0.804. For satisfaction, the Arithmetic mean ($\bar{x}$ =3.62, SD=0.821) indicates that their actual service experiences were satisfied.

Table 4 Mean and Standard Deviation of Service Quality

Service Quality of China Southern Airline	**N=400**		**Satisfaction Level**
	$\bar{x}$	**S.D.**	
Tangible	3.61	.861	Satisfied
Reliability	3.67	.884	Satisfied
Responsiveness	3.62	.862	Satisfied
Assurance	3.61	.831	Satisfied
Empathy	3.62	.862	Satisfied
Total average	**3.63**	**.860**	**Satisfied**

The highest satisfaction is observed in the dimension of Reliability ($\bar{x}$ = 3.67, SD=0.884), followed by Empathy ($\bar{x}$ = 3.62, SD=0.862), Responsiveness ($\bar{x}$ = 3.62, SD=0.862), Assurance ($\bar{x}$ = 3.61, SD=0.831), and Tangibles ($\bar{x}$ = 3.61, SD=0.861).

Table 5 Correlations of the service quality and satisfaction of China Southern Airlines

		SERVQUAL	Satisfaction
SERVQUAL	Pearson correlation	1	.939**
	Sig. (two-tailed)		.000
	Sum of Squares and Cross Product	259.975	247.206
	Covariance	.647	.620
	Number of cases	400	400
Satisfaction	Pearson correlation	.939**	1
	Sig. (two-tailed)	.000	
	Sum of Squares and Cross Product	247.206	268.630
	Covariance	.620	.673
	Number of cases	400	400

** significant level = 0.05

The Pearson correlation coefficient between SERVQUAL and Satisfaction, the Pearson correlation coefficient is 0.939. This indicates a strong positive linear relationship between service quality and customer satisfaction. The p-value is very close to zero (0.000). This means that the observed correlations are statistically significant, indicating that the relationship between service quality and customer satisfaction is not likely to have occurred by chance.

In summary, the table suggests a statistically significant positive relationship between service quality (SERVQUAL) and customer satisfaction for China Southern Airlines. The correlation coefficient of 0.939 indicates that as service quality improves, customer satisfaction also tends to increase.

Table 6 Correlation matrix between service quality and consumer satisfaction

	Tangible	Reliability	Responsiveness	Assurance	Empathy	Satisfaction
Tangible	1					
Reliability	.853**	1				
Responsiveness	.857**	.835**	1			
Assurance	.856**	.830**	.849**	1		
Empathy	.833**	.837**	.837**	.845**	1	
Satisfaction	.871**	.875**	.881**	.886**	.878**	1

** significant level = 0.05

This correlation matrix shows the degree and direction of linear relationships between the variables, and it appears that consumer satisfaction has a significant correlation with Tangible (0.871), Reliability (0.875), Responsiveness (0.881), Assurance (0.886), and Empathy (0.878).

Discussion and Conclusion

Relationship of Service Quality with Customer Satisfaction in order to observe the individual linear correlation between customer satisfaction and each variable under the service quality, Pearson's product-moment correlation test was done. according to the correlation analysis, there are positive correlations between each dimension of service quality and customer satisfaction.

Overall, based on the provided data, the Pearson correlation coefficient (p=.939**) between SERVQUAL and Satisfaction indicates that there is a significant correlation between service quality and satisfaction. This suggests that in this study, there is a significant relationship between service quality and consumer satisfaction, as indicated by the research results.

Tangibles: Research results show that passengers are satisfied with the appearance and grooming of the cabin crew. Most passengers are satisfied with the comfort of the cabin interior and the variety of food and beverage services. Tangibles encompass aspects that consumers can see, touch, and feel. In this regard, passengers typically have certain expectations regarding the appearance and grooming of cabin crew and desire a comfortable cabin environment with high-quality food. Gummesson (1991) presented numerous dimensions on which customers might evaluate the tangible element of their service experience. The dimensions derived from three perspectives of the tangibles elements: the manufacturing/goods perspective (Garvin,1988), a psychological perspective concerned with aspects of tangibility that affect consumers' ability to interact with products in everyday life (Norman, 1988), and an environmental perspective that addresses the impact of the larger physical environment of the service experience on the evaluation of it (Baker, 1986).The

tangibles dimension was considered more important when evaluating in-flight service quality than when evaluating ground service quality.

Reliability: Research results reveal that consumers' satisfaction with the quality of service from China Southern Airlines is consistently at a high level. Most passengers believe that the airline provides clear solutions when addressing issues. Flights are punctual and dependable. When flight changes occur, China Southern Airlines provides detailed explanations and arrangements. Reliability involves aspects such as the punctuality of flights and the ability to resolve issues. Passengers' satisfaction with cabin crew providing accurate and reliable emergency and medical assistance indicates the airline's success in training and preparing cabin crew to handle potential emergencies effectively. Chou et al. (2011) assess carrier administration quality in a Taiwanese aircraft and found that dependability and affirmation are the principal significant measurements. In terms of the findings, reliability, understand ability, and security criteria were the most important criteria. Therefore, airlines should consider these in their web-based marketing strategies and strengthen the perception of reliability in the minds of the consumers (Bakir & Atalik, 2021).

Responsiveness: Research results show that consumers find customer service to be responsive and flexible in addressing questions and needs. They also exhibit a positive attitude when handling complaints and issues, offering timely flight information and updates. Responsiveness pertains to the airline's prompt response to passenger needs and issues. It shows that the airline demonstrates a high level of service in meeting customer needs and expectations across various aspects. The substantial part of the overall responsibility for the improvement of service quality rests upon the employees detailed to contact and deliver to the passengers. Stum and Church (1990) call such customer service employees “corporate ambassadors" Which is most important to make travelers’ loyalty and organizational image. Nambisan et al. (2016) explained that responsiveness is crucial to improving customer perceptions of service quality.

Assurance: Research results indicate that most passengers perceive a high level of professionalism in the airline's passenger service. The cabin crew efficiently handles in-flight emergencies and calm passenger emotions. They maintain composure and professionalism when dealing with emergencies. Staff effectively address consumer issues, ensuring timely resolution of passenger problems.

The research results indicate that the airline's employees exhibit a high level of professionalism, can respond to emergencies calmly and professionally, and effectively address passenger concerns and doubts. Passengers have become increasingly concerned about aviation companies' safety and emergency response capabilities. It's important to recognize that no flight can entirely avoid crisis events, and an airline's ability to respond to emergency situations directly reflects its competence. Safety should always be the top priority in providing services. Enhancing emergency preparedness requires cabin crews to possess the necessary skills to handle various emergency situations (Qin , 2021).

Empathy: Research results show that most passengers believe that employees genuinely care about and respect them during communication. They exhibit a high degree of empathy when dealing with passengers. Ground service personnel cater to the individual needs of different special passengers (elderly, disabled,

pregnant, etc.). China Southern Airlines actively collects passenger opinions and suggestions and responds positively to building constructive customer relationships.

Researchers also suggest that empathy, care and attentiveness shown by frontline service employee to customer lead to customer service (Gorry & Westbrook,2011). Particularly in the literature concerning service, empathy is regarded as an essential element for fruitful employee and customer communications that commonly lead to altruistic motivation and pro-social and altruistic behavior (Aksoy, 2013; Itani & Inyang, 2015).

Recommendation

China Southern Airlines can take several strategic steps to enhance its service quality and improve overall customer satisfaction.

In terms of tangibles, the airline should focus on upgrading cabin interiors, including seat design and comfort, as well as the quality and availability of facilities. Providing more spacious and comfortable seating, ensuring cleanliness, and enhancing aesthetics will contribute to a more pleasant passenger experience.

The airline should prioritize on-time arrivals and departures while promptly communicating any flight changes or disruptions to passengers. Transparent and detailed explanations for changes, along with alternative arrangements, will help passengers feel valued and confident in the airline's commitment to their comfort and convenience.

Responsiveness can be improved by continuous staff training to enhance their ability to address passenger needs swiftly and proactively. Establishing a dedicated emergency response team and offering multiple communication channels will ensure passengers have access to timely information and support, ultimately enhancing their overall experience.

Assurance involves training employees to handle emergencies and remain professional in challenging situations. Implementing an effective complaint-handling mechanism will demonstrate the airline's commitment to resolving passenger issues promptly and efficiently, fostering trust in service quality.

China Southern Airlines should encourage employees to show empathy, especially when dealing with special passengers. Providing specific training on how to assist elderly, disabled, and pregnant passengers is essential. Actively seeking and acting on passenger feedback and suggestions will further enhance mutual trust and satisfaction.

Future research can further study the relationship between service quality and consumer satisfaction by conducting more in-depth quantitative and qualitative analyses, as well as by comprehensively considering multiple potential influencing factors.

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR
VOL.3, NO.1; JAN. – MAR.; 2024, ISSN 2822-0412 (Online)

Sustainable Finance Exploration: Analyzing the Impact of Environmental, Social, Governance (ESG) Information Disclosure in the Supply Chain

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Received: March 6, 2024 / Revised: March 24, 2024 / Accepted: April 3, 2024
Doi: 10.14456/scsr.2024.8

Abstract

This study explores the challenges and strategies related to Environmental, Social, Governance (ESG) information disclosure within supply chains. Initially, through case studies across various sectors, it was observed that businesses encounter issues such as inadequate energy management, insufficient efforts in energy saving and carbon reduction, and a lack of certified greenhouse gas inventories and certification management concerning environmental protection, sustainable operations, and risk management. Furthermore, addressing the gaps in supplier audits, the study suggests improvements in operational continuity management, supplier selection, and management, energy management and emission reduction initiatives, overtime control, and anti-discrimination practices, and emergency preparedness and chemical management.

From a business benefits perspective, disclosing ESG information can enhance a company's environmental image, mitigate operational risks, foster social responsibility, and support corporate sustainability. Regarding stakeholder interactions, it is recommended that companies enhance their communication with stakeholders, understand their expectations, and establish an effective feedback mechanism. The study identifies the main challenges in ESG information disclosure as the authenticity of the information, stakeholder engagement, and regulatory uncertainties. It offers insights for practitioners, highlighting the critical role of ESG information technology applications, the influence of regulations and policies, and the verification and credibility of ESG information.

The study concludes with suggestions for future research, including cross-industry comparative studies, long-term impact assessments of ESG information, and exploring stakeholder participation and feedback. These recommendations aim to deepen the understanding of ESG information disclosure in supply chains and provide more targeted guidance and advice for businesses.

Keywords: Supply Chain ESG, Information Disclosure, Environmental Image, Operational Risk Stakeholders

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Introduction

Background

Within the nine pivotal aspects of Corporate Sustainability, trends have been identified, highlighting sustainable finance as a key trend (Schoenmaker & Schramade, 2018). For companies seeking to incorporate sustainable finance into their supply chains, several strategic recommendations are proposed for comprehensive analysis. Firstly, companies should advocate for the adoption of internal carbon pricing, ensuring the full incorporation of carbon emission costs into their financial planning and operational strategies. Secondly, prioritizing biodiversity within environmental management is crucial, emphasizing ecological conservation and eco-friendly practices throughout the supply chain. The push towards a circular economy necessitates that companies explore recycling opportunities within their product life cycles to minimize resource waste. The call for science-based targets and a net-zero trajectory encourages companies to engage in scientific and technological innovation, developing technologies for emission reduction to achieve carbon neutrality. With a focus on new climate technologies, companies are advised to invest in and deploy emerging technologies to tackle climate change challenges. The expectation for sustainable finance suggests that companies integrate Environmental, Social, Governance (ESG) principles within their financial strategies to attract investors towards sustainable finance initiatives. Enhancing collaborations with social innovation organizations calls for stronger partnerships between companies and stakeholders to foster social innovation. Increasing ESG engagement among all employees underlines the significance of internal training and education, ensuring comprehensive participation in ESG initiatives. Moreover, establishing Diversity, Equity, and Inclusion (DEI) as a norm requires companies to champion diversity and equality in their management and culture, weaving DEI principles into everyday operations (Rumyantseva & Tarutko, 2022)

To advance sustainable finance, companies must weave sustainable finance principles and ESG considerations into their overarching operational strategies, including financial planning and decision-making. Establishing a transparent ESG performance and financial information disclosure mechanism is crucial for accountability to shareholders and stakeholders. Exploring sustainable finance instruments, like green bonds and socially responsible investments, can enhance investor participation in sustainable finance projects, supporting sustainability-oriented endeavors. Furthermore, educating and raising awareness about sustainable finance within the company and among supply chain participants ensures that personnel are well-equipped to adhere to sustainable finance standards. Forming partnerships with financial institutions, governmental bodies, and businesses can share best practices and optimize resource use. Companies should also navigate sustainable finance risks, such as climate change, environmental incidents, and social upheaval, by developing robust risk management strategies to maintain resilience against uncertainties. By embedding sustainable finance into their core strategies and promoting ESG practices through disclosure, investment, education, and partnerships, companies can achieve sustainable finance objectives in their supply chains, contributing to broader sustainability goals.

Objectives of the Study

The objectives of this study are outlined as follows:

1. To explore the tangible outcomes of embedding sustainable finance principles into corporate practices and assess the integration of ESG factors into companies' overall strategies. This includes examining the influence of such integration on the financial planning and decision-making processes within organizations.

2. To analyze the effects of implementing transparent information disclosure mechanisms on the perception and engagement of shareholders, stakeholders, and other relevant parties. This involves investigating how these mechanisms can effectively convey a company's ESG performance and financial data, aiming to understand the broader implications of transparency on sustainable finance practices within corporations.

3. To evaluate the capacity of corporations to identify, adopt, and utilize various sustainable finance instruments, with a focus on green bonds and socially responsible investments. This includes exploring how these financial tools impact investor engagement in sustainable finance initiatives and their potential to mobilize funds for supporting sustainability projects.

Research Questions

Research questions to be addressed in this study include:

1. On the practical effects of corporate integration of sustainable finance principles:
   - How does incorporating ESG factors into a company's overall strategy yield tangible sustainability benefits?
   - What are the direct consequences of this integration on the financial planning and decision-making processes within the company?
2. Concerning the impact of transparent disclosure mechanisms on stakeholders:
   - Can a transparent ESG disclosure mechanism enhance the relationship between the company and its shareholders, stakeholders, and other relevant entities?
   - In what ways can this disclosure mechanism effectively communicate ESG performance and related financial information externally?
3. On the capabilities of companies to explore and apply sustainable financial instruments:
   - What challenges do companies encounter when attempting to utilize sustainable finance instruments such as green bonds and socially responsible investments? (Bhutta et al., 2022)
   - How do these financial tools influence investors' interest and willingness to engage in sustainable finance initiatives led by the company?
   - Through what means can companies effectively generate funds to back sustainability projects using these instruments?

Literature review

Sustainable Finance

The Concept of Sustainable Finance

Sustainable finance, commonly known as green finance or climate finance, encompasses financial investment solutions aimed at fostering sustainable environmental development. These initiatives are instrumental in propelling a sustainable economy forward, supporting eco-friendly products, and influencing policies in favor of environmental conservation. By embedding sustainability considerations into the operational expenses, risks, and returns of businesses and financial institutions, sustainable finance plays a pivotal role not just in combating climate change but also in unlocking economic opportunities. Essentially, it represents a strategic approach that urges corporations and financial entities to incorporate environmental sustainability into their operational ethos, thereby committing to investments that are beneficial for the planet. B. Literature on ESG Information Disclosure in Supply Chains.

In 2023 is considered a pivotal year for international sustainable development and climate governance. In late April 2022, the European Financial Reporting Advisory Group (EFRAG) released the preliminary version of the first "European Sustainability Reporting Standards" (ESRS), which received approval from the European Union (EU) in November (Eklund & Vaaler, 2023). This new standard is a crucial component of the "Corporate Sustainability Reporting Directive" (CSRD), expanding the scope from the original 11,700 companies to 50,000 companies (Europe, 2022). The EU Commission is expected to formally adopt ESRS by June 30, 2023, and implement corresponding industry-specific standards by June 30, 2024.

At the same time, the U.S. Securities and Exchange Commission (SEC) announced in March 2022 that it would require listed companies to disclose their greenhouse gas emissions data (including Scope 1 to 3) in their annual reports for 2023 or 2024, depending on market capitalization, and to disclose the financial risks that companies may face in response to climate change by Task Force on Climate-related Financial Disclosures (TCFD).

In addition, the International Sustainability Standards Board (ISSB), established by the International Financial Reporting Standards (IFRS) Foundation, published two drafts in 2022 — the General Disclosure Framework (S1) and Climate-related Disclosures (S2) (Ball, 2006). During COP27, the ISSB intensified its focus on Scope 3 Greenhouse Gas (GHG) data and announced in December its intention to release the final version of the standard in the first quarter of 2023. The signing of a memorandum of cooperation between the ISSB and the Ministry of Finance of China, the establishment of an office in Beijing, and plans to discuss the introduction of corresponding standards with more Asian countries mark a new era for global sustainability and financial standards.2.2 ESG Framework A.

ESG Concept and Importance

The Environmental, Social, and Governance (ESG) concept is gaining momentum in both corporate and financial sectors. ESG assessment involves evaluating a company's performance in environmental protection, social responsibility, and good governance. This article explores the impact of ESG on the supply chain, particularly focusing on how ESG disclosure affects companies and the entire supply chain ecosystem.

The importance of ESG is multifaceted. Firstly, ESG assessment serves as a crucial indicator for investors and stakeholders to evaluate the value and risks associated with enterprises. Investors increasingly consider sustainability performance and factor in ESG criteria in their investment decisions. Secondly, ESG practices help companies enhance their corporate image, build brand value, and attract a broader customer and partner base. Moreover, global regulations are becoming more stringent regarding ESG, compelling companies to adhere to corresponding standards and guidelines to mitigate potential legal risks.

In the supply chain, ESG information disclosure has become a pivotal step for enterprises to achieve sustainability goals. By revealing the ESG practices of suppliers and partners, companies can assess the sustainability of the entire value chain, thereby improving transparency and traceability throughout the supply chain. This paper will delve into the actual impact of ESG in the supply chain, specifically exploring the effects of ESG information disclosure on supply chain operations and business decisions, providing valuable insights for enterprises aiming for more sustainable supply chain management.

Definition and Scope of Sustainable Finance

Sustainable finance is a comprehensive concept focusing on how financial activities can concurrently support economic development and promote environmental and social sustainability. This includes practices in the financial sector such as investment, financing, and insurance, with an emphasis on long-term value creation and risk management.

In sustainable finance, special attention is given to integrating ESG factors into the financial decision-making process. This integration helps assess the impact of potential investments and incentivizes investors to choose more sustainable projects. In the supply chain, these green financial instruments also influence the overall environmental performance of the company's operations and supply chain.

Sustainable finance encompasses green finance, concentrating on financial activities that support environmental sustainability. This may involve investing in renewable energy, energy-saving projects, or raising funds through the issuance of green bonds. In the supply chain, these green financial instruments also affect the overall environmental performance of the company's operations and supply chain.

Moreover, sustainable finance also involves social responsibility and governance. This includes the role of companies in society, such as promoting social equity and improving labor conditions. Detailed exploration is needed to understand how these social and governance factors relate to financial activities and impact the sustainability of supply chains.

ESG Elements in the Supply Chain

ESG elements in the supply chain encompass environmental protection, social justice, and good governance. Companies must ensure that every link in the supply chain aligns with the basic principles of sustainable finance by formulating clear policies and taking concrete measures.

Integrating ESG elements into the supply chain is crucial for achieving sustainable finance goals. On the environmental front, companies need to assess the carbon footprint of their supply chains and develop strategies to reduce greenhouse gas emissions. This could include choosing green suppliers, optimizing transportation and logistics, and promoting eco-friendly product design. Through the guidance of ESG

standards, companies in the supply chain can holistically consider their ecological footprint, thereby reducing their adverse impact on the environment.

In the social dimension, companies must assess the labor conditions, social responsibility, and human rights of their supply chain partners. This involves ensuring that suppliers provide fair wages and hours, promoting diversity and inclusion, and prohibiting child and forced labor. ESG standards guide companies in building a more just and sustainable supply chain while improving social integrity.

Governance also demands attention in the supply chain. This includes establishing transparent governance mechanisms to ensure fair treatment of all parties in the supply chain. Companies must assess their suppliers' governance structures to guard against corruption risks. ESG standards drive higher levels of ethics and compliance in supply chains.

Research Methods

This article adopts the case study method to conduct an in-depth discussion and analysis of relevant cases.

Results and Discussion

Relevant Standards for Sustainable Finance

The main structure of Sustainable Financial is illustrated in Figure 1.

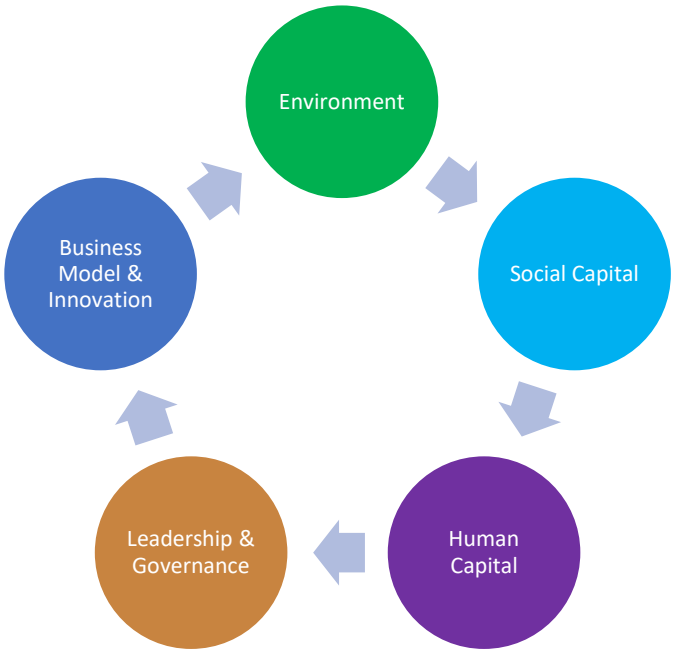

Figure 1 The main considerations of sustainable finance

In order to achieve the goal of sustainable finance, a number of standards related to sustainable finance have been formulated, which are explained below.

ISSB Guidelines

The International Sustainability Standards Board (ISSB) officially published two major international sustainability information disclosure framework standards in June 2023 (de Villiers & Dimes, 2023).

Established by the International Financial Reporting Standards (IFRS) Foundation at the end of 2021, the ISSB announced drafts of two disclosure standards in March of the following year. These drafts, based on the Task Force on Climate-related Financial Disclosures (TCFD) disclosure framework, are named the "General Requirements for Disclosure of Sustainability-related Financial Information" (referred to as S1) and "Climate-related Disclosures" (referred to as S2)(Lyons, 2022). Simultaneously, in 2022, the IFRS incorporated the Climate Disclosure Standards Board (CDSB) and the Value Reporting Foundation (VRF). This development signifies a significant step in the consolidation and evolution of international sustainability and financial standards. B. International Financial Reporting Standards (IFRS) is a set of international financial reporting standards issued by the International Accounting Standards Board (IASB). The goal of IFRS is to provide consistent, transparent, and comparable financial reporting standards globally, allowing investors, analysts, regulators, and other stakeholders to understand and compare corporate financial reporting across different countries and regions more easily.

IFRS replaces the financial reporting standards developed by individual countries and regions, streamlining international trade and investment while enhancing the transparency of global capital markets. This simplifies financial reporting and analysis for multinational companies and investors working under different accounting frameworks. IFRS applies not only to public companies but also to other types of organizations, including private companies and non-profit organizations. As a globally accepted financial reporting standard, many countries and regions have adopted or adapted IFRS to comply with local regulations and environments

Taiwan Version of the IFRS Sustainability Standard

The Taiwan Stock Exchange has completed amendments to the "Regulations Governing the Preparation and Filing of Perpetual Reports by Listed Companies." The main amendments include:

1. Referring to the 2021 update of the Global Reporting Initiative (GRI): Companies should use the latest version of GRI Common Criteria, Industry Guidelines, and Subject Matter Guidelines to prepare sustainability reports.

2. Considering the Sustainability Accounting Standards Board (SASB): Companies should formulate sustainability-related indicators based on industrial significance and investor concern. This includes industries like food, chemicals, finance, insurance, cement, plastics, steel, oil, electricity, gas, semiconductors, computers, optoelectronics, communication networks, electronic components, and channels, all of which need to strengthen the disclosure of industrial sustainability indicators according to specific schedules.

3. For companies with paid-in capital of more than 2 billion yuan but less than 5 billion yuan, the first preparation of a sustainability report may be applicable from 2024, excluding the food, chemical, and financial and insurance industries.

4. Task Force on Climate-related Financial Disclosures (TCFD): Companies are required to disclose nine climate-related information items.

5. Strengthen the quality of sustainability reports: Introduction of relevant regulations for institutions and personnel required to believe in sustainability reports. "Key Points for the Management of Listed Over-The-Counter (OTC) Companies in the Sustainability Report of Confident Institutions" will be released in 2024, effective from that year, and announced in the fourth quarter of 2022.

The International Sustainability Standards Board (ISSB) issued the "Sustainability Disclosure Standards" in June 2023. The Taiwan Financial Supervisory Commission announced its plan to adopt and integrate the Taiwan version of the IFRS Sustainability Standards in response to the domestic industrial environment. In the initial stage, companies with a capital of 10 billion yuan are required to compile sustainable information in 2026 and disclose it to the public in 2027. The measure is expected to apply to all listed companies in 2029.

Task Force on Climate-related Financial Disclosures (TCFD)

Task Force on Climate-related Financial Disclosures (TCFD) is a set of standardized voluntary climate-related financial disclosure recommendations issued by the Climate-related Financial Disclosure Working Group established by the G20 Forum for International Economic Cooperation. Its purpose is to discuss how the financial industry should respond to climate-related issues and help investors and decision-makers understand and assess accurately the climate change risks and opportunities faced by enterprises.

European Sustainability Reporting Standards (ESRS)

The European Commission's Executive Board approved a proposal for the Corporate Sustainability Reporting Directive (CSRD), which would replace existing reporting requirements for ESG. Starting from 2024, 50,000 European companies will be required to prepare sustainability reports. As part of the CSRD, the European Union will publish the first draft European Sustainability Reporting Standards (ESRS). The scope and depth of disclosure requirements are much stricter than the current Non-Financial Reporting Directive (NFRD) Affected companies must disclose hundreds of metrics and targets by the ESRS reporting standards. Companies that have complied with the NFRD will implement CSRD in their 2025 report. Therefore, it is crucial to plan and manage internal organizational data early to ensure the authenticity and completeness of the data support.

Corporate Sustainability Reporting Directive (CSRD)

The Corporate Sustainability Reporting Directive (CSRD) is the new EU legislation that requires all European businesses to publish regular reports on their environmental and social impact activities. It helps investors, consumers, policymakers, and other stakeholders evaluate the non-financial performance of large companies. As a result, CSRD encourages European businesses to develop more responsible business practices.

Factors Influencing the Disclosure of ESG Information in the Supply Chain

The Importance of Supply Chain Sustainability Finance

The aforementioned standards, including the ISSB Standard, IFRS Standard, TCFD Climate-related Financial Disclosure, ESRS European Sustainability Reporting Standard, and CSRD Corporate Sustainability Reporting Directive, cover various aspects of corporate sustainability finance and sustainable development. Their importance in supply chain sustainability finance is reflected in several aspects:

1. Disclosure and Transparency: These guidelines and directives encourage companies to make more comprehensive and transparent disclosures about their sustainability and environmental, social, and governance (ESG) performance. Supply chain transparency is crucial for stakeholders to better understand the actions and impacts of businesses in the supply chain, including environmental and social impacts.

2. Risk Management: These standards require companies to assess and disclose risks related to climate change, ESG, and sustainability.

Table 1 Impact of Key Sustainability Decrees/Standards on Supply Chain Management

Decrees/Standards	Aspects of impact	Influence content
ISSB guidelines	Disclosure and transparency, risk management, ESG integration, compliance requirements	Encourage companies to disclose more comprehensive and transparent information on sustainability and ESG, including supply chain transparency, risk management, and compliance with ISSB standards.
IFRS Standards	Disclosure and transparency, risk management, ESG integration, compliance requirements	Providing consistent, transparent, and comparable financial reporting standards and providing comprehensive financial disclosures to companies also affects information related to sustainability and ESG.
TCFD Climate-related Financial Disclosures	Disclosure and transparency, risk management, ESG integration	Provide standardized climate-related financial information disclosure recommendations, emphasizing how companies should respond to climate-related issues, which can help assess climate change risks and opportunities, and affect risk management and ESG integration.
ESRS European Sustainability Reporting Standards	Disclosure and transparency, risk management, ESG integration, compliance requirements	Strengthen the sustainability reporting requirements of European companies, covering hundreds of indicators and targets, to provide a more comprehensive disclosure of companies, affecting the sustainability and compliance of the supply chain.
CSRD Corporate Sustainability Reporting Directive	Disclosure and transparency, risk management, ESG integration, compliance requirements	The mandatory requirement for European companies to comply with specific sustainability reporting standards requires companies to actively assess sustainability in their supply chains to ensure compliance with regulatory requirements, impacting risk management and ESG integration.

In the table above, each ordinance or standard has a different degree of impact on disclosure and transparency, risk management, ESG integration, and compliance requirements. Together, they push companies to consider sustainability and ESG factors more holistically and strengthen relevant disclosure and management measures in supply chain management to ensure business sustainability and long-term value creation.

Stakeholders' expectations for sustainable finance

The following is a table of analysis of the expectations of stakeholders in the above-mentioned decrees. In this table, it shows the expectations and influence of the stakeholders of the enterprise on sustainable finance.

Table 2 Stakeholder Expectations and Influence on Sustainable Finance in Key Sustainability Decrees

Decrees/Standards	Stakeholder expectations	Influence content
ISSB guidelines	- Investors: Expect more comprehensive ESG disclosures and understand the status of corporate sustainability and risk management.	- Companies need to provide more detailed disclosures, including relevant information in the supply chain, to meet investors' demand for ESG information.
IFRS Standards	- Investors, analysts: expect consistent, transparent, and comparable financial reporting standards, including ESG-related information.	- Companies need to incorporate ESG factors into their financial reports and provide more comprehensive financial disclosures to meet investors' detailed understanding of sustainability and risks.
TCFD Climate-related Financial Disclosures	- Investors and regulators: expect standardized climate-related financial disclosures to assess climate risks and opportunities.	- Companies need to provide climate-related financial information, including climate risks and opportunities in their supply chains, in accordance with standards to meet the demand for climate-related information from investors and regulators.
ESRS European Sustainability Reporting Standards	- Investors, Governments, Consumers: Expect more detailed sustainability reporting, including impacts in the supply chain.	- Companies need to provide more comprehensive and massive disclosures, including data from their supply chains, to meet the expectations and demands of multiple organizations for corporate sustainability.
CSRD Corporate Sustainability Reporting Directive	- Investors, governments, regulators: Expect companies to follow specific sustainability reporting standards and increase transparency.	- Companies are required to comply with the Directive and provide standard-compliant sustainability reports to meet various corporate sustainability expectations and regulatory requirements.

These regulations and standards reflect the expectations of stakeholders regarding corporate sustainability and supply chain management. Investors expect more detailed ESG disclosures, governments and regulators expect greater transparency and compliance with specific standards, and consumers expect more detailed sustainability reporting. Businesses need to respond to these expectations in order to build trust, improve competitiveness and ensure sustainable operations.

Case studies

Practical case analysis of enterprises

(1) Case 1: Enhancing Supplier Network through ESG Data

Environmental, Social, and Governance (ESG) considerations have been pivotal in corporate consciousness for over a century. In recent years, the escalating pressure on businesses to conduct responsible operations has compelled them to extend this awareness throughout their entire supply chain. In an era marked by ever-expanding regulatory frameworks, any lapses in conduct can swiftly be brought to light through social media channels. Consequently, companies are now compelled to thoroughly evaluate ESG certifications across all nodes in their supply chains.

Supply chains play a central role in ESG performance, accounting for up to 80% of the environmental impact in various industries. Serving as a nexus between businesses and society by connecting with employees, communities, and consumers, the supply chain significantly influences corporate reputation and financial risk management. The recent pandemic has underscored the crucial role of supply chains in ensuring the resilience of a company's operations. This has prompted businesses to recognize that managing ESG impacts within their supply chains is as critical as ensuring product quality, cost-effectiveness, and timely delivery. This extends beyond Tier 1 suppliers to include downstream suppliers. Monitoring the behavior of secondary and tertiary suppliers, often located in different countries with limited direct customer interaction, becomes imperative. Thus, ESG data becomes a vital tool for procurement professionals to enhance visibility in these areas. We have compiled the information above into a structured form for supply chain managers to reference in their procurement and collaboration efforts.

Table 3 Overview of ESG Integration Solutions Inspection in Enterprise Supply Chains

field	Solution/Plan	description
ESG adoption	ESG Sustainability Label	Introduce the sustainability label to prove the company's superior performance in environmental, social and governance aspects.
	ESG Intelligence	Leverage intelligent data analytics to provide deep insights into environmental, social, and governance factors.
	risk management	Comprehensive management of enterprise risks, including data APIs, sustainable risk management platforms, accounts receivable collection and other solutions.
	Enterprise Data API Solution	Provide enterprise data APIs for risk management and decision support.
	ESG sustainable risk management platform	Focus on integrating ESG factors for risk management, emphasizing sustainable risk management.
	Accounts receivable collection	Manage accounts receivable and ensure business liquidity, taking into account social and governance considerations.
	Corporate credit report	Provide corporate credit reports to assess the credit risk of partners.
	Financial risk management	Emphasis is placed on risk management in the financial aspect, while considering the impact of ESG factors.
	Supplier risk management	Manage supplier risks, including environmental and social risks in the supply chain.
other	Marketing & Marketing Outreach	Carry out marketing and marketing development, emphasize the sustainability of the enterprise, and attract more customers with the same values.
	Compliance management	Emphasis is placed on compliance to ensure that businesses operate legally and ethically.
	Smart collection dashboard	Provides an intelligent collection dashboard to help businesses manage and collect payments more effectively.
	Partner Acceleration Program	Accelerate the development of partners, emphasizing shared values and sustainable development.

Table 3 (Cont.)

field	Solution/Plan	description
	Accounts receivable collection	Manage accounts receivable and ensure business liquidity, taking into account social and governance considerations.
	Corporate credit report	Provide corporate credit reports to assess the credit risk of partners.
	Financial risk management	Emphasis is placed on risk management in the financial aspect, while considering the impact of ESG factors.
	Supplier risk management	Manage supplier risks, including environmental and social risks in the supply chain.
other	Marketing & Marketing Outreach	Carry out marketing and marketing development, emphasize the sustainability of the enterprise, and attract more customers with the same values.
	Compliance management	Emphasis is placed on compliance to ensure that businesses operate legally and ethically.
	Smart collection dashboard	Provides an intelligent collection dashboard to help businesses manage and collect payments more effectively.
	Partner Acceleration Program	Accelerate the development of partners, emphasizing shared values and sustainable development.

The table above provides a comprehensive summary of the various solutions, initiatives, and tools discussed in different areas, accompanied by their respective descriptions. These programs and tools play a pivotal role in assisting companies in realizing their objectives related to ESG adoption and risk management, all while underscoring the significance of sustainability.

Effective ESG Disclosure Strategy for the Supply Chain

Wistron employs a robust supply chain sustainability management process that encompasses essential requirements for both existing and new suppliers, ensuring adherence to the Wistron Supplier Code of Conduct. This comprehensive management process spans various aspects, including green product procurement, Conflict Minerals Reporting Template (CMRT) surveys, supplier self-assessment questionnaires, supplier performance management, sustainability audits, and coaching for improvements (Whitelock, 2015).

To guarantee that suppliers possess fundamental sustainability capabilities, Wistron has implemented training programs for supply chain personnel qualifications and supplier management. Procurement and related staff undergo sustainability training covering the Responsible Business Alliance's (RBA) code of ethical conduct, integrity management, corporate governance, as well as general sustainability courses encompassing conflict minerals, green management, green partners, laws and regulations, negotiation skills, and more.

Supplier auditors at Wistron are required to undergo supplier audit course training, achieving a subject score of 80 or above to earn auditor accreditation and conduct supplier audits. Internally, Wistron provides relevant supply chain training courses. A total of 260 auditors participated in training on integrity management, corporate governance, and related topics, while 883 individuals underwent 609 hours of sustainability management training. Additionally, 28 auditors received 97 hours of training. Wistron conducts thorough risk factor assessments, as illustrated in the table below.

Table 4 Wistron suppliers' main sustainability risk sharing factors in 2022

face	risk
environmental protection	- There is no mechanism for energy management, energy conservation and carbon reduction - Management of uncertified greenhouse gas inventory certification - No use of green electricity or renewable energy
Sustainability & Operational Risk Management	- Failure to manage contingency plans for business continuity - Not participating in the Carbon Disclosure Initiative

Table 5 Wistron Supplier Sustainability Management Improvement Action Plan

face	Issues	Improve actions
Sustainability & Operational Risk Management	Operational continuity management	- Promote corporate social responsibility, employee care, corporate governance, environmental protection and social welfare - Focus on complying with government regulations, protecting the right to work, and promoting health and safety at work - Develop green products, reduce environmental impact, and take social and environmental responsibility - Prevent disruptions to operational activities by incorporating prevention and recovery controls and procedures to minimize disruptions to operations due to disasters and management failures
Supply chain sustainability management	Supplier selection/management	- Establish a robust supply chain risk management program - Identify risks at all stages of the supply chain - Improve the accuracy of demand forecasts and establish safety stock
environmental protection	Energy management/emission reduction programs	- Formulate energy policies and combine relevant emission reduction actions, formulate emission reduction plans and emission reduction targets - Conduct energy monitoring, establish relevant regulations to identify and have clear quantitative indicators, formulate energy and resource control procedures, and implement carbon reduction in accordance with the procedures
Human rights and labor security	Overtime control overtime/anti-discrimination	- Establish an electronic overtime application control system, which requires overtime application in advance, and the system will automatically generate an early warning signal when the overtime hours are exceeded - Regularly organize anti-discrimination education and training programs for anti-discrimination issues, and include them in annual training plans, conduct employee training, and implement record-keeping management

Table 5 (Cont.)

face	Issues	Improve actions
Occupational health and safety	Lack of knowledge of emergency preparedness/chemicals management	- Strengthen the awareness of the protection of operating staff - Escape routes are marked - Safety Escape Education and Training - Posting warning signs and control measures on relevant facilities and areas - Appropriate security and improvement facilities - Chemical Safety Data Sheets (SDS) for spot-checking

Conclusions

Key Findings and Results

Business Benefits

The study reveals that implementing corresponding improvement actions in supply chain sustainability management can bring various business benefits. Key findings include:

1. Environmental Protection and Energy Conservation: Establishing energy management mechanisms, implementing energy conservation, carbon reduction initiatives, and using green or renewable energy contribute to reducing environmental impact, meeting sustainable development goals, and enhancing corporate image.

2. Sustainability & Operational Risk Management: Engaging in operational continuity management, participating in the Carbon Disclosure Program, and creating operational continuity contingency plans can reduce operational risks and enhance the company's resilience to emergencies.

3. Supply Chain Sustainability Management: Developing a comprehensive supply chain risk management plan improves demand forecasting accuracy, enhances supply chain stability, and reduces the risk of potential operational disruptions.

4. Human Rights and Labor Protection: Controlling overtime work, addressing anti-discrimination issues, and strengthening occupational safety and health contribute to protecting employees' rights, improving the working environment, and enhancing employee satisfaction.

5. Environmental Initiatives: Developing energy policies, conducting energy monitoring, establishing emission reduction plans, and emphasizing chemical management aid in reducing a company's environmental footprint and complying with relevant regulations.

Overall, these actions not only help companies achieve sustainability goals but also yield practical business benefits, including improved brand image, risk reduction, enhanced supply chain stability, and a safer, healthier, and fairer working environment, thereby improving overall competitiveness.

Stakeholder Interaction

The investigation and analysis of stakeholder interaction in supply chain sustainability management yield the following main findings:

1. Increased Transparency: Establishing mechanisms for environmental protection, sustainability, and operational risk management, as well as supplier sustainability management, increases transparency for external stakeholders. Clear disclosure of environmental policies, risk management plans, and supply chain sustainability fosters better understanding of the company's sustainability policy.

2. Active Participation in Sustainability Initiatives: Actively responding to sustainability initiatives by participating in carbon disclosure programs and establishing operational contingency plans aligns with societal expectations, strengthens the company's leadership position in sustainability, and earns stakeholders' trust.

3. Employee Training and Participation: Implementing measures like overtime work control and training courses enhances internal employees' awareness and participation in sustainability management. This fosters positive sustainability culture and recognition of corporate values.

4. Supply Chain Collaboration: Promoting collaboration with suppliers through a supply chain risk management program helps jointly address risks and establishes stronger partnerships in the value chain.

Overall, these stakeholder strategies and actions not only meet societal expectations but also bring positive business-level benefits. Close collaboration with stakeholders enables companies to achieve sustainability goals, gain marketplace support, and promote overall business development.

Challenges in ESG Information Disclosure in the Supply Chain

Implications for Practice

This study identifies challenges in supply chain ESG disclosure and provides suggestions for the practice community. Overcoming these challenges requires cross-departmental collaboration and global consensus. Practitioners should actively address these challenges to better achieve Sustainable Development Goals and improve overall supply chain sustainability.

1. Transparency and Standardization Needs: Establishing a more transparent and standardized disclosure mechanism is crucial. Developing common standards and guidelines can enable consistent ESG information reporting across supply chains, reducing complexity.

2. Data Collection and Monitoring Technologies: Strengthening data collection and monitoring technologies, especially in environmental protection, sustainability, and operational risk management, is essential. Introducing advanced technologies like the Internet of Things (IoT) and big data analytics can enhance accuracy and real-time ESG information collection.

3. Training and Awareness-Raising: Practitioners should strengthen internal staff training to raise awareness and understanding of ESG disclosures. Regular sustainability-related training programs are essential to equip employees with sufficient knowledge for the disclosure process.

4. Partner Collaboration: All parties in the supply chain should establish closer collaboration to promote ESG information disclosure. Sharing information and collaborative problem-solving ensure the completeness and accuracy of disclosure.

5. Government-Industry Cooperation: Closer collaboration between governments and industry associations is necessary to develop more binding regulations and standards. This can increase companies' willingness to disclose and ensure that disclosed information accurately reflects supply chain ESG practices.

Recommendations for Future Research

While this study explores challenges in supply chain ESG disclosure, future research can further deepen the understanding of this topic and propose concrete solutions. Recommendations for future research include:

1) Cross-Industry Comparative Research: Conduct cross-industry comparative studies on supply chain ESG information disclosure to analyze challenges faced by different industries and identify industry-specific best practices.

2) ESG Information Technology Applications: Explore the application of advanced technologies like blockchain, artificial intelligence, machine learning, etc., to enhance ESG information disclosure in the supply chain.

3) Stakeholder Participation and Feedback: Conduct in-depth studies on stakeholder participation and feedback mechanisms in ESG information disclosure in the supply chain.

4) Impact of Regulations and Policies: Analyze regulations and policies on ESG information disclosure in different countries and regions, evaluating their impact on corporate disclosure.

5) Verification and Credibility of ESG Information: Examine existing ESG information verification mechanisms to propose comprehensive standards ensuring credibility and authenticity of disclosed information.

6) Long-Term Impact Assessment: Conduct long-term impact assessments of supply chain ESG information disclosure, evaluating corporate performance, shareholder value, social impact, etc., for a comprehensive understanding of disclosure effectiveness and long-term impacts.

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR
VOL.3, NO.1; JAN. – MAR.; 2024, ISSN 2822-0412 (Online)

Interplay Between Carbon Trading and Supply Chain Management: A Case Study of the Taiwan Carbon Exchange

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Received: March 8, 2024 / Revised: March 24, 2024 / Accepted: April 3, 2024
Doi: 10.14456/scsr.2024.9

Abstract

This study conducts an in-depth examination of the Taiwan Carbon Exchange through a case study approach, employing diverse research methods such as data collection, corporate interviews, analysis, and the utilization of questionnaires to gain insights into its operational model and broader impact on the carbon market. Corporate interviews yield firsthand insights and opinions from key industry stakeholders, while questionnaires ensure a broader participant base, fostering a more diverse range of opinions and data. Focusing on the carbon exchange as the subject of research allows for a thorough analysis of Taiwan's practicalities in carbon trading. The empirical information gathered strengthens the study's conclusions and enhances their reliability. This research aims to provide a comprehensive understanding of the carbon exchange's operational framework, its influence on the carbon market, and the future trajectory of Taiwan's carbon trading development.

Keywords: Carbon Exchange, Environmental Sustainability, Emission Rights, Taiwan Carbon Market Climate Change

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Introduction

Climate change and carbon emissions

Climate change stands as one of the most pressing global challenges, transcending geographical and industrial boundaries with its profound impacts. Scientific evidence unequivocally attributes the escalating planetary temperatures to the substantial release of greenhouse gases, particularly carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), stemming from human activities. This has induced a greenhouse effect, resulting in detrimental consequences such as extreme weather events—storms, floods, and droughts - that pose severe threats to ecosystems, economies, and societies (Hansen et al., 2013)

The Kyoto Protocol, established in 1997, aimed to curb greenhouse gas emissions from industrialized and transitioning economies by setting individual targets. It introduced three carbon trading market mechanisms: the Clean Development Mechanism, International Emissions Trading, and Common Reduction Mechanism. (Hepburn, 2007). Subsequently, the Paris Agreement, adopted in 2015, became a legally binding treaty necessitating the creation of new rules for carbon markets. Article 6 of the agreement outlines how countries can collaborate through the international carbon market to meet emission reduction goals (Falkner, 2016).

Human industrial activities, energy use, and transportation are the primary sources of carbon emissions, particularly from the combustion of fossil fuels. Carbon dioxide, a byproduct of this process, intensifies global warming, contributes to rising sea levels, and fuels frequent extreme weather events. Mitigating carbon emissions has evolved into a collective responsibility, integral to achieving sustainable development goals (Kharecha et al.,2013).

Addressing this challenge mandates coordinated global efforts. Governments must formulate effective policies to propel the shift toward a low-carbon economy, with active participation from companies in supply chain management playing a pivotal role. Implementing a carbon trading scheme serves as a financial incentive for companies to adopt cleaner and more sustainable practices, thereby reducing their carbon footprint. The establishment of the Taiwan Carbon Exchange stands as a significant stride in this direction, serving as an illustrative model. It offers insights into the symbiotic relationship between carbon trading and supply chain management to combat climate change, providing valuable references and inspiration for global regions grappling with similar challenges (Wang et al., 2019).

The rise of the global carbon market

The Urgency of Establishing an Efficient Voluntary Carbon Market in the Face of Climate Change

The urgency of addressing climate change necessitates the prompt establishment of a robust carbon market, serving as a pivotal tool in accelerating global efforts to combat rising temperatures. As the imperative to curb global warming intensifies, the creation of an efficient voluntary carbon market emerges as a crucial stride towards achieving net-zero emissions.

Distinguishing between compliance markets and voluntary markets, the former entails government-regulated emissions trading schemes, allocating carbon allowances to companies. Conversely, voluntary carbon markets focus on financing initiatives that diminish greenhouse gas emissions. Participants in this market can procure carbon credits from sellers to offset their emissions (Ahonen et al., 2022).

The significance of a carbon market stems from the Paris Agreement's mandate to limit global warming to below 1.5°C. Meeting this target necessitates a 45% reduction in greenhouse gas emissions by 2030 and achieving net-zero emissions by 2050. Despite this imperative, current emission levels indicate a substantial gap in reaching the 2050 net-zero target. In the pursuit of decarbonizing the climate value chain, establishing an efficient voluntary carbon market becomes a crucial step in attaining the net-zero emissions goal. Through the avoidance and elimination of emissions, carbon markets play a pivotal role in reducing net emissions. Companies can draw guidance from the Emissions Exchange's Net Zero Guidelines, providing a roadmap with key steps essential for achieving global net-zero targets (Fankhauser et al., 2022).

Significance of Investigating Carbon Trading and its Impact on Supply Chain Management

In the past, there was limited public awareness regarding the intricacies of carbon trading, particularly within the realm of supply chain management. For professionals in both practical and theoretical aspects of supply chain management, delving into comprehensive discussions and analyses of these subjects is paramount to enhancing their expertise and practical skills. The establishment of the Taiwan Carbon Exchange presents a unique opportunity to delve deeper into research and discussions surrounding carbon trading and its intersection with supply chain management.

Carbon trading is a nuanced domain encompassing intricate mechanisms and policies, necessitating a thorough understanding of its processes and content. Principally, two types of carbon trading exist: compliant markets and voluntary markets. Government-regulated compliance markets involve the issuance of carbon allowances to companies, with the government overseeing and facilitating the trading of carbon emissions. In contrast, voluntary markets primarily serve to finance activities that mitigate greenhouse gas emissions, allowing participants to acquire carbon credits for offsetting their emissions.

For supply chain managers, a comprehensive grasp of carbon trading content becomes instrumental in aiding companies to adeptly navigate the challenges posed by climate change. Participation in carbon trading enables companies to align with environmental objectives by curbing their carbon footprint, all while reaping corresponding economic incentives. This underscores the necessity for supply chain management to prioritize the assessment, monitoring, and reduction of carbon emissions, ensuring active company engagement in the carbon market. Consequently, through in-depth discussions and analyses centered around the establishment of the Taiwan Carbon Exchange, a clearer comprehension of the impact and challenges of carbon trading on supply chain management emerges. This endeavor not only contributes to academic research but also furnishes practical guidance and insights for supply chain managers in real-world applications.

Research Objectives

1. Amidst the establishment of the Taiwan Carbon Exchange, what strategies should supply chain managers adopt to comprehend and navigate the intricate mechanisms and policies of carbon trading, enhancing both the environmental efficiency and economic benefits of enterprises?

2. What delineates the characteristics and roles of the compliance market and voluntary market within the realm of carbon trading? Furthermore, how do firms' engagements in these markets differ in terms of impact on supply chain management and overall firm performance?

3. Within the landscape of carbon trading mechanisms, with a specific focus on voluntary carbon markets, how can supply chain management achieve a symbiotic relationship between carbon emission reduction and economic incentives? What exemplifies best practices and strategies that companies can adopt to align with global net-zero emission targets?

Research Questions

1. Supply Chain Strategies: How can managers balance environmental efficiency and economic benefits in navigating carbon trading within the Taiwan Carbon Exchange?
2. Market Impact: What sets compliance and voluntary carbon markets apart, and how do they influence supply chain management and overall firm performance?
3. Sustainable Practices: In carbon trading mechanisms, particularly voluntary markets, how can supply chain management harmonize carbon reduction with economic incentives and adopt strategies for global net-zero emission targets?

Literature Review

Carbon trading concepts and principles

Basic concepts of carbon trading

Carbon Emission Reduction. Targets To achieve carbon neutrality, various carbon pricing mechanisms such as carbon credits, taxes, or fees are implemented to incentivize enterprises to curtail carbon emissions. Companies are required not only to conduct comprehensive carbon inventories, devise pathways towards net-zero emissions, and embrace green energy but also to actively minimize their greenhouse gas emissions. For sectors facing challenges in immediate emission reduction, the acquisition of carbon credits and offsetting emissions play a pivotal role until technological advancements allow for more sustainable practices (Newel et al., 2013).

Carbon Trading Strategies. In the realm of carbon trading, two distinct categories emerge voluntary reduction quota trading and incremental offset trading. Enterprises holding surplus carbon credits can opt to sell them to buyers in need through the carbon exchange. Voluntary Reduction Quota Trading: This involves enterprises voluntarily adopting measures for emission reduction within the bounds of non-mandatory legal provisions. By proactively reducing emissions, companies earn carbon credits and position themselves as suppliers within the carbon trading market. Incremental Offset Trading: Compliant with EPA regulations, incremental offsets pertain to greenhouse gas emission reductions undertaken by development units. These offsets encompass various strategies, such as transitioning to natural gas, biogas, or biomass instead of coal or oil-fired equipment, utilizing greenhouse gas recovery and reuse technologies, and upgrading or replacing existing boilers. This approach aims to incentivize companies to invest in environmental protection and technological innovation, fostering more efficient greenhouse gas reductions.

Carbon Pricing Strategies. Carbon pricing involves incorporating carbon emissions into the economic system and using pricing mechanisms to drive the reduction of greenhouse gas emissions. Various practices fall under carbon pricing, namely carbon trading, carbon tax, and carbon fee (Narasimhan et al., 2018). Carbon

Trading: Facilitated through the carbon trading market, enterprises engage in buying and selling carbon credits, with prices subject to market supply and demand fluctuations. This dynamic pricing encourages companies to actively partake in emission reduction activities, offering economic incentives within the market mechanism.

1) Carbon Tax: In this approach, the government imposes a fixed-price tax on each unit of carbon emissions. The collection of carbon tax falls under the purview of financial authorities, and the generated revenue may be allocated to diverse purposes, including social welfare, income tax reduction, and the development of low-carbon infrastructure.

2) Carbon Fee: Resembling a carbon tax, the carbon fee's price may vary based on environmental policy adjustments. As proposed in Taiwan's amendment, the carbon fee, overseen by the Environmental Protection Agency, will be collected from major carbon emitters. The collected funds will contribute to a climate fund supporting low-carbon initiatives, green energy, and subsidizing industrial transformation.

Whether through carbon trading, carbon tax, or carbon fee, their shared objective is to economically incentivize companies, integrating carbon emissions into the economic system to achieve substantial reductions in greenhouse gas emissions. This pricing approach is widely recognized as the most effective tool for carbon reduction, collectively known as carbon pricing (Steinebach et al., 2021).

Table 1 Comparison of carbon pricing methods

Carbon Pricing	peculiarity	channel	Actuator	use
Carbon trading	Prices fluctuate with the market	Carbon trading market	Government, carbon exchange	Carbon trading, voluntary reduction and incremental offsetting by enterprises
Carbon tax, carbon fee	Fixed price	Determined by the government	government	Tax purposes include social welfare, income tax reduction, and the development of low-carbon infrastructure
Carbon fee	Variable price	EPD	EPD	It will be used to develop low-carbon, green energy, and subsidize industrial transformation

Models of the Carbon Trading Market

Table 2 offers a comparative analysis of various carbon credit generation methods, enhancing comprehension of the distinctive characteristics and providing illustrative examples for each method

Table 2 Carbon credit generation mode

How it is generated	peculiarity	channel	Actuator	example
Cap control and trading	From mandatory control, the government sets a cap on the total amount of emissions, and enterprises need to buy carbon credits if they exceed the quota, and if the emissions of enterprises are less than the quota, they can be converted into carbon credits and sold.	government, carbon trading market	EU carbon trading market, US RGGI, South Korea	Tesla sells carbon rights to gasoline car manufacturers
Voluntary carbon markets	Enterprises take the initiative to obtain carbon credits through carbon reduction, renewable energy and other projects, which can be sold or exchanged in the voluntary market.	Gold Standard, VCS, Taiwan Environmental Protection Agency's reduction and offset management mechanism	International agencies, Environmental Protection Agency	Companies earn carbon credits by supporting emission reduction programs, which can be used for carbon offsets.

Economic Benefits of Carbon Trading

Research on carbon trading indicates the successful outcomes of both the Regional Greenhouse Gas Initiative (RGGI) and EU Emissions Trading System (EU ETS) in emission reduction (Van Den Berg et al., 2014). The EU ETS, in particular, has not only facilitated an eco-friendly technological transition but has also demonstrated no adverse effects on economic performance (Zhang et al., 2020).

Challenging the conventional wisdom that the means to solve a problem cannot be the culprit, carbon trading introduces a counter-intuitive perspective. It views the factors contributing to the problem as potential solutions. This approach, exemplified by carbon trading, presents an innovative method of addressing environmental issues through capitalist means. According to a 2016 World Bank analysis, as of May 1, 2016, 90 countries were planning to implement emissions trading schemes, carbon taxes, or other policies to price carbon, indicating a global shift towards recognizing the cost of carbon emissions. With 17 existing emissions trading schemes worldwide and potential establishment of 13 more in the future, the scope of global carbon emission control is expected to widen. Emissions Trading Schemes (ETS) will emerge as a crucial policy tool for greenhouse gas management, fostering the rapid development of the corresponding carbon trading market.

ETS not only aids in reducing greenhouse gas emissions but also opens up new opportunities in green businesses. This mechanism attains emission reduction targets through commercial avenues, allowing companies to engage in buying and selling emission quantities on trading platforms. This, in turn, encourages

industry players to invest in and develop carbon reduction technologies, creating a positive cycle. Consequently, ETS not only accomplishes emission reduction goals but also propels the advancement of related technology industries.

Supply Chain Management and Carbon Footprint

Fundamentals of Supply Chain Management

At its core, Supply Chain Management (SCM) entails the comprehensive oversight of goods, data, and financial processes associated with products or services, spanning from raw material procurement to final product delivery. While some may consider the supply chain synonymous with logistics, logistics constitutes just one facet of the broader supply chain.

Introduced by American management scientist Michael Porter in 1985, supply chain management is a strategic concept with various definitions. As a strategic concept, SCM seamlessly integrates the entire spectrum of corporate activities, from raw material procurement to end-customer sales, leveraging corresponding information systems and computer management technology.

SCM involves the holistic management of material (product) flow, information flow, and capital flow, constituting a vital aspect of enterprise operational management. It typically encompasses procurement, manufacturing, logistics, and supply chain planning, along with relevant information analysis and financial management. With the evolution of economic globalization, the domain and scope of supply chain management have expanded to encompass international logistics, production outsourcing, strategic procurement, and more. This expansion aligns with a focus on global market industry operations, value chain management, and associated risk and sustainability considerations (Lee, 2011).

Quantifying Carbon Emissions

A carbon footprint signifies the volume of greenhouse gas emissions attributed to a specific individual, organization, product, or activity. Human activities, ranging from food cultivation and transportation to household electricity use, contribute to varying degrees of greenhouse gas emissions. Typically expressed as the amount of carbon dioxide per unit, examples include an individual's daily carbon footprint of 30 kilograms of carbon dioxide, Google's 2022 carbon footprint of 10.2 million tons of carbon dioxide, a Renouvo sugarcane straw with a carbon footprint of 2.83 grams of carbon dioxide, or a flight from London Heathrow Airport to New York JFK with a carbon footprint of 0.9 metric tons of carbon dioxide (Ou et al., 2013).

Calculating a carbon footprint is intricate due to numerous indirect emissions, alongside direct emissions and electricity usage. Individuals often use online calculation software to estimate average values. Meanwhile, businesses adhere to ISO14064 criteria for organizational carbon footprint calculations, ensuring a credible representation of the carbon footprint's boundary range, emission sources, activity data, and emission factors. Complying with ISO14064 standards allows organizations to disclose carbon footprint information through Environmental, Social, and Governance (ESG) reports.

To assess a product's carbon footprint, ISO14067 criteria are employed. This standard evaluates the complete product life cycle, encompassing raw material acquisition, manufacturing, transportation, product use, and end-of-life disposal. The resulting carbon footprint data, endorsed by carbon label approval organizations globally, provides a comprehensive understanding of a product's environmental impact (Lacoste, et al., 2019).

Carbon Footprint Reduction Strategies

Addressing and mitigating one's carbon footprint is a vital concern that warrants universal attention. While global leaders are tasked with comprehensive climate change initiatives, individual daily actions significantly contribute to environmental impact. Several strategies empower individuals to diminish their carbon footprint, including maintaining energy-efficient homes, minimizing food waste, adopting a plant-centric diet, reducing driving and air travel, and practicing mindful consumption habits. Despite these changes appearing modest, collective efforts yield positive environmental and climate benefits (Zheng & Suh, 2019).

Carbon Neutrality and Supply Chain Sustainability

The United Nations Global Compact (UNGC) underscores the formidable challenge businesses face in transitioning toward sustainability, particularly concerning the intricate nature of supply chains. While setting carbon neutrality and net-zero emission goals is not inherently difficult, the true challenge lies in translating these commitments into tangible actions. Managing supply chain emissions is a hurdle not exclusive to large corporations; it is equally critical for small and medium-sized enterprises (SMEs), comprising 90% of the global business population, to comprehend and implement sustainable practices. As 80% of corporate carbon emissions emanate from the supply chain, driving decarbonization within this framework becomes a pivotal concern (Zhang et al., 2023).

In industries such as cement and steel, where emissions primarily stem from the manufacturing process, the urgency to prompt supply chain decarbonization may be less pronounced. Here, a priority strategy involves reducing internal emissions and embracing renewable energy. Conversely, sectors like food, information technology, healthcare, or financial services attribute emissions mainly to "purchased products and services" and "investment." The former entails raw material procurement, presenting opportunities for emission reduction through material redesign or transitioning to recycled alternatives. The latter emphasizes incorporating sustainability performance into lending criteria within the financial industry, making it challenging for underperforming companies to secure funding.

Industries dealing with non-consumable products like oil, gas, and metals contribute significantly to Scope 3 emissions due to the substantial carbon output during the "processing of sold products" and "use of sold products," both falling under Scope 3 classifications.

Research Methods

This study adopts a case study approach to conduct an in-depth examination of the Taiwan Carbon Exchange. Employing a diverse set of research methods, including data collection, analysis, and corporate interviews, as well as questionnaire surveys with response statistics, the research aims to present a comprehensive understanding of the exchange's operations and its impact on the carbon market. Corporate interviews serve as a valuable source of firsthand insights from industry stakeholders, ensuring a practical perspective, while questionnaires broaden the participation base, capturing diverse opinions and data. Focusing on the Taiwan Carbon Exchange as the research subject facilitates a thorough analysis of the country's carbon trading landscape. The incorporation of empirical information enhances the reliability of research conclusions, providing robust support for the study's findings.

Results and Discussion

Establishment of the Taiwan Carbon Exchange

Historical Context

The official establishment of the Taiwan Carbon Exchange on August 7, 2023, marks a significant milestone for Taiwan in confronting the challenges posed by climate change. It stands as a pivotal component of Taiwan's commitment to align with the global net-zero goal. In the face of increasing global awareness of climate change threats, carbon trading markets have emerged as vital tools for addressing environmental concerns. Notably, various Asian countries, including China, Japan, South Korea, and Singapore, have already implemented their carbon exchanges. The European Union's Emissions Trading System (EU-ETS) has been in operation since 2005, the United States has its carbon trading system, and Southeast Asian nations are actively considering carbon trading in their policy frameworks. Taiwan's establishment of a carbon exchange signifies a positive stride in enhancing its emission reduction infrastructure, aligning with international standards, and progressing towards the adoption of a comprehensive carbon trading market mechanism (Lee, 2023).

Purpose and Positioning of the Establishment

The inception of the Taiwan Carbon Exchange serves a dual purpose, not only fostering international trade relations for Taiwan but also positioning the nation as an active participant in global climate risk management. Beyond these diplomatic and environmental considerations, the establishment of the Taiwan Carbon Exchange acts as a catalyst for enterprises to embrace low-carbon practices, propelling them toward accelerated sustainable development. By engaging in meticulous methodological demonstrations on both domestic and international fronts, companies can augment their carbon credits. This can be achieved through the implementation of technological solutions aimed at reducing or sequestering greenhouse gases, leveraging natural carbon sinks to mitigate or eliminate greenhouse gases, and influencing behavioral changes. Beyond serving internal consumption needs, businesses can further capitalize on their sustainability endeavors by entering the trading market, thus turning their environmental commitments into profitable ventures (Lin et al., 2015).

Modes and Mechanisms of Operation

1. Emission Rights Allocation.

Within an emissions trading scheme, a central authority or government agency takes charge of allocating or selling a predetermined quantity ("cap") of permits, each granting the holder the right to emit a specific amount of a particular pollutant over a defined timeframe. Emitters are obligated to possess permits corresponding to their actual emissions. Those seeking to increase their emissions must acquire additional permits from willing sellers. Furthermore, financial derivatives related to these emission quotas can be actively traded on the secondary market (Pan et al., 2014).

Emissions trading represents a flexible approach to environmental regulation, allowing organizations and markets the autonomy to determine optimal strategies for achieving policy objectives. This stands in contrast to more prescriptive environmental regulations like Best Available Technology (BAT) standards and government subsidies. Many economists endorse emissions trading as an efficient and effective policy tool for curbing pollutant emissions.

2. Market Trading Rules and Establishing a Carbon Trading Mechanism

The market trading mechanism of carbon credits is as follows.

Table 3 Comparison of carbon trading mechanisms

Carbon trading mechanism	introduce
Carbon credits	Carbon rights refer to the right to carbon emissions, and its design mechanism is derived from the concept of carbon pricing, which is based on 1 ton of carbon emissions. Companies and countries can calculate the total amount of carbon reduction based on this unit, which will gradually develop into a tradable product after the signing of the Kyoto Protocol. The government or private units can buy and sell carbon credits as carbon offsets.
Mandatory carbon market	Mandatory carbon markets to implement total carbon emission controls, such as EU countries, New Zealand and other countries. The amount of carbon emitted by enterprises is subject to a cap and cannot be infinitely emitted. Enterprises are committed to carbon reduction, so that carbon emissions are below the upper limit, so that carbon credits can be sold to other enterprises. If an enterprise's carbon emissions exceed the cap, it must purchase excess carbon credits from other enterprises to achieve the carbon reduction target.
Voluntary carbon markets	The voluntary carbon market is a voluntary carbon market for enterprises to take the initiative to reduce carbon emissions and capture carbon emissions, such as using renewable energy, investing in afforestation, etc. After the implementation of carbon reduction projects, enterprises apply for certification from international carbon reduction verification agencies and obtain carbon rights. It is an uncapped and non-mandatory system, allowing even companies that are not subject to government carbon emission controls to participate.

The official establishment of the Taiwan Carbon Exchange on August 7, 2023, signifies a significant stride in Taiwan's commitment to addressing climate change and aligning with the global net-zero carbon goal. In the wake of heightened global attention to climate change, carbon trading markets have emerged as pivotal tools for managing this challenge, with countries like China, Japan, South Korea, and Singapore already having established their own carbon exchanges. The Taiwan government's establishment of the carbon exchange serves a dual purpose: not only does it enhance Taiwan's role in international trade, but it also incentivizes enterprises through low-carbon dividends, fostering sustainable development. The operational framework of the carbon exchange involves the allocation of emission rights. A central authority or government agency assigns a finite number of permits, with enterprises holding corresponding carbon credits based on their emissions.

The market trading rules encompass both a mandatory carbon market and a voluntary carbon market. The mandatory carbon market regulates the overall carbon emissions allocated to enterprises, whereas the voluntary carbon market empowers enterprises to proactively engage in carbon reduction projects, gaining

carbon credits upon successful certification. These credits represent the rights to carbon emissions, conceptualized around carbon pricing, where one ton of carbon emissions equals one tradable unit—a product for carbon offsetting.

These measures are instrumental in shaping Taiwan's robust emission reduction system, promoting adherence to international standards, and advancing towards a comprehensive carbon trading market mechanism.

3. The Evolving Role of the Regulator in Carbon Trading

Currently, the Taiwan Carbon Exchange primarily focuses on delivering carbon consulting and education/training services. However, as regulations about greenhouse gas emissions reach completion, the role of carbon exchanges is poised for expansion. In the forthcoming landscape, the carbon exchange will facilitate industries across the island in proposing voluntary reduction projects and acquiring carbon emission reduction quotas. These credits will undergo transparent and open trading on the exchange, not only fostering carbon trading within China but also aiding Taiwanese companies in meeting the escalating carbon reduction demands of the global supply chain market (Lederer, 2012). The introduction of the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM) in October this year, incorporating carbon tariffs, mandates importers to procure CBAM certificates or demonstrate carbon emission payment proof for carbon-intensive goods sold to the EU. This underscores the rising expectations for corporate carbon reduction responsibilities within the global supply chain. In this context, the official listing of the Taiwan Carbon Exchange, impending carbon fee enforcement, and the establishment of a comprehensive carbon credit system are anticipated to empower Taiwanese enterprises in successfully navigating the challenges of green transformation.

Impacts and challenges

1. Corporate Engagement: A Case Study on CHIMEI's Global Carbon Trading Initiatives

In a significant move, CHIMEI declared its participation in Climate Impact X (CIX), a prominent global carbon trading platform based in Singapore, back in April of this year. This milestone positions CHIMEI as one of the few Taiwanese companies actively engaged in the international carbon trading market and notably the first Taiwanese company to successfully conduct carbon trading and offsetting on the CIX platform. The company, renowned for its "Clean & Green" commitment, further solidified its dedication to global carbon neutrality trends.

Marking another achievement, CHIMEI procured 10,000 tons of carbon credits from forest conservation projects in Cambodia and Peru, a noteworthy step in its pursuit of sustainable practices. These acquired carbon credits, certified by the Verified Carbon Standard (VCS), adhere to various United Nations Sustainable Development Goals (SDGs), including initiatives promoting local women's employment, ensuring clean water resources, and supporting biodiversity.

The intended utilization of these carbon credits by CHIMEI is to offset the carbon emissions stemming from internal employees' daily commuting and business travel spanning 2021 to 2025. Notably, the company has already successfully offset a total of 1,416 metric tons of carbon emissions in 2021, underscoring its commitment to operational sustainability.

Despite ongoing international debates on the legitimacy of companies purchasing carbon credits for offsetting, CHIMEI remains steadfast in seeking solutions that contribute to global greenhouse gas reduction. By actively participating in the voluntary carbon market, the company aims to take proactive responsibility for its carbon emissions, aligning with broader sustainability objectives on a global scale (Chimei Cooperation, 2022).

2. Government Policy Facilitation for Carbon Trading in Taiwan

Taiwan's Environmental Protection Agency (EPA) recently outlined the future trajectory of carbon trading in the country, unveiling plans centered around the Taiwan Carbon Rights Exchange and the EPA's matchmaking trading platform. This comprehensive approach aims to address carbon trading and Environmental Impact Assessment (EIA) incremental offsets for both enterprises and government entities. To further assist businesses in navigating carbon-related intricacies, the Environmental Protection Department has established a dedicated hotline to promptly address inquiries (Huang & Wu, 2009).

The current domestic demand for carbon credits in Taiwan falls into two primary categories. Firstly, there's the incremental offset mandated by EIA regulations, and secondly, voluntary initiatives by enterprises aiming for carbon neutrality due to factors like Environmental, Social, and Governance (ESG) sustainability promotion. Projects such as Zhuke Baoshan, Zhongke Expansion, and the establishment of industrial parks by the Ministry of Economic Affairs already require substantial annual carbon credits. As Taiwan's carbon trading landscape evolves, the demand for carbon credits is anticipated to surge.

The EPA's strategy involves categorizing Taiwan's carbon allowance exchange into two types: domestic reduction quota and international reduction quota. The domestic reduction quota is earmarked for domestic trading, primarily catering to enterprises with EIA offset requirements to prevent carbon price manipulation. In contrast, the international reduction quota will serve industries pursuing their carbon reduction goals. The carbon credit exchange will meticulously vet and provide high-quality carbon credits, validated by relevant units, to prevent duplicate trading. Simultaneously, the EPA will introduce a matchmaking trading platform to address specific needs such as the transition from old fuel vehicles and locomotives to electric alternatives. This initiative aims to facilitate developers with EIA needs in securing stable and cost-effective carbon credits.

To disseminate accurate carbon reduction information encompassing aspects like carbon inventory, inspection, carbon fee collection planning, the EU's Carbon Border Adjustment Mechanism (CBAM), carbon sinks, carbon rights, and carbon trading, the Environmental Protection Department has established a dedicated hotline and email service. Five telephone lines are operational during working hours to promptly respond to pertinent questions from enterprises and the public.

Carbon Trading and Supply Chain Management Practices of Taiwanese Enterprises

Corporate Engagement and Impact in Carbon Trading

In a significant move towards addressing carbon emissions, the Taiwan Carbon Rights Exchange recently inaugurated the "International Carbon Rights Trading Platform." This platform, featuring seven carbon rights products accredited by the international independent carbon rights issuing agency "Gold Standard" (GS), witnessed active participation from 27 Taiwanese companies on its launch day. Notable participants include industry giants like TSMC, Sinosteel, and private financial entities. The inaugural trading session resulted in an

international carbon rights trading volume of 88,520 metric tons, translating to a total transaction value of approximately $800,000 (equivalent to NT$24 million) (Han, et al., 2023).

Expressing satisfaction with the enthusiastic response, Sherman Lin, Chairman of the carbon exchange, highlighted the significance of this initiative. While the initial participation primarily comprised large enterprises, the carbon exchange aims to extend support to small and medium-sized enterprises (SMEs). By eliminating the need for SMEs to open cross-border accounts for acquiring carbon rights, the exchange seeks to reduce trading costs and facilitate the broader goal of achieving industrial carbon neutrality (TCX, 2023).

Carbon Trading's Integration and Influence on Supply Chain Management

The impact of the Taiwan Carbon Exchange has reverberated positively throughout supply chain management, steering enterprises toward environmentally sustainable practices. The establishment of carbon exchanges acts as a catalyst, urging companies to proactively address their carbon emissions, thereby significantly influencing the environmental sustainability of the entire supply chain. The presence of carbon exchanges motivates companies to actively curtail carbon emissions to lower carbon trading costs. This impetus to reduce emissions directly shapes a company's approach to supply chain management, fostering a more eco-friendly and sustainable strategy. Companies extend their focus beyond internal carbon emissions, encouraging suppliers and partners to engage in emission reduction initiatives, collectively forging an environmentally responsible supply chain system.

Furthermore, carbon exchanges establish an equitable marketplace for carbon trading, ensuring that the cost of carbon is transparently reflected in product prices. Consequently, supply chain management necessitates a more meticulous evaluation of suppliers, considering their carbon footprint and environmental practices. This paradigm shift challenges the conventional emphasis solely on cost, compelling companies to holistically integrate environmental considerations into their supply chain decision-making.

Ultimately, the operation of the carbon exchange prompts companies to institute proactive internal carbon management measures. These measures encompass the adoption of emission reduction technologies and enhancements in energy efficiency. Beyond reducing carbon costs, these internal initiatives enhance enterprise competitiveness within the supply chain, positioning companies favorably in the carbon trading market (TCX, 2023).

Carbon Trading Triumphs and Trials

Since its launch on August 7, the Taiwan Carbon Exchange has celebrated its initial success with the completion of the first batch of carbon credit trading on December 22. The inauguration of the international carbon credit trading platform witnessed the active participation of 27 prominent enterprises, including industry leaders such as TSMC, Hon Hai, CLP, and Yushan Gold. The estimated first-day turnover exceeded $800,000, with the financial holding industry emerging as the largest contributor.

Sherman Lin, the chairman of the carbon exchange, highlighted the global development of the international carbon pricing mechanism, with various countries actively establishing carbon trading platforms. Yushan Financial Holdings, a participant in the first batch, declared its commitment to achieving a net-zero goal by 2050. Through the purchase of 5,000 tons of carbon credits, the company plans to offset the carbon footprint associated with its buildings, zero-carbon credit cards, zero-carbon ATMs, and financial products and services.

Yushan Financial Holdings has been proactive in environmental initiatives since 2017, implementing ISO14064 greenhouse gas inventories across its domestic and foreign business bases. The company has embraced green building concepts, utilized low-pollution materials, adopted energy-efficient appliances, and promoted water-saving practices. In the credit card sector, Yushan Financial Holdings has achieved carbon neutrality for new credit cards issued yearly since 2019, with plans to transition all cards to zero-carbon status by 2025. Moreover, the company obtained carbon footprint certification for ATM transactions in 2023, making every transaction at Yushan ATMs a carbon-neutral, green initiative.

Chen Maoqin, the general manager of Yushan Financial Holdings, expressed optimism about the new milestone in carbon trading. Recognizing the market mechanism's crucial role in achieving net-zero goals, he pledged to continue promoting industry-wide net-zero transformations through financial guidance, leveraging financial influence, and collaborating with customers and partners to build a sustainable and carbon-neutral future (Yao, 2023).

Questions and Suggestions

Addressing Challenges and Seeking Solutions

Despite the successful launch and completion of the first batch of carbon trading on August 7 by the Taiwan Carbon Exchange, there are notable areas of concern demanding attention. Firstly, the participation of 27 companies, including industry giants like TSMC, Hon Hai, and CLP, raises questions about whether it adequately represents the comprehensive involvement of various industry leaders in achieving carbon neutrality objectives. Secondly, the projected turnover of the carbon trading market at $800,000 appears relatively modest compared to the global carbon trading market, potentially impacting its competitiveness on a global scale. Furthermore, the practical implications of companies utilizing carbon offsets through carbon rights on their internal operations and sustainable development are yet to be thoroughly observed (TCX, 2023).

Charting the Future Trajectory of Taiwan's Carbon Trading

After a successful inauguration, the Taiwan Carbon Exchange is poised to overcome challenges and chart a more expansive and competitive course. To bolster future development, the exchange should proactively align with global carbon market trends, fostering collaborations with international carbon trading platforms to attract wider participation from global enterprises and investors. Emphasizing the inclusion of small and medium-sized enterprises (SMEs) will diversify carbon neutrality practices.

To invigorate the market, a commitment to innovation in trading mechanisms is essential. Introducing additional financial instruments linked to the carbon market will enhance transparency and stability in carbon prices. Collaboration between carbon exchanges and governments is recommended for the formulation of clear regulations and policies, establishing a standardized and secure carbon trading environment. Strengthening the credibility of the carbon market will attract more enterprises, positioning the Taiwan Carbon Exchange as a key player regionally and globally.

In a final strategic move, fostering close collaboration with enterprises and environmental protection organizations will empower the Taiwan Carbon Credit Exchange to offer comprehensive carbon-neutral solutions. This collaborative model incentivizes enterprises to integrate carbon offsets into their core business

operations, advancing corporate sustainability objectives. Through such synergistic efforts, Taiwanese companies can achieve substantial progress in addressing climate change, elevating the Taiwan Carbon Exchange to a prominent position in global green finance.

Proposals for Government and Corporate Responses:

To address the identified challenges, proactive measures are recommended. The carbon credit exchange should undertake extensive publicity efforts, promoting the diversification of the carbon trading market by attracting industries beyond manufacturing and finance. The creation of additional carbon credit trading platforms will enhance market vibrancy, enticing a broader spectrum of enterprises to engage in carbon neutrality initiatives. Encouraging enterprises to actively integrate carbon offsets into their internal operations post-acquisition of carbon credits is crucial for driving genuine green transformations. This step aligns the possession of carbon credits with tangible actions that foster sustainability within enterprises. Government and environmental protection agencies play a pivotal role by providing comprehensive support, including supervisory measures for the carbon market and strategic policy guidance. This collaboration ensures seamless operation and sustained development of carbon exchanges. These recommendations aim to optimize the functionality of the carbon credit exchange, empowering it to catalyze meaningful change in the carbon market. By aligning with these proposals, Taiwanese enterprises can navigate toward a more sustainable future (TCX, 2023).

Conclusion

Study Summary

The inauguration of the Taiwan Carbon Exchange stands as a pivotal advancement in Taiwan's response to the climate crisis. The enthusiastic participation of prominent enterprises, including industry leaders like TSMC, Hon Hai, and CLP, underscores the business community's profound commitment to carbon reduction and sustainable development. This initial success in domestic carbon trading showcases tangible outcomes at the enterprise level, reflecting Taiwanese companies' dedication to achieving net-zero goals.

To chart the future course of the carbon market, the Taiwan Carbon Exchange is urged to fortify international collaborations, actively integrating into the global carbon market system for enhanced competitiveness. Collaborative efforts with the government are pivotal in establishing standardized carbon market regulations, fostering transparency, and ensuring market stability. The exchange should strategically diversify market participants, with a particular focus on engaging small and medium-sized enterprises, injecting vitality into the carbon market.

Crucially, through symbiotic partnerships with enterprises and environmental protection agencies, the Carbon Exchange can offer comprehensive carbon-neutral solutions. By facilitating the translation of carbon reduction measures into actionable initiatives, the exchange is poised to propel Taiwanese enterprises towards substantial achievements in sustainable development. This holistic approach aims to position the Taiwan Carbon Exchange as a global leader in green finance, contributing significantly to the planet's sustainable future.

Academic Contributions

This study delves into the establishment and operational intricacies of the Taiwan Carbon Exchange, offering not just on-the-ground insights into carbon trading market development but also contributing valuable empirical data to the academic realm. Firstly, it scrutinizes the global carbon trading market's international trends, shedding light on countries' responses to climate change challenges, and serving as a crucial reference for global carbon market studies. Secondly, by analyzing specific cases, the research provides an in-depth examination of Taiwan's carbon exchange operation mode and associated policy measures, offering scholars concrete insights for carbon market planning and development. Lastly, the identified issues and suggestions for the carbon exchange serve as enlightening contributions, guiding future academic research directions.

This research is poised to enrich the academic community's comprehension of the carbon trading market and furnish abundant materials for subsequent in-depth investigations in related fields. Future research endeavors are anticipated to delve deeper into aspects such as the carbon market's regulatory environment, market participant behavior patterns, and the tangible impact of the carbon market on enterprises' sustainable development. This comprehensive perspective aims to explore the evolution of the carbon trading market and its broader implications for climate change response.

Practical Implications:

The study outcomes carry significant practical implications for the application of carbon exchanges. Firstly, the success of Taiwan's carbon exchange underscores the feasibility and importance of other nations or regions establishing carbon trading mechanisms. By introducing a carbon market, governments, enterprises, and investors can actively engage in climate change prevention and control, working towards more ambitious carbon reduction objectives. Secondly, findings indicate that companies like Taiwan's Yushan Financial Holdings, committed to net-zero targets and achieving carbon neutrality through carbon credit purchases, not only foster the growth of green finance but also enhance their competitive edge in sustainable development. Lastly, the burgeoning carbon trading market opens up new business prospects. Financial institutions engaging in carbon credit trading and companies specializing in carbon inventory and emission reduction technologies stand to capitalize on growth opportunities in this emerging sector.

In summary, the study's results offer tangible suggestions for the practical application of carbon trading. These insights hold reference value for government agencies shaping policies and provide concrete, viable directions for enterprises developing sustainable strategies. This, in turn, can expedite the advancement of carbon markets and catalyze broader initiatives to combat climate change.

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR
VOL.3, NO.1; JAN. – MAR.; 2024, ISSN 2822-0412 (Online)

Exploring the Implementation of the 7Ps in Guangdong's MBA Education Programs: A Comprehensive Study

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Received: August 26,2023 / Revised: March 27, 2024 / Accepted: April 3, 2024
Doi: 10.14456/scsr.2024.10

Abstract

This paper applies the 7Ps marketing strategy to optimize MBA education marketing in Guangdong, China, covering product, price, place, promotion, people, physical evidence, and pre-interview aspects. The core product focuses on doctoral program application, subject assessment, and international accreditation, with tangible products emphasizing brand building, practical activities, and rankings. Additional offerings include enhancing internationalization, increasing student cohesion, providing life-oriented services, establishing an alumni management model, and improving service levels. Pricing aims for reasonability over being the lowest, while optimization of place involves physical, virtual, and hybrid channels. Promotion strategies include an all-staff approach, PR enhancement, word-of-mouth marketing, and media synergy. Management extends to faculty, staff, mentors, counselors, and committee members. Creating professional enrollment materials is emphasized, alongside pre-interview promotion and teaching MBA students marketing skills, reflecting the globalization context for tailoring marketing strategies.

Keywords: Marketing Strategy, MBA study, 7Ps, Master of Business Administration

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Introduction

Over the past decade, China's economy has experienced continuous growth, attracting increasing global attention. In 2011, China's GDP reached $7.55 trillion, precisely $7,551,545,321,799, accounting for 10.2211% of the world's GDP. By 2022, China's GDP surpassed the milestone of $17.96 trillion, precisely $17,963,170,521,079, representing 17.8628% of the world's GDP. As a result, China has become the world's second-largest economy. According to the United Nations Conference on Trade and Development, China emerged as the largest recipient of global foreign direct investment (FDI) in 2020, attracting a capital inflow of $163 billion. With its rapid economic development, China is increasingly recognized as the largest international education market globally (Zreik, 2023).

Due to its open policies and ongoing economic reforms, China has consistently sustained an average GDP growth rate of over 9% for the past two decades (Morrison, 2002). The swift development of the Chinese economy and its further integration into the global market create an urgent demand for qualified professionals with Master of Business Administration (MBA) credentials to contribute to China’s economic prosperity (Newell, 1999; Shi, 2000; Southworth, 1999). However, Chinese higher education institutions are fundamentally incapable of meeting the demand for managerial talent, resulting in a significant gap between supply and demand that presents a vast market for MBA education.

Table 1 GDP Data for China from 2011 to 2022

years	GDP (US Dollar)	% of the world
2011	7.55 trillion (7,551,545,321,799)	10.2211%
2012	8.53 trillion (8,532,185,615,746)	11.2970%
2013	9.57 trillion (9,570,470,577,244)	12.3275%
2014	10.48 trillion (10,475,624,783,235)	13.1345%
2015	11.06 trillion (11,061,573,199,439)	14.7066%
2016	11.23 trillion (11,233,314,018,690)	14.6867%
2017	12.31 trillion (12,310,491,176,727)	15.1156%
2018	13.89 trillion (13,894,907,485,398)	16.0631%
2019	14.28 trillion (14,279,968,485,748)	16.2775%
2020	14.69 trillion (14,687,743,556,969)	17.2361%
2021	17.82 trillion (17,820,459,342,451)	18.3939%
2022	17.96 trillion (17,963,170,521,079)	17.8628%

Since the early 1990s, MBA education in Mainland China has experienced rapid development. In 1991, the establishment of a National MBA Coordinating Group led to the implementation of pilot MBA courses. Initially, nine universities were authorized to offer a total of 86 pilot MBA courses (Wang, 1999). Subsequently, an additional 17 universities were included in this experimental initiative, resulting in a total of 26 universities eligible to provide MBA education in China by 1993. Given the general lack of specialized knowledge and teaching materials for MBA education in Chinese higher education institutions, many of these experimental universities sought assistance from foreign counterparts. Notably, Nanjing University collaborated with the University of Missouri-Columbia, Tsinghua University received support from the University of Western Ontario, and Peking University partnered with Fordham University.

Understandably, many Chinese MBA programs initially incorporated Western curricula into their courses (Shi, 2000). By 2002, Guangdong's MBA education transitioned from the experimental stage to a developmental stage, with 62 universities authorized to offer MBA courses, among which 30 universities were approved to provide Executive Master of Business Administration (EMBA) courses. By 2022, the number of institutions offering MBA education in China had reached 277. Enrollment numbers surged from less than 30,000 in 2011 to 50,000 in 2022. The MBA journey in China has evolved from nonexistence to significance, from modest beginnings to substantial scale, and from relative obscurity to being a sought-after dream for millions of candidates. MBA programs have significantly contributed to society by nurturing a substantial number of middle and senior-level management professionals.

Table 2 Provincial MBA Program Applicants and Admissions from 2011 to 2023

Years	Number of applicants	Number of admissions	Admission ratio
2011	90614	29736	32.82%
2012	106862	28931	27.07%
2013	123017	32625	26.52%
2014	128299	31944	24.90%
2015	122016	30363	24.88%
2016	109580	24642	22.49%
2017	142389	35112	24.66%
2018	170096	38915	22.89%
2019	204160	40000	27.00%

Table 2 (Cont.)

Years	Number of applicants	Number of admissions	Admission ratio
2020	about 22 0,000	42315	26.45%
2021	about 230,000	about 50000	about 27.78%
2022	about 25000	about 50000	About20%
2023	about 250,000	about 51842	About20%

With the burgeoning landscape of MBA education in China, students now have an array of programs to choose from, ranging from those offered by prestigious "Double First Class" universities to local institutions. Additionally, students can consider various types of programs such as Professional Master, Academic Master, and Executive Master of Business Administration, among others. Consequently, marketing challenges in MBA education are inevitable. In China, the entrance to MBA programs typically follows a unified examination system, where students must undergo nationwide entrance examinations and interviews for admission. Moreover, the Chinese MBA landscape incorporates a pre-interview marketing model, with some universities offering students the chance to participate in interviews before the national entrance exam, potentially leading to direct admission.

Notably, Guangdong's MBA admission criteria include specific work experience requirements. Applicants must possess a bachelor's degree with three years of work experience, an associate degree with five years of work experience, or a graduate degree with two years of work experience to be eligible for the MBA program. These criteria differ from those of many foreign universities, highlighting the need for tailored marketing strategies that may not be universally applicable across different countries and timeframes.

This research aims to leverage the 7Ps framework within the context of China's specific circumstances to explore effective MBA marketing strategies. Its objective is to offer valuable insights for marketing MBA education in China and serve as a reference for future marketing endeavors in this domain.

Literature Review

The marketing mix refers to a set of controllable marketing tools that an institution employs to elicit the desired response from its diverse target markets (Ivy, 2008). Grönroos (1997) introduced the concept of the 4Ps marketing mix, which includes product, price, promotion, and place (distribution). Booms and Bitner (1981) extended the 4Ps marketing mix to 7Ps by adding participants, processes, and physical evidence. Kotler (1986a, 1986b) augmented the 4Ps with political power and public opinion, evolving it to the 6Ps. Baumgartner (1991) expanded the marketing mix to 15Ps, incorporating elements such as product/service, price, promotion, place, people, politics, public relations, probe, partition, prioritize, position, profit, plan, performance, and positive implementations.

Goldsmith (1999) introduced the personalized "P" to reflect the trends of the internet era, studying the 8Ps marketing mix, which encompasses McCarthy's 4Ps, personalization, and the 3Ps of service path: personnel, physical assets, and procedures. Ivy (2008) investigated MBA education in the South African region using a 7Ps marketing mix: people, promotion, price, program, prominence, prospectus, and premiums. Kotler and Keller (2012) explored a 4P+4P marketing mix, incorporating product, price, promotion, place, people, processes, programs, and performance.

John et al. (2023) studied the MBA landscape in the Indian region, referencing Ivy's 7Ps marketing mix and proposed a 10Ps marketing mix, including people, promotion, price, program, prominence, prospectus, premiums, pass-rate, placements, and probity. These various marketing mix strategies have emerged based on different geographical regions and research subjects. However, as the world's second-largest economy, China has made significant strides in MBA education, necessitating the development of a marketing mix strategy tailored to the unique Chinese context (Tabelessy et al., 2023).

This article was chosen due to its comprehensive exploration of MBA marketing strategies through the lens of the 7Ps framework: product, price, place, promotion, participants, physical evidence, and pre-approval interview. By encompassing these key components, the article provides a holistic understanding of the marketing dynamics within the MBA education sector. The inclusion of these factors allows for a thorough analysis of how MBA programs are positioned, priced, promoted, and perceived by various stakeholders. Additionally, the consideration of participants and pre-approval interviews sheds light on the importance of engaging with prospective students and addressing their needs throughout the enrollment process. To analyze and synthesize this article effectively, one can scrutinize each P individually to assess its impact on MBA marketing strategies while also synthesizing the interactions and interdependencies between these elements. By critically evaluating how each aspect contributes to the overall marketing mix, one can glean valuable insights into optimizing MBA education marketing efforts and enhancing student enrollment experiences.

Methodology

The research methodology employed in this study involved conducting in-depth interviews with participants. These interviews were conducted multiple times, typically ranging from 3 to 4 sessions or more, depending on the depth of understanding required and the complexity of the research questions. This multi-session approach allowed researchers to delve deeply into participants' perspectives, experiences, and insights, facilitating a comprehensive exploration of the research topic.

To ensure the suitability and reliability of the information gathered from these interviews, several measures were implemented. Firstly, interview participants were carefully selected based on their expertise, experience, and relevance to the research topic. This helped ensure that the information provided was accurate and insightful. Additionally, interview questions were designed to be open-ended and flexible, allowing for detailed exploration of key themes and issues. This approach encouraged participants to share their perspectives freely, contributing to the richness and depth of the data collected.

Furthermore, techniques such as member checking and triangulation were utilized to verify the consistency and validity of the information obtained from the interviews. Member checking involved sharing

preliminary findings with participants to confirm their accuracy and relevance, while triangulation involved cross-referencing information from multiple sources to corroborate key findings. By employing these rigorous methods, the study was able to confirm the results obtained from the in-depth interviews and enhance the overall reliability of the research findings.

Design of Interview Questions

To gain a comprehensive understanding of the perspectives of MBA education administrators and students regarding marketing strategies in the Chinese context, this study employed a combination of face-to-face and telephone interviews. These interviews were designed to explore the viewpoints of both MBA administrators and students regarding marketing strategies within the realm of Chinese MBA education. The interview questions were structured around two primary levels of inquiry: firstly, participants' perceptions and recommendations concerning marketing in Chinese MBA education, and secondly, their insights and suggestions regarding the future development of MBA education in China.

Interview Process and Method

To determine the number of samples and how many students each, several factors need consideration, including the research scope, diversity of perspectives, and feasibility. In this study, purposive sampling was employed to select five universities in Guangdong Province, China, namely Guangdong University of Finance and Economics, Guangzhou University, Guangdong University of Technology, Guangdong University of Foreign Studies, and South China Normal University. A total of 10 administrators and 20 MBA students participated in the in-depth interviews.

The number of samples, particularly the breakdown of administrators, was determined based on the need for qualitative analysis and representation from different administrative roles within the universities. In this case, 10 administrators were selected, including 5 deans (including associate deans), 4 department heads, and 1 lecturer, to ensure diverse perspectives from key decision-makers and influencers in MBA education.

For student participants, the number was determined to ensure a balanced representation across the selected universities and to capture a variety of perspectives and experiences. With 20 MBA students selected, an average of 4 students were included from each university, ensuring a reasonable sample size while maintaining diversity in participant demographics and program experiences.

The actual interview questions related to the marketing mix 7Ps were tailored to elicit insights from both administrators and students regarding their perceptions, experiences, and suggestions for MBA enrollment strategies and program satisfaction. For administrators, questions focused on effective enrollment strategies, perceptions of Chinese MBA programs, and future development trajectories. For students, questions explored aspects of their chosen MBA programs that appealed to them, anticipations, satisfaction levels, and suggestions for program enhancement. These questions aimed to gather comprehensive insights into the marketing dynamics of MBA education in the Chinese context.

Results

Through in-depth interviews with 10 administrators and 20 MBA students, comprehensive discussions were conducted to gather insights into promoting the Chinese MBA education market. Following the compilation and organization of their opinions and recommendations, the resulting 7Ps marketing mix for promoting the Chinese MBA education market is as follows:

Figure 1 Diagram of MBA 7Ps Marketing Mix

Product

Product refers to a combination of goods that individuals acquire through purchases to fulfill specific needs and desires. It serves as the focal point of a company's marketing efforts, aligning societal demands with business provisions. Products play a crucial role in a company's competitiveness, necessitating continuous updates to cater to evolving market needs. Thus, having a superior product is essential for effective marketing. The success of a product strategy hinges on its correctness and effectiveness once introduced to the market. The overall product encompasses three levels: the core product, tangible product, and augmented product.

1. Core Product

The core product refers to the fundamental utility or benefit that a product provides. It represents the ultimate need of customers and holds their highest value. The core product addresses customers' genuine needs and real intentions. It forms the most fundamental level of a product, satisfying customers' essential requirements – the tangible essence of what customers purchase. For MBA education, the core product is the construction of the MBA discipline. By studying for an MBA, individuals accumulate knowledge and enhance

their educational qualifications, thus boosting their core competitiveness. Achieving breakthroughs in MBA discipline construction requires an emphasis on doctoral program applications, subject evaluations, and international accreditation.

The presence of doctoral programs in business administration significantly influences candidates' willingness to apply to MBA education institutions in China. Some students view an MBA as a stepping stone toward a future doctoral degree, considering it comparatively easier to obtain than other master's degrees. Institutions offering doctoral programs are more attractive to these students. Therefore, MBA education institutions must prioritize the development of doctoral programs in business administration as a crucial initiative. In Guangdong Province, there are a total of 5 institutions with doctoral programs in business administration: Sun Yat-sen University, South China University of Technology, Jinan University, South China Agricultural University, and Guangzhou University. However, regular undergraduate universities such as Guangdong University of Finance and Economics, Guangdong University of Foreign Studies, and Guangdong University of Technology do not offer doctoral programs in this field.

Table 3 List of Colleges and Universities with Doctoral Programs in Business Administration in Guangdong Province

serial number	School Name	status of the doctoral curriculum
1	Sun Yat-sen University	Sun Yat-sen University has a doctoral program for first-level disciplines in business administration and 5 doctoral programs for second-level disciplines in business administration
2	South China University of Technology	South China University of Technology has doctoral programs in the first level disciplines of business administration and three doctoral programs in second-level disciplines in business administration
3	Jinan University	Jinan University has a doctoral program for first-level disciplines in business administration and 7 doctoral programs for second-level disciplines in business administration

Table 3 (Cont.)

serial number	School Name	status of the doctoral curriculum
4	South China Agricultural University	South China Agricultural University has doctoral programs in the first-level disciplines of business administration and 5 doctoral programs in the second-level disciplines in business administration
5	Guangzhou University	Guangzhou University has doctoral programs in the first-level disciplines of business administration and 4 doctoral programs in the second-level disciplines of business administration

2. Subject Evaluation

Subject evaluation plays a pivotal role in assessing discipline construction levels, diagnosing developmental issues within a field of study, and measuring the quality of talent cultivation. It also serves as a robust means to promote the development of China's distinctive theoretical and discourse systems, playing a vital role in the principles of "promoting construction through evaluation" and "promoting improvement through evaluation." In the initial national professional degree level evaluation, Guangdong University of Foreign Studies, Guangdong University of Technology, and Guangdong University of Finance and Economics were graded as B-, C, and C, respectively, for their MBA programs.

In the assessment of MBA programs across various institutions, Sun Yat-sen University received an A rating, indicating a high level of achievement. South China Technology University's assessment is not available. Jinan University and South China Agricultural University also lack assessment information. Shantou University received a C rating, while South China Normal University was rated slightly higher at C+. Shenzhen University obtained a B rating. Guangdong University of Finance and Economics received a C rating, while Guangzhou University's assessment status is not provided. Guangdong University of Technology received a C rating, and assessment information for Guangdong University of Foreign Studies is not provided.

3. International Accreditation

Established in 1967, the Association of MBAs (AMBA) is recognized as one of the three authoritative global international accreditation systems for business education, alongside the Association to Advance Collegiate Schools of Business (AACSB) and the European Quality Improvement System (EQUIS). AMBA is an international accreditation system exclusively focused on MBA programs, emphasizing the development of business, and MBA programs, emphasizing the development of business and management practices. It aims to assist member institutions in progressing from success to excellence.

For business schools, achieving AMBA accreditation signifies international recognition of their educational standards, particularly the teaching quality of their MBA programs. For MBA students and alumni,

the value of their degrees is significantly elevated. For employers, choosing graduates from accredited institutions indicates a higher level of quality assurance.

Table 4 International accreditation of MBA colleges in Guangdong Province

serial number	institutions	AACSB	EQUIS	AMBA
1	Sun Yat-sen University	certified	certified	Certified
2	South China Technology University	certified	Pass certification eligibility assessment	Certified by AMBA
3	Jinan University	About to be certified	not yet started	certified
4	South China Agricultural University	not yet started	not yet started	BGA member
5	Shantou University	not yet started	not yet started	BGA member
6	South China Normal University	not yet started	not yet started	BGA member
7	Shenzhen University	enter the final stage	not yet started	Starting certification
8	Guangdong University of Finance and Economics	member	not yet started	BGA member
9	Guangzhou University	turning on	not yet started	Starting certification
10	Guangdong University of Technology	member	not yet started	BGA member
11	Guangdong University of Foreign Studies	member	starting	Certified by AMBA

The landscape of subject development within MBA education institutions in China faces numerous challenges, including a shortage of academic leaders, limited national-level research projects, inadequate platforms and teams at the national level, and a scarcity of articles in top international journals. Subject development, being a cornerstone of institutional growth, requires comprehensive efforts and long-term commitment. It encompasses seven key modules: ideological and political education, talent cultivation, faculty team enhancement, scientific research advancement, platform establishment, international exchange promotion, and institutional mechanism refinement. Addressing these challenges and investing in these modules are essential for the sustainable development and advancement of MBA education institutions in China.

4. Optimization of Tangible Products

Tangible products refer to the specific forms or ways in which a product is presented to achieve the desired satisfaction in the target market. These mainly include branding, practical activities, rankings, and more. Burton Clark's perspective that "decentralized control leads to university competition, where the focus of competition is obtaining relative reputation. Once reputation is established, it becomes the university's most unique and valuable resource" is equally applicable to the MBA education market. The reputation of MBA institutions is reflected in the brand's recognition, reputation, and loyalty. Building and continuously enhancing the reputation of MBA education is a systematic process involving innovative concepts, curriculum design, faculty strength, management quality, and service standards. Branding efficiently transforms resources into value and gains customer recognition. This signifies quality and reputation assurance, guides consumer choices, and also serves a profit-oriented function. To enhance the brand image of Chinese MBA education institutions, breakthroughs should be made in branding, distinctive activities, and rankings.

5. Branding

"Brand is quality" and "Brand is vitality." As MBA education reform deepens, establishing an MBA education brand is an essential path for the development of every cultivating institution. The MBA brand serves as a crucial channel to enter the student and employment markets. Establishing a brand can secure the future of MBA education. A renowned MBA education brand not only attracts potential high-quality students but also contributes to fostering excellent talent and facilitating re-employment among students. It drives the overall development of MBA education. The importance of branding is evident across various aspects such as enrollment, education, and employment.

6. Practical Activities

MBA education encompasses more than just academic courses. Schools leverage their resources to provide students with abundant practical opportunities. Monthly financial forums or entrepreneurship salons, inviting practicing mentors and entrepreneurs to campus for exchanges, facilitate the sharing of practical experiences in entrepreneurship and management.

7. Rankings

Currently, multiple media-driven MBA education rankings have emerged in China. These include "China's Most Influential MBA Rankings" co-hosted by the World Manager Weekly and Chief Executive Officer

magazine, "China's Best MBA Rankings" launched by Manager magazine, and "Most Market-Valued MBA" by Fortune (Chinese edition).

8.Additional Products

This is the third level of the overall product, referring to the additional services or benefits that customers receive when purchasing a product. These can include offerings such as credit provision, free delivery, installation, maintenance, returns, and after-sales services. Modern market competition not only revolves around what products are produced and sold but also the nature of the additional services and benefits provided. While past market competition mainly focused on the competition of the product itself, today it also encompasses the competition of services.

The teaching of MBA programs condenses the management experiences of top business leaders into a two-year curriculum, providing students with exposure to various aspects of business management. It equips them with tools and frameworks for making a range of decisions, nurturing the future leaders of the corporate world. In addition to this, if MBA institutions can offer extra value beyond the core program, these "surprises" can impact the choices of MBA applicants. The additional value of MBA education includes opportunities for international exchanges, membership in alumni clubs, and networking events.

Price

Price is not merely the tuition fee figure presented by MBA institutions. A reputable MBA education provider will seek ways to reduce or eliminate psychological costs associated with pricing. Chinese MBA education institutions should adhere to rational pricing rather than a strategy of lowest pricing. The concept of the lowest pricing might even be perceived as top by MBA applicants as a passive choice made due to the lack of innovative value-added measures by the MBA institution. The author suggests that maintaining the price of MBA programs within two-thirds of the fees of local universities is competitive. Adjustments in pricing can be implemented gradually, following a "take small steps without stopping" approach. Additionally, setting up a range of scholarship policies can attract candidates, contributing to brand enhancement.

Comparing the tuition fees of various universities in Guangdong Province over the past four years, it is evident that among the 10 local institutions, 9 MBA programs have made adjustments in their fees. Specifically, in 2020, five institutions adjusted their fees, followed by two institutions in 2021.

Table 5 Statistics on Part-time MBA Tuition Fees of Colleges and Universities in Guangdong Province from 2019 to 2022

	School	Part-time MBA Tuition Fee (RMB) and Academic Length			
		2019	2020	2021	2022
1	School of Management, Sun Yat-sen University	255,000/ 3 years	255,000/ 3 years	255,000/ 3 years	318,000/ 3 years
2	Lingnan College of Sun Yat-sen University	255,000/ 3 years	255,000/ 3 years	255,000/ 3 years	268,000/ 3 years

Table 5 (Cont.)

	School	Part-time MBA Tuition Fee (RMB) and Academic Lengt			
		2019	2020	2021	2022
3	School of Technology South China University	200,000/ 3 years	200,000/ 3 years	200,000/ 3 years	200,000/ 3 years
4	Jinan University	155,000/ 3 years	200,000/ 3 years	298,000/ 3 years	298,000/ 3 years
5	Shenzhen University	118,000/ 3 years	198,000/ 3 years	198,000/ 3 years	198,000/ 3 years
6	South China Normal University	135,000/ 3 years	135,000/ 3 years	168,000/ 3 years	168,000/ 3 years
7	Guangdong University of Foreign Study	108,000/ 3 years	138,000/ 3 years	168,000/ 3 years	168,000/ 3 years
8	Guangdong University of Finance and Economics	100,000/ 2.5 years	100,000/ 2.5 years	120,000/ 2.5 years	168,000/ 3 years
9	Shantou University	108,000/ 3 years	108,000/ 3 years	120,000/ 2.5 years	120,000/ 2.5 years
10	Guangdong University of Technology	75,000/ 3 years	108,000/ 3 years	135,000/ 3 years	135,000/ 3 years

Place

The distribution strategy holds significant importance within the broader marketing framework, impacting cost reduction and competitive advantage enhancement. As market dynamics evolve, so do marketing channels, necessitating adaptations to meet changing consumer behaviors. In the context of Chinese MBA education, where 72% of candidates rely on recommendations from peers and 25% utilize media websites for information gathering, optimizing media channels and strengthening connections with referrals and coaching organizations become paramount. This integration of internal and external marketing efforts ensures alignment between MBA marketing targets and institutional objectives. Recognizing the unique nature of MBA programs, reliant on word-of-mouth recommendations and brand enhancement, this article's distribution strategy emphasizes the optimization of physical, virtual, and hybrid channels:

Expanding Physical Channels: Engaging with relevant government departments, business associations, and benchmark enterprises is essential for specialized areas like big data intelligence and intelligent manufacturing. Providing early batch applications and exam preparation consultations, along with distributing study materials, can enhance engagement with MBA aspirants.

Enhancing Virtual Channels: Leveraging internet technologies and mainstream social media platforms enables the dissemination of MBA program information through soft articles and advertisements, catering to online information seekers.

Combining Virtual and Physical Channels: Recognizing the limitations of online marketing in facilitating real-time interactions, coaching institution websites can serve as initial touchpoints for candidates. Subsequently, organizing in-person presentations by coaching institutions helps provide experiential insights and enrollment information, augmenting the effectiveness of marketing efforts.

Promotion

The promotion strategy plays a pivotal role in conveying product information to consumers, encompassing techniques like personal selling, public relations, marketing promotions, and media advertising. Its ultimate goal is to captivate consumers' attention, stimulate interest, evoke desire, and prompt purchase behavior, thereby achieving sales objectives. In the realm of MBA program marketing, enrollment departments continually analyze market dynamics and adjust promotion strategies based on product characteristics and market responses. It is imperative for Chinese MBA programs to adopt a whole-team marketing approach, leveraging resources from various departments and engaging academic leaders, teaching staff, external mentors, and other stakeholders in the marketing effort. Establishing a unified front and nurturing strong public relations are vital aspects, particularly in maintaining positive relationships with student recommenders and enhancing promotional efforts. Furthermore, emphasizing word-of-mouth marketing ensures long-term and sustainable development by leveraging its credibility, targeting precision, cost-effectiveness, and high success rates. In the digital era, MBA marketing must embrace new media platforms such as mobile apps, social media, and WeChat to expand brand promotion efforts. Through alumni engagement, MBA forums, and diverse activities, institutions can enhance the visibility and reputation of their MBA programs, ultimately attracting more prospective students.

Participants

In the fiercely competitive landscape of MBA education, effective management of personnel is imperative for institutions to thrive. Offering convenient access to MBA services and even personalized assistance, such as on-site support from teachers, particularly for corporate clients, can greatly enhance customer satisfaction and loyalty. Therefore, Chinese MBA institutions must prioritize the efficient management and optimization of personnel involved in MBA education. This includes faculty members, administrative staff, mentors, counseling coordinators, and class representatives. By ensuring that these individuals are well-equipped, motivated, and aligned with the institution's objectives, MBA institutions can deliver high-quality education and services, ultimately attracting and retaining valuable customers in the competitive market.

Physical evidence

The promotional strategy for educational programs, including MBA institutions, differs from conventional business promotion due to the unique nature of educational services and target markets. Instead of relying heavily on traditional advertising and personal selling, educational programs should concentrate their promotional efforts on their primary target markets. Word-of-mouth recommendations and public relations efforts play a crucial role in promoting educational programs effectively. Positive experiences shared by students

contribute significantly to enhancing the brand value and reputation of educational institutions. Collaborating with government entities, corporations, and institutions to organize educational projects further promotes the brand and attracts potential students.

Regarding tangible displays, creating well-designed and professional enrollment brochures, prospectuses, and presentations is essential. These materials serve as important tools for prospective MBA applicants to assess the quality of education and make informed decisions. Enrollment brochures should reflect the institution's sophistication and professionalism, providing tangible evidence of the service quality. They should focus on presenting key aspects such as the institution's history, course overview, student activities, and testimonials from graduates. Emphasis should be placed on maintaining a consistent style aligned with the institution's message, presenting comprehensive content, and ensuring a visually appealing and easy-to-read presentation for MBA applicants.

Pre-approval interview

In China, the mainstream approach for domestic MBA candidates involves participation in the National MBA Entrance Examination, which offers two specific formats: the Early Batch and the Regular Batch. The Early Batch entails a pre-interview, Management Admission Test, and Interview, while the Regular Batch follows a process similar to postgraduate program entrance examinations, with candidates taking a preliminary exam followed by an interview assessing various aspects. Successful candidates receive conditional acceptance, completing additional steps before final admission. The concept of the early interview, where the interview precedes the written exam, aims to identify candidates with strong practical management abilities early on, aligning with the MBA program's emphasis on practical skills over academic knowledge. Early interviews hold significance for schools by enhancing brand influence, identifying high-quality candidates, and increasing interaction to support candidates' success. For candidates, early interviews offer more admission opportunities, a higher proportion of admission quotas, and lower admission score requirements, providing a pathway for candidates with practical skills to access MBA programs effectively.

Discussion and Conclusion

This paper provides a comprehensive review of the 7Ps marketing mix framework and its application to analyze the marketing strategy of Chinese MBA programs. The study focuses on seven key elements: product, price, promotion, place (distribution), participants, pre-approval interview, and physical evidence. Strategies proposed include strengthening curriculum development and brand construction to enhance product value, optimizing pricing policies, expanding physical and virtual channels, enriching promotion through personnel models and social media platforms, optimizing personnel strategies, leveraging pre-approval interviews, and utilizing word-of-mouth promotion and tangible marketing materials.

In addition to the 7Ps framework, the paper discusses the variations in marketing mix proposed by scholars such as Ivy, Kotler and Keller, and Kishore Thomas John. Despite differences in the number of Ps and specific factors, all scholars emphasize the importance of product (program), price, and people. The paper suggests that elements like prominence and premiums could be considered under the product umbrella, while prospectus materials are part of tangible evidence in contemporary marketing.

Furthermore, the study proposes integrating early interviews as a significant component within the 7Ps marketing mix, highlighting their role in capturing potential students and enhancing admission chances. Additionally, it recommends integrating various promotional materials under the category of physical evidence to enhance marketing effectiveness.

In conclusion, this study introduces the 7Ps marketing framework and its application to student recruitment for master's programs. It lays the foundation for future research and provides valuable insights into effective marketing strategies for academic institutions. The paper demonstrates the potential for further quantitative research and case studies in this area, emphasizing the importance of marketing analysis skills in academic recruitment efforts.

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR
VOL.3, NO.1; JAN. – MAR.; 2024, ISSN 2822-0412 (Online)

An Academic Inquiry into ESG Strategy Communication and the Enhancement of Operational Control within the Supply Chain

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Received: March 6, 2024 / Revised: March 27, 2024 / Accepted: April 3, 2024
Doi: 10.14456/scsr.2024.11

Abstract

This study delves into the effective integration of sustainability goals within corporate strategies and supply chain management, focusing on the strategies and practices of ASUS and TSMC in implementing Environmental, Social, Governance (ESG) initiatives and enhancing supply chain operations. ASUS exemplifies how embedding sustainability into corporate culture and decision-making processes can help companies stay competitive globally and foster long-term value growth. It prioritizes diverse options and consumer preferences, sets medium- to long-term sustainability objectives, and views sustainability performance as integral to its economic outcomes. Furthermore, ASUS emphasizes ESG performance to investors and senior management as a catalyst for innovation and value enhancement, revolutionizing supply chain management through the enforcement of a stringent supplier code of conduct and the assessment of supply chain ESG metrics. Taiwan Semiconductor Manufacturing Company Limited, TSMC, a global semiconductor industry leader, anchors its ESG strategy in robust corporate governance, environmental sustainability promotion, and proactive engagement in social responsibilities. It achieves transparent and equitable decision-making via rigorous corporate governance standards, aims to minimize energy consumption and carbon emissions, and enhances product energy efficiency with cutting-edge technologies. In supply chain management, TSMC enforces strict evaluation and selection protocols for suppliers, mandating adherence to environmental and social standards, and fosters the sustainability of the supply chain through the joint development of sustainable solutions. The analysis of ASUS and TSMC illustrates how companies can proactively undertake social responsibilities and advance environmental sustainability while seeking economic gains through varied methods and focuses. These initiatives not only positively influence their operational performance and brand reputation but also offer invaluable insights for other corporations, particularly in the seamless integration of ESG strategies into corporate culture and operations, and in fortifying sustainability within supply chain management.

Keywords: ESG strategy, supply chain management, sustainable development, ASUS, TSMC

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Introduction

Background

According to the World Economic Forum's (WEF) 112 Global Risks Report, climate-related risks dominate the list of top global threats in the coming decade, constituting four out of the top 10 risks. These encompass frequent extreme weather events, unsuccessful climate action, human-induced environmental harm, and biodiversity loss (Evans et al., 2017). Concurrently, the Intergovernmental Panel on Climate Change's (IPCC) AR6 report highlights specific climate risks for Taiwan, including heightened rainfall intensity, prolonged periods of maximum rainfall, extended summers, and diminishing winters. In response to such climate shifts, organizational resilience becomes paramount to ensure comprehensive adaptability, with an immediate focus on diminishing reliance on natural energy sources (Chen., 2021).

Human activities are accelerating climate change effects, contributing to phenomena like extreme heatwaves, floods, torrential rains, black rains, droughts, tropical cyclones, and wildfires (Trenberth, 2018) The summer of 2023 was declared the hottest on record by the European Union's Copernicus Centre for Climate Change, witnessing a significant global temperature surge. Notably, Xinjiang province in northwestern China experienced an unprecedented temperature of 52.2°C, while California's Death Valley recorded Earth's highest-ever temperature at 56.7°C (Witze, 2019) These occurrences underscore the urgent need for proactive measures to counteract the looming threats of climate change.

The Sustainable Development Goals (SDGs) constitute the 2030 Agenda for Sustainable Development, endorsed by the United Nations in 2015 (Hák et al., 2016). This global initiative aims to unite governments, local entities, businesses, civil society organizations, and other stakeholders to collaboratively achieve 17 core objectives for global sustainable development. These goals will serve as a compass for policymaking, investments, and actions over the next 15 years, striving to create a world where every nation experiences sustained, inclusive, and sustainable economic growth, ensuring universal access to decent employment. Guided by this philosophy, the SDGs advocate for responsible production, consumption, and utilization of natural resources, including air, land, rivers, lakes, groundwater, and oceans.

In addition to the existing 17 SDGs, the latest addition, SDG18, emphasizes leveraging digital technologies to benefit the planet. Encompassing critical issues such as poverty eradication, hunger alleviation, enhanced health, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industrial innovation and infrastructure, reduced inequalities, sustainable urban-rural development, responsible consumption and production, climate action, life below water, life on land, peace, justice and institutions, and partnerships, the SDGs provide a holistic framework for sustainable development (Yusha'u, 2021) description of the main problem

According to the 2023 Corporate Sustainability White Paper, the corporate landscape is witnessing nine significant trends in Environmental, Social, and Governance (ESG) that shape the trajectory of sustainability. Firstly, internal carbon pricing is gaining traction, serving as an incentive for companies to adopt carbon reduction measures. Biodiversity conservation has emerged as a key environmental focus, drawing widespread attention. The adoption of circular economy practices continues to expand, establishing itself as a crucial aspect of corporate sustainability. Science-based emissions reductions, with a focus on achieving net-zero targets,

underscore the pivotal role of science and technology in emission reduction. Emerging climate technologies are taking the spotlight, emphasizing innovation's role in combatting climate change. Sustainable finance is highly anticipated as a key enabler for achieving corporate sustainability objectives. Social innovation organizations are expanding both in depth and breadth, showcasing the deepening collaboration between society and businesses. The emphasis on collective participation in ESG by all stakeholders highlights its indispensable role in sustainable development. Finally, diversity, equality, and inclusion have become integral standards, forming a crucial element in the corporate value system, often referred to as EDI (diversity, inclusion, equality).

Objectives of the Study

This study seeks to conduct a comprehensive examination and understanding of companies' practices in ESG strategy communication and the subsequent impact on internal and external stakeholders. Simultaneously, the research aims to evaluate how companies can integrate ESG considerations to enhance operational control within their supply chains, ultimately achieving sustainability goals. The overarching goal is to provide practical recommendations that drive companies toward more positive outcomes in ESG strategy and supply chain management, fostering sustainable growth across economic, social, and environmental dimensions.

Research Questions

The study will address the following interconnected research questions:

1) ESG Strategy Communication: How can organizations effectively communicate and strengthen ESG strategies internally and externally, fostering resonance of corresponding values and practices?

2) Supply Chain Operational Control: In supply chain management, how can operational control be enhanced through ESG considerations? This includes reducing environmental footprints, mitigating social risks, and improving governance mechanisms to achieve sustainable development goals?.

3) ESG Strategy and Operations Alignment: How can synergies between ESG strategy and supply chain operations be achieved to maximize the environmental and social impact of the organization while maintaining an appropriate governance structure?

Literature review

Background of ESG

ESG, an acronym for Environment, Social, and Governance, encapsulates a company's performance in these three crucial domains. The environmental aspect scrutinizes the enterprise's environmental footprint, the social aspect assesses its societal contributions and impacts, while corporate governance delves into internal management and transparency practices.

ESG holds significance as it offers a comprehensive approach, moving beyond a company's mere financial performance to encompass its broader environmental, social, and governance standing. This holistic evaluation aligns with the sustainability concept, providing investors with a more complete understanding of a

company's value and long-term viability. Unlike the past, where investors predominantly focused on financial metrics, today's investors are increasingly concerned about a company's ESG impact, considering these factors vital to enterprise development, management performance, and information disclosure. Consequently, effective and accurate communication becomes imperative for companies to showcase their ESG endeavors and accomplishments to diverse stakeholders.

Operational Management of the Supply Chain

This segment of the study concentrates on supply chain management, acknowledging that a company's manufacturing and consumption processes collectively form an integrated supply chain. Evaluating a company necessitates examining not only its production phase but also its upstream raw material supply and downstream consumer use. This entails scrutinizing raw material procurement, product manufacturing, product transportation and storage, and cost control.

Effective supply chain management demands collaboration to manage risks and share information, fostering sustainable development and enhanced efficiency across the entire supply chain. Consequently, when exploring a company's ESG, it becomes essential to consider not only the company itself but the entire supply chain. This involves extensive communication between upstream and downstream supply chain partners.

Strategy Communication

Strategic communication involves effectively conveying an organization's strategic goals and plans to both internal and external stakeholders, including employees, investors, customers, and partners. It encompasses core enterprise goals, values, development directions, and corresponding implementation plans (Sciarelli et al., 2021).

In the realm of supply chain management, strategic communication assumes paramount importance, manifested in several key aspects:

1) Shared Understanding: Effective strategic communication ensures that all stakeholders within the supply chain comprehend the enterprise's overarching strategy and objectives. This alignment ensures that the entire supply chain operates cohesively, striving toward common goals.

2) Collaboration: As all facets of the supply chain must work harmoniously for efficient and cost-effective operations, strategic communication fosters transparency. It allows partners at different stages to understand and adapt to each other's strategies, promoting improved collaboration.

3) Risk Management: Transparent communication regarding potential risks and changes in the supply chain provides early warnings and facilitates appropriate responses. This proactive approach minimizes the likelihood of production disruptions, inventory issues, or other supply chain risks.

4) ESG Integration: Particularly concerning ESG, strategic communication empowers companies to articulate their commitments and actions toward sustainability. This communication is instrumental in embedding ESG goals into supply chain management, propelling sustainable practices throughout the supply chain (Van Duuren, et al., 2016). In summary, strategic communication plays a pivotal role in building trust, transparency, and collaboration within the supply chain, thereby enhancing overall supply chain effectiveness and sustainability. Figure 1 illustrates a schematic diagram depicting the use of business models to facilitate communication.

Figure 1 Use business models to assist communication.

Research Methods

Strategy Map

This study utilizes a strategy map as a primary tool for investigation. A strategy map is a visual representation that outlines an organization's fundamental strategy, goals, and associated implementation plans. Typically, it visually illustrates the interconnections among different strategic elements, offering a clear depiction of the overall strategic direction. The primary aim of a strategy map is to facilitate team members' understanding, alignment, and effective execution of the organization's strategic plan (Kaplan & Norton, 2004).

In the context of supply chain management, the application of a strategy map encompasses several critical aspects:

1) Integrated Supply Chain Strategy: A strategy map can visually articulate an enterprise's supply chain strategy, encompassing elements such as raw material procurement, production, logistics, storage, and other integral links. This visualization ensures that the entire supply chain operates cohesively within the same strategic framework.

2) Emphasis on Key Objectives: By utilizing a strategy map, companies can distinctly identify key objectives within supply chain management, such as enhancing efficiency, reducing costs, improving quality, and more. This clarity aids in focusing attention and allocating resources effectively to the most critical areas.

3) Communication & Empathy: Serving as an excellent communication tool, a strategy map succinctly presents complex strategic messages to team members and stakeholders. This aids in building empathy and ensures that all involved parties comprehend and support the supply chain strategy.

4) Assessment and Adjustment: Strategy maps enable companies to regularly assess the efficacy of their supply chain strategy execution. If deviations or adjustments are deemed necessary, a strategy map guides appropriate modifications to ensure alignment with the overall corporate strategy.

The linchpin for driving strategy execution lies in people, and it is imperative that all members deeply understand the outcomes and impact of strategy execution. Visualization through a strategy map stands out as the most effective approach for achieving this. Applying strategy maps to supply chain management enhances overall collaboration, ensures alignment of supply chain activities with corporate strategy, and empowers teams to comprehend and execute strategic plans more effectively.

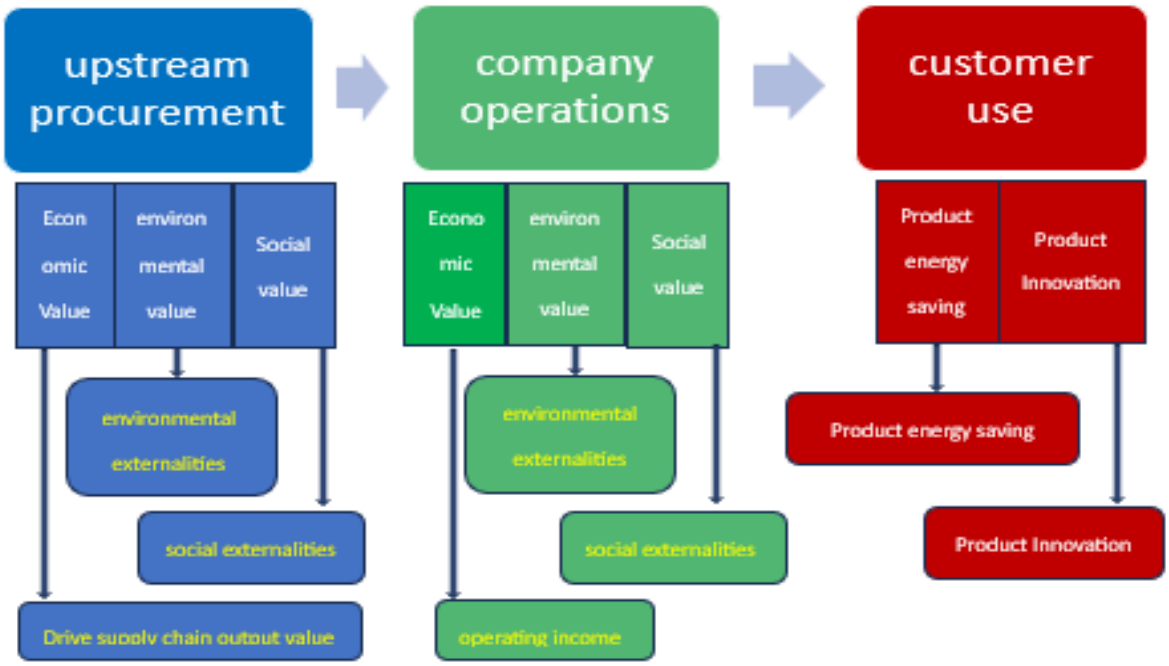

Figure 2 An Example of a Sustainable Impact Strategy Map

Comparative Conceptual Research Methods

Conceptual comparative research is a method that scrutinizes abstract concepts to comprehend and analyze the similarities and differences among different concepts, theories, or models. This approach underscores the comparison of different concepts to elucidate their characteristics, commonalities, strengths, or limitations. Key features of the Comparative Conceptual Research Method include:

1) Clear Concept Definition: The researcher begins by precisely defining the concept, theory, or model under comparison. This involves identifying the core elements of the concept for systematic analysis.

2) Comparison of Similarities and Differences: In-depth comparisons are conducted, focusing on the similarities and differences between concepts. This may involve comparing definitions, characteristics, scope of application, theoretical basis, and other aspects of the concept.

3) Analytical Characteristics: Through comparison, the researcher analyzes the characteristics of each concept, unveiling strengths and weaknesses. This provides insights into the meaning, application, and impact of each concept in a specific context.

4) Establishment of a Theoretical Framework: A conceptual comparative approach aids in establishing a theoretical framework, enabling researchers to develop a more comprehensive and profound understanding of the study's field. This contributes to expanding knowledge in the subject area.

5) Theoretical Deduction: Comparing different concepts allows researchers to make theoretical deductions, proposing new theories or models based on the comparative results. This fills gaps in existing theories or provides more comprehensive explanations.

Comparative conceptual research is often employed to explore and comprehend the interrelationships between different concepts. Given the abstract nature of environmental, social, and corporate governance concepts in ESG studies, a comparative examination of these concepts will foster more In-Depth discussions and research on the ESG topic.

Case Study Method

This study also incorporates case studies of various companies to comprehend the strategic maps adopted in response to ESG.

Results and Discussion

Different Response Strategies under ESG

In the realm of ESG, companies can adopt diverse response strategies, as delineated in Table 1. This table categorizes the response strategies according to the three ESG modules: Environmental, Social, and Governance. It provides a comprehensive overview of the strategies that companies can employ to tackle challenges and fulfill the requirements across various aspects.

Table 1 Strategies Adoptable by Enterprises in the Context of ESG

ESG Module	Response Strategy
Environmental	- Develop a sustainability plan to reduce your carbon footprint and save energy. - Promote a circular economy and reduce the use of hazardous substances. - Invest in green technology and innovation.
Social	- Promote diversity and inclusion and ensure that social diversity is reflected within the organization. - Enhance employee well-being, including improving working conditions and providing a safe and healthy working environment. - Take measures to promote gender equality, cultural diversity and racial equality.

Table 1 (Cont.)

ESG Module	Response Strategy
Governance	- Strengthen corporate governance, transparency and accountability. - Disclose financial information and establish an effective code of ethics. - Promote shareholder participation and balance the interests of all stakeholders.
Respond to risks	- Conduct a comprehensive ESG risk assessment and develop a risk management strategy. - Establish a crisis response plan to address the impact that unexpected events may have on ESG performance.
Stakeholder involvement	- Actively participate in dialogue with stakeholders to understand their needs and expectations. - Incorporate stakeholder feedback and adjust ESG strategies and practices.

Strategy Map Analysis

Figure 3 Policy Diagnosis and Management Architecture

Figure 3 illustrates a comprehensive map outlining how companies respond to ESG strategies.

Case Analysis

ASUS's Corporate Sustainability Performance

The overview chart in Table 2 provides a concise summary of ASUS's corporate sustainability performance. It encompasses key elements such as diversity options, the integration of sustainability into operational plans, sustainability concepts, sustainability strategies, and the supplier code of conduct. This

comprehensive overview serves as a valuable snapshot of ASUS's commitment and approach to corporate sustainability. (Yeh, 2021)

Table 2 Overview of ASUS's corporate sustainability performance (ASUS, 2023)

firm	Asus
Diversification of options	- Preferences can be expressed in ways never before possible - Companies that you can choose to buy and work for based on your values
Sustainability is integrated into the business plan	- Integrate strategic sustainability into operational plans - Set medium- and long-term sustainability goals - Management sustainability performance is the same as economic performance - Measure program progress with assessment tools - Establish a bridge of communication between stakeholders in different fields to jointly create corporate and social sustainability
The concept of sustainability	- Investment institutions regard corporate governance, environmental, and social performance as one of the top priorities in investment evaluation
Perpetual Strategy	- Established a sustainability unit in 2000 - Make sustainability an integral part of business decisions - Adopt data-based measurement and technology-based management < - Incorporate environmental and social considerations into every decision-making process - Shaping sustainable competitive advantage
Supplier Code of Conduct	- Become a full member of the Responsible Business Alliance (RBA). - Establish a supplier code of conduct, require suppliers to comply with and encourage upstream suppliers to do the same - Strengthen protections for young workers and female employees - Integrate suppliers' ESG performance into the selection and management process - Ensure that suppliers comply with the Code of Conduct through annual audits - Lead the supply chain to a sustainable transformation and make substantial contributions to the UN SDGs

The table below outlines the relevant ESG concepts and initiatives, providing a chronological overview of TSMC's progression and dedication to the Sustainable Development Goals (SDGs). It highlights key actions

taken by TSMC in alignment with specific SDGs, illustrating the company's proactive engagement with sustainable practices over time.

Table 3 TSMC's Development and Commitment to SDGs (TSMC, 2023)

Time	Specifics	Main actions
2021	By the United Nations Development Programme (UNDP) "Enterprise SDG Impact Standards" released the "Enterprise SDG Impact Standards", TSMC has set a long-term sustainability goal for the Republic of China for 119 years, and regularly reviews the progress and degree of compliance, and dynamically reviews the appropriateness of adding or removing targets.	- Set long-term sustainability goals - Regularly review progress and attainment of targets – review the appropriateness of adding or removing targets
2022	TSMC pledged 52 long-term goals that echo the SDGs, adding 5 new goals, including managing employee health and stress, hiring employees with disabilities, reducing carbon dioxide derived from waste, cultivating semiconductor workers, and requiring suppliers to participate in CDP's supply chain projects.	- Committed to 52 long-term goals that echo th e SDGs - 5 new goals - Continuously reflect on and expand opportunities across the value chain to contribute to the SDGs
2021	78% of the targets (37) continued to make progress and achieved the annual targets, which is a positive trend of the green light level, while 22% of the targets (10) are negative, of which 3 goals are at the yellow light level, and 2 goals are still exceeding last year's performance although they have not reached the annual target.	- Positive Trend Goals: Continue to make progress and achieve goals - Among the targets of negative trend, there is a distinction between yellow and red-light levels - regardless of positive or negative trend targets, the company continues to implement corresponding sustainable actions.

Conclusion

This study underscores the pivotal role of integrating sustainability goals into business strategies and supply chain management for companies to remain competitive in the global market and achieve sustained value growth. Examining ASUS and TSMC reveals their unwavering commitment to environmental stewardship, social responsibility, and robust governance standards. Both companies showcase initiatives to fortify the sustainability and efficiency of their supply chains through innovative measures and collaborative efforts.

The ASUS and TSMC case study illuminate key elements. Firstly, well-defined ESG goals and strategies form the bedrock for sustainable development and heightened shareholder value. Secondly, rigorous control and evaluation of the supply chain not only mitigate operational risks but also enhances enterprises' adaptability to external changes and foster innovation. Moreover, proactive corporate social responsibility implementation fosters brand image and deepens trust among customers and investors.

ASUS and TSMC exhibit innovative practices in supply chain management and substantial investments in sustainable development, setting high benchmarks for the entire industry. Their endeavors contribute to steering the industry towards a more sustainable and responsible trajectory.

In conclusion, the analysis of ASUS and TSMC underscores that the successful execution of ESG strategies and adept management of supply chain operations are paramount for enterprises navigating the dynamic global market. It also emphasizes the crucial role of business leaders in propelling sustainability and social responsibility forward, alongside the imperative of continuous innovation and collaboration in strategic planning and execution. As global demand for sustainability rises, companies must continually adjust and optimize their ESG strategies and supply chain management practices to ensure enduring success and positive impact.

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR
VOL.3, NO.1; JAN. – MAR.; 2024, ISSN 2822-0412 (Online)

Hydrogen Energy Supply Chain: Production, Storage, and Applications – An Exploratory Study

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Received: March 6,2024 / Revised: March 30, 2024 / Accepted: April 3, 2024
Doi: 10.14456/scsr.2024.12

Abstract

This study explores the role of hydrogen as a clean and efficient secondary energy source in the global energy transition. Hydrogen has gained significant attention in energy research due to its zero carbon emissions, high heat value, safety features, and versatile applications. The research aims to comprehensively understand the role and impact of hydrogen in future energy systems. Through current survey methods and data analysis, the study elucidates the trends in hydrogen technology development, influence of policies, regulations, and its position in the global energy transition. The technological evolution of the hydrogen supply chain, including green hydrogen, blue hydrogen, hydrogen storage, and transportation, is highlighted. Government support, especially driven by Taiwan's hydrogen development goals and related regulations, has accelerated the growth of the hydrogen industry. In the global energy transition, hydrogen emerges as a key factor in achieving goals due to its zero emissions, diverse applications, and advantages in energy storage. However, hydrogen still faces challenges in technology and cost. Therefore, future research is recommended to focus on addressing technical bottlenecks in hydrogen production, storage, transportation, applications, while enhancing international cooperation and technological innovation. Additionally, further understanding of the practical impact of government policies on the hydrogen industry is essential to promote its broader application in the global energy system.

Keywords: Hydrogen Technology, Policy and Regulation, Global Transition, Supply Chain Innovation.

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Introduction

Background

Hydrogen, as a clean and efficient secondary energy source, holds significant importance in constructing a clean, low-carbon, safe, and efficient energy system. It has ascended to a strategic energy position at the national level and is expected to play a crucial role in the grand processes of carbon peaking and carbon neutrality (Caineng et al., 2021).

Research Motivation

Hydrogen energy possesses multiple advantages, making it a focal point in current energy research. Some key advantages include zero carbon emissions, high heat value, environmental friendliness, high energy content, addressing climate change and improving air quality (Apak et al., 2017).

Research Purpose

Environmental and climate issues associated with traditional energy use urge us to focus on renewable energy sources. In this context, hydrogen, as a potential clean energy source, has sparked widespread interest. Its motivation for research lies not only in its apparent advantages, such as zero carbon emissions and high heat value but also in its potential to be a key element in achieving energy transition goals.

Research Questions

How is the urgent need for energy transition triggered by environmental and climate issues resulting from traditional energy use? What aspects embody the motivation for hydrogen energy research, including features like zero carbon emissions and high heat value? What specific progress has been made in the current state of hydrogen energy research in terms of technological development and achievements? How is the diversity of hydrogen research reflected in various countries globally? As the core for realizing hydrogen applications, what are the main components of the hydrogen supply chain, and what are the technological challenges and application prospects associated with each stage?

Literature Review

Major research achievements in international hydrogen energy studies

1. Historical Development of Hydrogen Energy

The historical development of hydrogen energy can be traced back to the early 19th century when chemist Henry Cavendish first discovered hydrogen gas (West & Cavendish, 2014). However, it was not until the early 20th century that hydrogen's applications began to capture people's attention. Early experiments and fuel cell discoveries in the early 19th century, the decomposition of water and the discovery of hydrogen gas laid the foundation for hydrogen. In 1800, Henry Cavendish successfully separated hydrogen gas through experiments (Sandstede et al., 2010). Subsequently, Swedish scientist Sven Otto and British scientist William Grove proposed the concept of fuel cells in 1839 and 1842, respectively, and achieved the conversion of hydrogen and oxygen into electricity (Lucia, 2014).

Hydrogen in industrial and aviation applications (during early 20th century), hydrogen found wide applications in ammonia production and in aviation, such as in airships and hydrogen balloons. However, due

to the highly explosive nature of hydrogen gas, it led to significant accidents, most notably the 1937 Hindenburg airship disaster (DiLisi, 2017).

During petroleum era and rediscovery of hydrogen fuel (Late 20th Century), with the rise of the petroleum industry, interest in hydrogen gradually waned. However, in the late 20th century, rising oil prices and concerns about energy security and the environment renewed interest in hydrogen as a clean energy source. During this period, fuel cell technology further developed, and exploration of hydrogen applications in transportation began. Rise of modern hydrogen energy (during 21st Century), with the rise of climate change and the sustainable energy agenda, hydrogen energy once again became a focus. Countries worldwide invested in hydrogen technology development, promoting the production of green hydrogen for applications in vehicles, energy storage, and more. The use of hydrogen fuel cell vehicles and hydrogen fuel cell buses expanded gradually in the transportation sector (Kim et al., 2021).

2. Current Research Status of the Hydrogen Energy Supply Chain

The following are some key aspects of the current research status of the hydrogen energy supply chain: Research on Hydrogen Production Technologies: Researchers are dedicated in developing more efficient, economical, and environmentally friendly hydrogen production technologies. Various hydrogen production methods, including water electrolysis, natural gas steam reforming, and biomass gasification, are under investigation (Zhu et al., 2023). Additionally, the production of green hydrogen, using renewable energy for water electrolysis, photocatalysis, crucial for reducing the carbon footprint of hydrogen production. Research on Hydrogen Storage and Transportation Technologies: Research focuses on developing efficient and safe hydrogen storage and transportation technologies (Moradi & Groth, 2019). Various technologies, including liquid hydrogen, solid adsorption, and hydrogenation storage, are being explored to ensure the effective storage and transportation of hydrogen.

Research on Hydrogen Energy Application Technologies: In terms of hydrogen energy applications, fuel cell technology is a significant research area. Researchers aim to improve fuel cell efficiency, reduce costs, and expand its applications in various sectors such as transportation, industry, and households. Additionally, technologies like hydrogen fuel cell vehicles and hydrogen energy storage systems are actively being researched and developed. Research on Hydrogen Energy Policies and Regulations: Governments worldwide formulate policies and regulations related to hydrogen energy to facilitate its development. This includes funding support, establishing standards and regulations, and promoting industry cooperation. Global Hydrogen Energy Cooperation and Experimental Projects: International organizations and countries collaborate on hydrogen energy, jointly advancing the development of hydrogen technology. Moreover, large-scale experimental projects, such as hydrogen production demonstration plants and hydrogen infrastructure construction, are underway to verify the feasibility and scalability of hydrogen energy technologies.

Overview of the Hydrogen Energy Supply Chain

1. Upstream, Midstream, and Downstream of the Hydrogen Industry

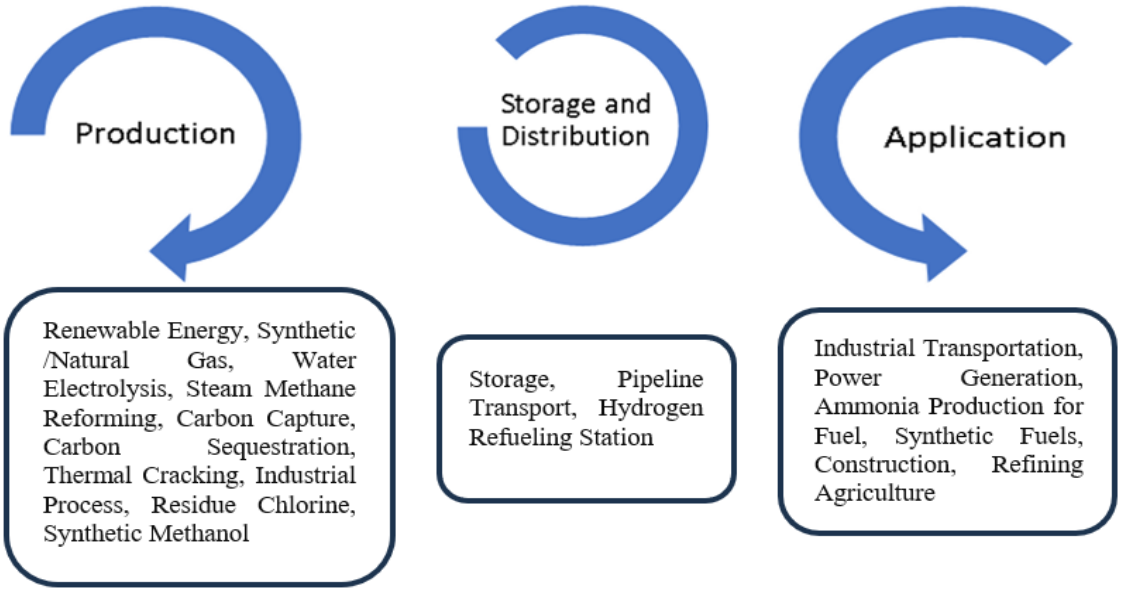

Figure 1 illustrates the main components of the hydrogen energy supply chain.

Production stage

Hydrogen production from fossil fuels: Hydrogen production from fossil fuels is currently the primary source of hydrogen, including coal-based and natural gas-based hydrogen production technologies. Coal-based hydrogen production is stable, efficient, and cost-effective. The estimated cost of hydrogen production is approximately 12.64 CNY/kg, when the raw coal price is 800 CNY/ton. Among natural gas-based hydrogen technologies, steam methane reforming is mature and widely used internationally. The estimated cost of natural gas-based hydrogen production is approximately 12.79 CNY/kg, when the natural gas price is 2.5 CNY/Nm3, with natural gas raw material costs accounting for over 70% of the total cost (Steinberg & Cheng, 1989).

Hydrogen production from renewable energy: Industrial by-product hydrogen resources are abundant and can serve as a transitional hydrogen source in the early stages of hydrogen development. Hydrogen production from industrial by-products includes hydrogen by-product from coke oven gas, hydrogen by-product from chlor-alkali chemical industry, hydrogen by-product from alkane dehydrogenation, hydrogen by-product from synthetic ammonia and methanol (Amin et al., 2022).

Hydrogen production from industrial waste: Hydrogen production from industrial waste is a green and sustainable method, typically involving gasification or chemical conversion processes. Possible methods include gasification processes, catalytic conversion, biological reactions, and methane reforming. Different types of waste and hydrogen production methods affect efficiency, cost, and environmental impact. Ensuring environmental friendliness and safety in the hydrogen production process is crucial. As technology advances and the hydrogen economy develops, research and applications of converting industrial waste into hydrogen will continue to receive attention (Kapdan & Kargi, 2006).

Electrolysis of water for hydrogen production: Water electrolysis for hydrogen production includes alkaline electrolysis (AWE), proton exchange membrane (PEM) electrolysis, and solid oxide electrolysis (SOEC). Alkaline electrolysis is mature, with low equipment costs and higher economic viability. PEM electrolysis has become the mainstream electrolysis technology due to its adaptability to renewable energy generation fluctuations and higher energy conversion efficiency. According to data from the International Energy Agency (IEA), PEM electrolysis accounted for over 80% of global newly installed electrolysis capacity from 2015 to 2019.

Storage and Transportation Stage

Hydrogen storage methods include high-pressure gaseous hydrogen storage, low-temperature liquid hydrogen storage, solid-state hydrogen storage, and hydrogen gas pipeline transportation. Currently, high-pressure gaseous hydrogen storage technology is relatively mature and is the primary storage and transportation method.

Liquid hydrogen: Liquid hydrogen refers to the process of cooling hydrogen gas to -252.72°C under standard atmospheric pressure and storing it in specially designed highly vacuum-insulated containers. Liquid hydrogen has a density 845 times that of gaseous hydrogen at room temperature and pressure, making it suitable for long-distance and large-scale transportation. However, it involves significant equipment investment and higher energy consumption (Aziz, 2021).

Hydrogen gas compression storage: Gaseous hydrogen is typically stored in 20 MPa steel hydrogen cylinders and transported by long tube trailers, suitable for short-distance and small-scale transportation (Barthélémy et al., 2017).

Solid-state hydrogen storage: Solid-state storage uses materials such as metal hydrides, chemical hydrides, or nanomaterials as hydrogen carriers, storing hydrogen through chemical and physical adsorption. Solid-state hydrogen storage has advantages such as high storage density, good safety, and high hydrogen purity. However, the technology is complex, costly, and lacks large-scale applications (Walker et al., 2008)

Hydrogen gas pipeline transportation: Pipeline transportation is a crucial method for large-scale, long-distance hydrogen transportation, but it involves substantial construction costs (Witkowski et al., 2017).

Hydrogen applications

Hydrogen is used in various sectors such as industrial, transportation, power generation, construction industries, agricultural, refining, production of ammonia and synthetic fuels.

Research methods adopted for hydrogen research.

Data collection methods

This study adopts a current situation survey method, collecting relevant data from various databases, consolidating it, and cross-verifying it with accessible literature.

Analysis methods

The countries or regions associated with hydrogen research include the European Union, China, Japan, and Taiwan. The analysis focuses on the most recent decade's data.

Key Issues and Challenges in the Hydrogen Energy Supply Chain

Application Stage of Hydrogen Energy

Hydrogen gas exhibits diverse applications and potential environmental benefits across various sectors. In the field of hydrogen fuel cell vehicles, this technology is gaining attention for its advantages such as zero emissions, rapid refueling, long driving range, and low noise. However, challenges faced include the establishment of hydrogen infrastructure, reduction of manufacturing costs, and enhancement of the green production of hydrogen. In industrial applications, hydrogen is utilized in processes such as chemical manufacturing, steel smelting, metal reduction, and glass production to replace some fossil fuel usage, thereby reducing carbon emissions. Additionally, hydrogen is considered an energy conversion medium in industries, applicable for thermal energy production or power generation through hydrogen combustion, aiming to improve efficiency and reduce dependence on traditional energy sources.

In the power generation sector, hydrogen can serve as a clean fuel applied in fuel cell systems or gas turbine generators, diminishing the demand for fossil fuels while achieving water vapor emissions. Moreover, hydrogen can be employed as a form of energy storage, converting surplus electricity into hydrogen to address the intermittency issues of renewable energy, thereby enhancing grid stability. Overall, hydrogen demonstrates its potential for diverse applications in these fields and plays a crucial role in the global energy transition, although continuous innovation and infrastructure development are essential for its widespread adoption.

Hydrogen Production and Market Analysis

Global Hydrogen Energy Industry Planning

According to the International Renewable Energy Agency (IRENA) Hydrogen Report, the two most promising markets in the global hydrogen energy industry are the upstream hydrogen production end with electrolysis and the downstream transportation sector with fuel cells. The potential market for fuel cells globally is estimated to reach as high as USD 21 billion to USD 25 billion by 2050 (Sokolov et al., 2019). Summary of Hydrogen Energy Industry Planning in Major Global Economies is tabulated in Table 1. H2 production methods

Hydrogen Production (10,000 tons)

Table 1: Summary of Hydrogen Energy Industry Planning in Major Global Economies

Country	Year H2 production methods	2020	2025	2030	2035	2050
China	Hydrogen Production (10,000 tons)	3,342	3,715	5,276	9,690	-
	Electrolyzer Installed Capacity (GW)	10	>35	>200	>500	-
	Hydrogen Production Method	Industrial By-product Hydrogen Purification, Green Hydrogen Pilot Operation	Low Carbon Emission Hydrogen Production, Liquid Hydrogen Transportation Hydrogen Production, Liquid Hydrogen Main Artery, High-Pressure Gas Microvascular Storage	Zero Carbon Emission	-	-

Table 1: (Cont.)

Country	Year / H2 production methods	2020	2025	2030	2035	2050
EU	Annual Hydrogen Production (10,000 tons)	980	-	-	-	-
	Electrolyzer Installed Capacity (GW)	1	6	40	-	-
	Hydrogen Production Method	1.4% Green Hydrogen Share	Annual Production of 1 million Tons of Green Hydrogen, Excess Renewable Energy Hydrogen Production	Annual Production of 10 million Tons of Green Hydrogen, Large-scale Hydrogen Production	1/3 of All Hydrogen Production is Ultra-low Carbon Hydrogen, Large-scale Hydrogen Power Generation Demonstration Projects	Large-scale Deployment of Renewable Hydrogen, Accounting for 1/4 of Energy Demand
USA	Electrolyzer Cost (USD/kW)	-	300	-	-	-
	Operating Lifetime (hours)	-	80,000	-	-	-
	Conversion Efficiency	-	65%	-	-	-
	Hydrogen Transport	-	2	-	-	-
	Share of Energy Demand	-	14%	-	-	-
Japan	Annual Hydrogen Production (tons)	4,000	300,000	5-10 million	-	-
	Low-pressure Power Generation Cost (JPY/kWh)	-	25	-	-	-
	High-pressure Power Generation Cost (JPY/kWh)	-	17	12	-	-
	Hydrogen Production Cost (USD/kg)	-	3	2	-	-

Source: EU Hydrogen Strategy, USA Hydrogen Program Development Plan, Japan Hydrogen Utilization Progress Table, Japan Basic Hydrogen Strategy, China Hydrogen Industry Development Report 2020, Compiled by Guosen Securities Economic Research Institute.

Hydrogen Refueling Station Market (China)

The hydrogen refueling station market is a big market for hydrogen energy industry. Table 2 is the market estimation of hydrogen refueling station in China (Li et al., 2021).

Table 2: Hydrogen Refueling Station (HRS) Market in China

Year → / HRS status ↓	2020	2035	2050
Completed Stations	118	-	-
Under Construction and Planned Stations	167	-	-
Operational Stations	101	-	-
Stations Ready for Operation	17	-	-
Deployment Rate	> 85%	-	-
Predicted Stations in 2035	-	1,500	10,000+
Central SOEs Plan (Stations)	-	-	-
Top 10 Provinces' Plans (2022/2023/2025)	-	-	420 / 597 / 927
2021-2025 Average Annual Investment	-	-	¥1.7-¥2.2 billion

Source: Statistics as of the end of 2020, Predictions from the "China Hydrogen and Fuel Cell White Paper." Central SOEs' planning data.

Hydrogen Storage Cylinder Market (China)

The hydrogen storage cylinder market is also a big market, Table 3 shows the potential hydrogen storage cylinder market in China (Wang et al., 2018).

Table 3 Future Development Forecast of China's Hydrogen Storage Cylinder Market

Year	Hydrogen Fuel Cell Vehicle Hydrogen Cylinder Annual New Market Demand (100 million RMB)	Growth Rate (CAGR)	Carbon Fiber Annual Demand for Hydrogen Cylinder Production (10,000 tons)	Growth Rate (CAGR)
2021	-	-	-	-
2022	-	-	-	-
2023	-	-	-	-
2024	-	-	-	-
2025	32	78%	0.6	88%
2030	111	-	2.5	-

Source: Provincial and municipal hydrogen fuel cell vehicle deployment plans, market estimates.

Fuel Cell Market (Japan)

The details of fuel cell market in Japan is summarized in Table 4 below

Table 4 Details of Fuel Cell Market in Japan

Year	Project/Model	Description	Goals/Achievements	Household Purchase Quantity
2008	ENE-FARM	Japan's "ENE-FARM" Cogeneration Project	Introducing hydrogen into fuel cells for power generation in residential homes, utilizing the generated heat for heating and hot water supply, forming a micro-cogeneration system with an overall efficiency of over 90%.	Breakthrough application of hydrogen in residential homes, with a sales target of 5.3 million units by 2030. As of 2019, approximately 320,000 Japanese households have purchased the Ene-Farm system.
2014/2016	Mirai/Clarity	Toyota Mirai and Honda Clarity Models	Promoting fuel cell vehicles, with Toyota introducing the second-generation Mirai in 2019, boasting a range exceeding 850 km, becoming a flagship product in the global fuel cell vehicle market.	-
2020	-	Addition of Fuel Cell Vehicles in Japan	Promoting fuel cell vehicles, with 761 new units added in 2020, accumulating a total of 3,902 units, expanding into areas such as buses, heavy trucks, and forklifts.	-

Source: Japan's "ENE-FARM" Cogeneration Project, Introduction of Toyota Mirai and Honda Clarity Models, Japan's Fuel Cell Vehicle Promotion Data.

Hydrogen Industry Supply Chain (Taiwan)

Taiwan is also trying to build its own hydrogen industry; Table 5 shows the recent progress of hydrogen industry supply chain in Taiwan (Lee et al., 2009).

Table 5 Overview of Recent Operational Performance of Taiwan's Hydrogen-related Supply Chain

Company	Significant Milestones and Plans	Product Portfolio	International Collaboration	Remarks
Xing Heng	- Initiating Hydrogen Fuel Cell Procurement Project, introducing hydrogen fuel cells starting 2023, with a total capacity of up to 10MW, expected to be completed by 2026. - Total project investment exceeds 4 billion NTD.	- Hydrogen-powered motorcycles - Hydrogen fuel cell systems	Not specifically mentioned international collaborations	Seen as a significant milestone for Taiwanese companies entering the hydrogen fuel cell market.
Chunghwa Electric Power	- Launching the "Hydrogen Hwa Ya Park A+" project, establishing a hydrogen production base in the Hwa Ya Park, including methanol reformers, fuel cells, etc. - Operation began in Q1 2023, targeting markets such as India, Southeast Asia, and China.	- Methanol reforming hydrogen production units - Hydrogen fuel cells - Hydrogen stacks and power units - Hydrogen-powered logistics vehicles - Hydrogen refueling stations - Smart microgrids	Not specifically mentioned international collaborations	Early entrant into technology for hydrogen applications.
CTCI Corporation	- Successfully securing orders from global fuel cell manufacturer Bloom Energy, manufacturing key components for hydrogen fuel cells. - CTCI, with a focus on heat treatment technology, manufactures heat pumps for Bloom Energy.	Heat reaction box ("Hot Box") - Hard-soldered plate heat exchangers	Included in South Korean SK Group's approximately $4.5 billion hydrogen fuel order; CTCI is responsible for manufacturing fuel cell reaction furnaces and related components.	Benefiting from the U.S. "Reducing Inflation Act," promoting the development of the battery industry with notable achievements.
Consus	- One of Bloom Energy's hydrogen fuel cell suppliers. - Supplies fuel cell power supplies to Bloom Energy.	Fuel cell power supplies	In the context of Bloom Energy's numerous orders, Consus has increased shipments of hardware power products.	Participating in Bloom Energy's hydrogen fuel cell supply, enhancing hardware power product sales.

Technical Challenges in the Hydrogen Supply Chain

Advances in Hydrogen Production Technology

Technological advancements pose a significant challenge for the future of the hydrogen supply chain. In this context, the fuel cell power system is exemplified to illustrate the ongoing developments (Lulianelli &

Basile, 2014). A fuel cell is a device that directly converts the chemical energy of a fuel into electrical energy. The basic principle involves hydrogen entering the fuel cell's anode, undergoing decomposition into hydrogen protons and electrons with the aid of a catalyst. The generated hydrogen protons traverse a proton exchange membrane to reach the fuel cell's cathode, where they combine with oxygen to form water with the help of another catalyst. Simultaneously, electrons travel through an external circuit to the fuel cell's cathode, generating electric current. Due to this process not being constrained by the Carnot cycle, the theoretical efficiency can exceed 90%, showcasing high theoretical economic viability. Unlike energy storage batteries such as lead-acid and lithium-ion, fuel cells operate akin to "generators," predominantly producing water during the conversion of chemical energy to electricity. Moreover, the absence of mechanical transmission components eliminates harmful gas emissions and noise pollution. The core of hydrogen fuel cell vehicles lies in their fuel cell engine system, comprising the fuel cell stack, hydrogen supply system, oxygen supply system, and engine controller.

• Hydrogen Supply System: Transports hydrogen from the hydrogen tank to the fuel cell stack. The supply system consists of an air filter, air compressor, and humidifier, providing oxygen to the fuel cell stack.

• Thermal Management System: Utilizes an independent water and coolant circuit to eliminate waste heat and reaction by-products (water). This contributes to maintaining system stability and efficiency.

The electricity generated by the fuel cell system drives the electric motor through a power control unit, propelling the vehicle. Auxiliary batteries provide additional power when needed. In the future development of the hydrogen industry, enhancing the efficiency and reducing the cost of fuel cell power systems will be a key challenge. Simultaneously, research into more environmentally friendly and efficient hydrogen and oxygen supply systems will drive technological progress. This, in turn, will further accelerate the adoption of hydrogen fuel cell vehicles, providing robust support for the development of clean energy transportation.

Improvement in Storage and Transportation Technology

Storage and transportation of hydrogen are central to liquid hydrogen technology and related equipment. Historically, due to limitations in equipment such as heat exchangers and insulators, coupled with inadequate standards, liquid hydrogen has mainly found applications in aerospace and defence, with slow development in civilian sectors. Equipment for liquid hydrogen preparation is provided by companies like Air Products (USA), Praxair, and Linde (Germany). Currently, Japan and USA consider liquid hydrogen tankers as crucial for transporting hydrogen to refueling stations (Zhang et al., 2024).

Economic Challenges

Cost Issues: While externally supplied high-pressure hydrogen filling stations play a crucial role in hydrogen development, the high construction cost poses an urgent issue. Overcoming challenges in technology and cost associated with liquid hydrogen production and transportation is imperative for the accelerated application of civilian liquid hydrogen. Moreover, reducing the construction cost of externally supplied high-pressure hydrogen filling stations will contribute to the widespread adoption of hydrogen energy. Future research and development should focus on improving related equipment technology, enhancing efficiency, and reducing costs to promote the broader application of hydrogen energy.

Investment and Capital Requirements: Anticipated investment opportunities in the hydrogen energy market will be divided into two stages: the first stage includes market opportunities for key equipment and materials, while the second stage involves the trillion-dollar-scale hydrogen storage and distribution market. We are confident in enterprises currently engaged in the development of integrated hydrogen businesses. These enterprises are expected to benefit significantly from market growth under the support of national subsidies in the short term. In the long run, they are poised to share a substantial market in hydrogen sales, demonstrating positive development prospects.

Environmental Impact Challenges

Environmental Impact of Hydrogen Production: Recent studies highlight some challenges in hydrogen energy systems, despite being considered an environmentally friendly alternative for reducing CO2 emissions. While hydrogen energy faces competition in the automotive sector, it is still seen as a potential alternative to fossil fuels in specific areas such as maritime, large trucks, trains, and industrial applications. However, studies indicate that hydrogen production processes heavily rely on fossil fuels, leading to an unavoidable carbon footprint. Thus, the environmental sustainability impact remains a significant consideration.

Impact of Hydrogen Production on Warming: Moreover, it is of concern that although hydrogen gas emits only water during chemical reactions, its impact on the Earth's climate is 11 times higher than that of carbon dioxide. This suggests that when seeking solutions to reduce CO2 emissions, careful assessment of the environmental impact of other alternative energy sources is necessary. For atmospheric hydrogen releases, each ton is equivalent to an 11-ton warming effect of carbon dioxide, complicating the true environmental benefits of hydrogen energy. In summary, hydrogen energy systems face complex challenges in environmental impact and warming effects. Improving production processes, increasing the proportion of renewable energy, and preventing hydrogen leaks are urgent keys to achieving the maximum benefits of hydrogen energy.

Conclusion

Summary of Research Findings

1. Technological Development Trends

The technological development of the hydrogen supply chain is currently in a phase of continuous innovation, exhibiting the following trends. Firstly, green hydrogen production technology realizes the electrolysis of water using renewable energy, emphasizing zero emissions and sustainability. Technological innovation is dedicated to increasing conversion efficiency and reducing energy consumption. Secondly, blue hydrogen technology involves the production of hydrogen through natural gas steam reforming or carbon oxide reforming while capturing and storing carbon dioxide, thereby reducing carbon emissions. Technological development focuses on improving efficiency and carbon dioxide handling. Additionally, hydrogen storage technologies include high-pressure liquid hydrogen, solid-state hydrogen storage, and hydride hydrogen storage, aiming to increase storage density, reduce energy losses, and enhance safety. Furthermore, hydrogen transport technologies encompass pipelines, liquid hydrogen, and hydrogen transport vehicles to improve transport efficiency and ensure safety. Finally, hydrogen applications in areas such as transportation, industry, and energy storage are continually evolving, including hydrogen fuel cell vehicles and hydrogen fuel cell power

generation systems. Overall, the trend in hydrogen technology development is moving towards greater environmental friendliness, efficiency, safety, and sustainability, with the potential to play a more crucial role in global energy transition.

2. Policy and Regulatory Impact

The impact of policies and regulations on the hydrogen supply chain cannot be ignored, particularly with the Taiwanese government actively introducing a series of regulations to promote the development of the hydrogen industry. The Taiwanese government has announced the goal of achieving a 10% share of hydrogen power generation by 2050 and has jointly established a hydrogen promotion task force with state-owned enterprises such as Taiwan Power Company (Tai power) and CPC Corporation. This task force is formulating Taiwan's future hydrogen development plan through demonstration projects, including natural gas blending for hydrogen power generation and hydrogen refueling stations. Simultaneously, relevant domestic supply chains are gradually being established, with examples such as China Steel Corporation possessing methanol reforming hydrogen production technology, and its hydrogen motorcycles have successfully entered the Indian market. In addition, the inauguration of the Xinxing Electronics', "Hydrogen Fuel Cell Power Generation System", with an investment of NT$4 billion, is scheduled for August 14, with international hydrogen experts witnessing this significant moment. Taiwan has incorporated hydrogen into the Energy Management Act, officially entering the "Hydrogen Year". The Bureau of Energy will follow regulations to promote the formulation of the "Hydrogen Station Installation Management Rules". The active promotion of government regulations and the accelerated development of related industries highlight the need for collaborative efforts among industry, government, and academia to drive hydrogen development.

3. Position of Hydrogen Energy in Global Energy Transition

Hydrogen energy plays a crucial role in global energy transition, being considered a potential clean energy source to reduce greenhouse gas emissions and facilitate energy transformation. Firstly, its zero-emission characteristics make hydrogen energy a sustainable solution to address climate change and reduce air pollution. The combustion of hydrogen gas produces only water, without releasing greenhouse gases such as carbon dioxide, making it an environmentally friendly energy source. Secondly, hydrogen energy has diverse applications and can be widely used in transportation, industry, and energy storage. In the transportation sector, hydrogen fuel cell vehicles and hydrogen-powered trains have become practical alternatives to traditional energy sources. In the industrial sector, hydrogen gas is seen as a potential option to replace conventional fossil fuels in manufacturing and production processes. Thirdly, hydrogen is considered an effective energy storage method, helping to address the instability of renewable energy sources. By converting excess electricity into hydrogen gas and reconverting it into electricity when needed, it enhances the stability and flexibility of the power grid. Additionally, the consensus on international cooperation in hydrogen energy and global initiatives and projects for hydrogen energy promotion facilitate international collaboration, contributing to the sharing of technology, cost reduction, and the acceleration of global energy transition. Finally, continuous innovation in hydrogen energy technology, including green hydrogen, blue hydrogen, and methane reforming, among other production methods, contributes to increasing production efficiency and reducing costs, making hydrogen more competitive.

Recommendations for Future Research

Currently, both large-scale renewable energy hydrogen production and the storage, transportation, distribution, and applications of hydrogen energy in industrial and transportation sectors are in the stage of technology demonstration and the localization of critical equipment, requiring strong government subsidies. From the perspective of hydrogen energy strategy, the current focus is on breaking through the key equipment and material technologies and applications in the transportation sector. This is intended to drive the development of the hydrogen energy storage and transportation segments, creating a spiral upward development dynamic. Ultimately, promoting the maturity of the terminal demand market after renewable energy hydrogen production and accelerating the rapid development of renewable energy hydrogen production are critical.

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