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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR

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In recent years, sustainability and environmental stewardship have become increasingly critical areas of research across disciplines. As global challenges such as climate change, biodiversity loss, pollution, and resource depletion continue to escalate, the need for innovative solutions and interdisciplinary collaboration has never been greater. This issue of the Journal of Sustainability and Environmental Research brings together a diverse collection of scholarly articles that explore emerging trends, technologies, policies, and community-based approaches aimed at fostering sustainable development and environmental conservation.

The articles featured in this volume highlight the importance of integrating scientific knowledge, technological innovation, and socio-economic considerations to achieve sustainability goals. From sustainable urban planning and circular economy initiatives to renewable energy solutions and climate-resilient agriculture, the research presented here underscores the interconnectedness of environmental, economic, and social systems. Moreover, it emphasizes the critical role of both local communities and global cooperation in advancing sustainable practices.

Supply Chain and Sustainability Research (SCSR) employs a **double-blind peer review system**, ensuring that the identities of both authors and reviewers remain anonymous. Each submitted manuscript undergoes evaluation by **three expert reviewers**, selected based on their expertise in the subject matter and/or the research methodology applied in the paper. Articles are assessed solely on their originality, academic merit, and alignment with the journal's scope and objectives. In cases where revisions are required, **our guidelines are designed to help authors improve their manuscripts towards successful publication**.

Publication Frequency: SCSR is published **four times a year**, according to the following schedule:

1. **First Issue:** January – March
2. **Second Issue:** April – June
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Greetings from Editor-in-Chief: Supply Chain and Sustainability Review (SCSR)

The integration of sustainability principles into supply chain management, logistics, transportation, and optimization techniques has gained increasing attention in recent years. One of the most pressing challenges faced by modern supply chain management is the need to balance operational efficiency with sustainability.

SCSR aims to advance research on sustainability applications across diverse fields including supply chain management, operations management, logistics, transportation, healthcare management, and fuzzy sets theory. Since its inaugural issue, the journal has consistently emphasized that sustainable development must go hand in hand with effective supply chain and logistics management.

We welcome submissions from academics and researchers across management-related disciplines. We seek original, high-quality research articles that address sustainability challenges within the management context and contribute to the mission of SCSR. Published articles will cover both theoretical and empirical research, including literature reviews, conceptual frameworks, qualitative case studies, and quantitative empirical analyses. All submissions must fully comply with SCSR's submission guidelines.

In light of ongoing global supply chain disruptions (such as the semiconductor shortage), the impact of supply chains on climate change and biodiversity, emerging regulatory frameworks promoting corporate social responsibility, and technological advancements such as blockchain, sustainable supply chain management has become increasingly critical for global business success. SCSR is committed to providing a platform for research that addresses these complex and evolving challenges.

This issue features six insightful research papers, each contributing valuable perspectives to the ongoing dialogue surrounding sustainability and supply chain management:

1. Climate Change, Natural Disasters, and Sustainable Water Resources Management in the Lancang-Mekong River Basin
2. An Examination of Taiwan's Policies in Responding to Climate Change
3. System Dynamics Engineering Cost Management Strategy from the Perspective of Supply Chain Management: An Effective Method to Control the Cost of Construction Projects
4. A Corporate Role Model in Climate Action: A Case Study of O'right's Net-Zero Emission Practices in Supply Chain Management
5. A Systematic Approach to ESG Integration and Crisis Management Systems in Supply Chains: A Theoretical Framework and Mathematical Models
6. Cross-border E-commerce Service Quality Model Construction and Variable Relationship Analysis.

Furthermore, we would like to take this opportunity to inform our readers about upcoming issues in 2025. The official Call for Papers is now available on the SCSR website, and we strongly encourage contributions from both new and returning authors.

This issue also marks another milestone in SCSR's journey as a growing academic platform. On behalf of the SCSR Editorial Team, it is my great pleasure to extend a warm welcome to all our readers, contributors,

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and partners. I would also like to express my sincere gratitude to our authors, editorial board members, and anonymous reviewers, all of whom have voluntarily dedicated their time and expertise to ensure the success of this journal. Your valuable contributions are essential to our continued growth.

We look forward to receiving your future submissions and to fostering ongoing collaboration in advancing knowledge at the intersection of supply chain management and sustainability.

Sincerely,

Jirasek Trimetsoothorn
Editor-in-Chief

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Climate Change, Natural Disasters, and Sustainable Water Resources Management in the Lancang-Mekong River Basin

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Cheng-Yi Kuo**

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Abstract

The Lancang-Mekong River Basin stands as the largest river basin in Southeast Asia, spanning across riparian states including China, Laos, Myanmar, Thailand, Cambodia, and Vietnam. In light of this significance, the Third Lancang-Mekong Cooperation Leaders' Meeting took place on August 24, 2020, aiming to foster consensus among these nations. However, despite such agreements, the region continues to face various disasters, including droughts, floods, and dam collapses, resulting in substantial damages.

This research endeavours to investigate the historical context of the Lancang-Mekong River Basin, focusing on water resources management within the area. By employing the perspectives of information sharing and coexist environment theory, the study aims to shed light on effective strategies for addressing these challenges. Through an examination of past practices, this research seeks to provide valuable insights into managing water resources in the Lancang-Mekong River Basin, promoting sustainable development and fostering cooperation among the riparian states.

Keywords: The Lancang-Mekong Cooperation (LMC), Mekong River Commission (MRC), Water Resources Management, Information Sharing, Coexist Environment Theory

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Introduction

The Mekong River, spanning 4,350 km, stands as the 12th longest river in the world, the seventh longest in Asia, and the longest in Southeast Asia. Originating from the Tibet-Qinghai plateau, the upstream portion known as Lancang flows through Qinghai, Tibet, and Yunnan provinces in China. The lower Mekong traverses Thailand, Laos, Myanmar, Cambodia, and Vietnam before flowing into the South China Sea (Ouyang, 2016). Supporting a population of 60 million, the lower Mekong basin has experienced a decline in water levels since 2019, with two consecutive years of record-breaking droughts reaching the lowest levels in the past 50 years. This has had detrimental effects on fishery and agricultural activities (The News Lens, 2020). A U.S. study reveals that while the headwaters of the basin received above-average rainfall from May to October 2019, areas in Laos and Thailand experienced below-average rainfall, particularly Thailand suffering from severe drought (Basist & Williams, 2020). There is ongoing debate regarding the impact of China's construction of 11 dams in the upper Mekong River basin, which retain water and potentially reduce water levels downstream by two-thirds. The Chinese government argues that the drought may be caused by reduced rainfall. However, criticism has arisen due to China sharing limited data with the six riparian countries, prompting the Thai government to request more information. In August 2020, a virtual summit for the Lancang-Mekong Cooperation (LMC) was held in response to the second consecutive year of record-low water levels in the Mekong River. The Mekong River Commission (MRC) emphasized the need for China to provide more data (Hung, 2020; Reuters, 2020).

A report from the U.S. think tank, Stimson Center, suggests that during a six-month period in 2019, rainfall exceeded the average, but China's dam operations resulted in more water being held back. Conversely, countries in the lower basin experienced severe drought conditions. It is argued that if China's dams did not restrict the flow, the Mekong River along the Thai-Laos border would have experienced above-average flows from April 2019 to the present (Eyler & Weatherby, 2020). These tensions stemming from different perspectives warrant examination. It is essential to explore whether upstream countries have influenced the damages and changes in average flows. Furthermore, the adoption of information sharing and coexist environment theory is crucial. Campbell asserts that direct human impacts on hydrology include irrigation, while indirect effects involve dams and land use. Although there have been speculations, further investigation is required to gather more evidence (Campbell, 2009). Based on Campbell's statement, the research seeks to address the following questions:

What are the recent evidences of direct and indirect human impacts on the Lancang-Mekong River Basin? The paper aims to explore the evidence of these impacts on the area in light of the changing ecological environment.

What are the opportunities for water resources management along the Lancang-Mekong River Basin? Through an information sharing approach, the paper will examine how sharing information can lead to improved

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methods of water resources management.

What considerations are given to water resources management in the Lancang-Mekong River Basin? Using a coexist environment perspective, the paper seeks to understand whether this perspective has influenced decision-making processes.

Literature Review

The Lancang-Mekong Cooperation (LMC)

The Lancang-Mekong Cooperation (LMC) was established in 2012, primarily driven by Thailand's initiative to develop the Lancang-Mekong region. Subsequently, China launched economic and diplomatic policies towards the LMC. In 2016, the LMC Leaders' Meeting took place, and the Sanya Declaration was announced, emphasizing cross-border cooperation in areas such as the economy and water resources. In 2018, China advocated for increased water cooperation, particularly in managing drought and flood situations (Grunwald, 2020). However, China's emphasis on the "Mekong Spirit" of water cooperation has faced criticism.

Information Sharing Approach Inform

As highlighted by Rafaeli and Raban, information sharing is defined as "the act of providing a helpful answer to a request for information" (Rafaeli & Raban, 2005). The nature of information is not clearly classified as solely private or public good. It can possess characteristics of both, leading to different ownership options and external influences that can either facilitate or hinder sharing. It is important to note that information-sharing issues cannot be solely attributed to "free riding". Regardless of whether information is intended for public or private benefit, the approach to information sharing significantly impacts the underlying issues.

Coexist Environment Theory

Godoy (2019) emphasizes that the core objective of coexistence theory is to establish mechanisms that prevent exclusion and encourage interaction and sharing among various entities. Since the 1950s and 1960s, the concept of coexistence has extended beyond biology and found applications in anthropology, sociology, economics, management, architecture, and political science. It is evident that the relevance of coexistence theory extends to environmental contexts, particularly in exploring the impact of water resources management on basin regions. This paper employs an information sharing approach and adopts coexist environment theory as a theoretical model to investigate water resources management in the Lancang-Mekong River Basin. Through these theoretical approaches, the research aims to comprehend the mechanisms through which information is shared and to analyze how the concepts of coexisting environment have influenced the ecological dynamics of the basin.

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Research Methodology

Documentary analysis is a systematic procedure used to review and analyze various types of documents, including books, diaries, journals, newspapers, and both printed and electronic materials. It is a researcher's intervention-free process that employs a systematic approach to evaluate the content of these documents (Bowen, 2009). In this research, the documentary analysis method was adopted to assess the evidence related to hydrology, encompassing direct and indirect human impacts, as well as the influences of international agreements on water resources management.

According to Ouyang (2016), the capitals of Laos and Cambodia are situated along the Mekong River, and the rice production of Thailand and Vietnam heavily relies on this vital waterway. The Mekong River basin is known for its abundant water resources, with an average water flow of 475 billion cubic meters, ranking it first in Southeast Asia. Campbell (2009) notes that the development of water resource management is significantly influenced by hydropower, specifically "the shift of water from the wet to the dry season via reservoir storage." However, this practice can lead to various challenges, including drought, river destruction, ecological changes in the water, and even dam collapse.

Results and Discussion

Drought

According to Ouyang (2016), the water resources of the Mekong River primarily come from rainfall and the melting of snow in the mountains. Beech (2020) highlights that while the water level in China was above average in 2019, lower stream countries experienced severe drought conditions. In some areas, the water levels dropped to the extent that riverbeds cracked and became exposed. For instance, in the Chiang Saen district of northern Thailand, the water level reached a historically low point. A study indicates that the construction of dams in China has resulted in the blocking of over 125 meters of water resources.

River Destruction

According to Xiao (2020), in December 2017, the Thai government announced that the Chinese government agreed to halt blasting activities. However, the blasting has resulted in significant changes to the ecological environment, and the construction of dams has impacted water resources and fishery activities. The evidence suggests that the river's ecology has been adversely affected by these activities.

Water Ecological Changes

Due to the alterations in water ecology, farmers in Chiang Rai, Thailand, have been compelled to relocate their farms to higher ground to prevent unnatural flooding. This displacement has had an impact on agricultural production, particularly the cultivation of bean sprouts. The diminishing number of bean sprout fields has been a cause for concern (BBC, 2018). Biologists have expressed apprehension about the ecological changes and their

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effects on plants, birds, and aquatic animals.

Dam Collapse

The catastrophic collapse of Saddle Dam D in Laos in 2018 has had a profound impact on the region. On 23rd July, approximately 500 million cubic meters of water was unleashed, resulting in a devastating flood. The consequences were severe, with at least seven villages sustaining damage, over 20 casualties, hundreds of people reported missing, 7,000 individuals forced to evacuate, and 14 bridges destroyed. Recognizing the gravity of the situation, the Laos government declared the affected area a national emergency disaster zone (Inclusive Development International, 2025)

Table 1 The Collapse of Saddle Dam D in Laos

July	22nd	21:00	Engineers found more than 10 cracks in Saddle Dam D, and the Laos authorities notified populations downstream to evacuate. However, heavy rain damaged the road, and the repair team cannot fix the cracks.
July	23rd	03:00	Released water from the main dam to lower the water level.
July	23rd	12:00	Dam problems were not controlled, and the Laos government evacuated downstream residents.
July	23rd	20:00	Dam collapsed and flooded villages downstream with about 500 million cubic meters of water.
July	24th	09:30	At least seven villages were flooded, more than 20 people killed, hundreds missing, about 7,000 evacuated, and 14 bridges destroyed.
July	26th		The South Korean government sent rescue team to help.

The Change of Lancang-Mekong River Basin

Satellite data analysis has revealed a significant disparity in the surface humidity levels between Yunnan Province in China and Thailand and Laos from May to October 2019. While the humidity levels in Yunnan Province remained above average, the water levels in Thailand and Laos were three meters lower. This discrepancy suggests that water was not adequately released to downstream countries, even during the monsoon season (Reuters, 2020). The data further highlights that although the source of the Mekong River, the Tibet-Qinghai plateau, did not experience drought conditions, downstream countries such as Cambodia and Thailand suffered from a severe lack of water resources (Wu, 2020).

Analysis of Diverse Schemes-Environmental Protect Agreement

In response to the ecological changes and damages occurring along the Lancong-Mekong River, riparian countries including China, Laos, Myanmar, Thailand, Cambodia, and Vietnam have established environmental protection agreements to ensure sustainability (see Table 2).

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Table 2 The Environmental Protect Agreement

1992	The Greater Mekong Sub-Region Initiative included China, Myanmar, Laos, Thailand, Cambodia and Vietnam.
1994	China, Laos, Myanmar and Thailand signed the agreement on waterway transportation in Mekong River.
2002	The government of Thailand approved environmental evaluation on waterway transportation.
2002-2003	China launched a blasting program along the Mekong River from Yunnan province to the border of Lao and Myanmar.
2003	The project was suspended by Thai cabinet due to local people and environmental groups against it.
2016	China launched the Lancang-Mekong Cooperation (members including Cambodia, China, Laos, Myanmar, Thailand, and Vietnam).
2017	Chinese vessels surveyed 15 rapids covering a 96-kilometer stretch of Mekong River along Thai border
2018	China advocated for increasing water cooperation, such as managing drought and flood
2019	The report on Lancang- Mekong Cooperation Development was announced
2020	The Third Lancang- Mekong Cooperation Leaders' Meeting

Lancang-Mekong Cooperation (LMC)

The Lancang-Mekong Cooperation (LMC) was initiated by the Chinese government in 2016 as an inter-governmental organization focused on water cooperation (Grunwald, 2020). While the LMC may not address all the challenges, it aims to foster trust among stakeholders and facilitate the resolution of certain issues.

Thai-Lao Cooperation

Thailand and Laos have established a cooperative agreement regarding the sharing of rainfall, drainage, and hydrological monitoring data along the Mekong River. Both countries have jointly developed the Xayaburi Reservoir Management Plan, which aims to analyze the water flow from the Mekong River into Thailand's northeastern region, with the goal of mitigating the risks of embankment overflow and flooding. This collaboration encompasses various aspects, including the management of the Xayaburi hydropower project, the sharing of water information, notification systems for water storage and flow, as well as emergency and safety management for the Xayaburi hydropower station (Medium,2020)

Strategy of Water Resources Management

It has been observed that the construction of numerous upstream dams for hydropower generation has resulted in adverse consequences for residents living downstream. Concerns have been raised regarding the exclusion of these residents, who rely on the water resources of the Mekong River, from the agreements made

between countries (Wu, 2020). The situation calls for authorities to consider the broader implications and exercise careful judgment with a deep understanding of the issue. Currently, there is a lack of effective constraints on natural resource management and authority. It is suggested that the international community collectively address this issue and establish comprehensive regulations among the countries along the Mekong River (BBC, 2015).

International Law Against Upstream Dam Construction

According to (Tsai, M., 2020), upstream parties such as China and Laos are not signatories to the Convention on the Law of the Non-Navigational Uses of International Watercourses or the Mekong River Agreement. This implies that prior consultation with downstream parties is not mandatory before constructing dams. However, it is argued that even non-contracting countries are still bound by international law. The obligations of upstream countries include the principles of 'reasonable and equitable use,' 'prevention of harm to other countries,' and 'protection of the ecosystem.' Moreover, the obligations to notify, consult, cooperate, and provide information are emphasized. Tsai, M (2020) contends that even though China is not a signatory, these obligations still apply. Specifically, the construction of the Sambor Dam in China has impacted 19,000 people, fish populations, and the ecosystem of the Mekong Delta.

Environmental Monitoring Data Transparency and Sharing

The Mekong Dam Monitor is an open-source online platform that utilizes remote sensing, satellite imagery, and GIS analysis to provide near-real-time monitoring of dams and environmental impacts in the Mekong basin (STIMSON, 2021). This platform plays a crucial role in monitoring the hydrology of the Mekong Basin and revealing water flow patterns. Water diplomacy serves as a political tool to promote equity, sustainability, peace, and cooperation. The adoption of a multi-track water diplomacy approach allows for an examination of water cooperation among riparian countries (Grunwald, 2020).

The transparency of environmental monitoring data and information sharing has significantly contributed to the understanding of water flow in the region, leading to improvements in water resources management. This increased transparency has also influenced the way riparian countries consider and address the coexistence of their environments. Consequently, nations are adopting a shared approach to managing water resources and promoting coexistence among themselves.

Conclusion

The research has focused on studying the evidence of water resources management in the Lancang-Mekong River Basin and investigating the direct and indirect human impacts on the area in recent years. The findings have revealed significant indirect human impacts on the basin. Despite the advocacy of environmental

protection agreements by riparian states, the effectiveness of these measures in safeguarding the environment has not been fully realized. Based on the evidence from water resources management, it is recommended that information sharing and the adoption of a coexist environment perspective are essential for achieving sustainable environmental management in the region.

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An Examination of Taiwan's Policies in Responding to Climate Change

Cheng-Yi Kuo*
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Abstract

This study explores Taiwan's climate strategies, highlighting both their strengths and areas for improvement. Initially, the paper provides an overview of Taiwan's current climate situation, establishing a baseline for understanding the existing policy landscape. It then critically evaluates the country's efforts concerning carbon emissions reduction, energy efficiency, and broader carbon-reduction initiatives implemented in recent years. The challenges encountered during the implementation of these strategies are thoroughly examined, leading to practical recommendations aimed at enhancing Taiwan's resilience to climate-related challenges. Key recommendations include improving policy coherence, enhancing risk mitigation strategies, increasing community involvement, refining oversight mechanisms, and supporting industrial evolution. This research seeks to guide future climate-focused policymaking in Taiwan by offering a comprehensive analysis and proposing innovative policy directions

Keywords: Climate Change, Policy Implementation, Effectiveness evaluation, Climate Related Challenges

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Introduction

The contemporary landscape of global climate change

Global climate change remains one of the most daunting challenges the world faces today. Since the Industrial Revolution, human activities have consistently released greenhouse gases, leading to increased atmospheric concentrations of these gases. This increase has triggered various climate shifts, including rising global average temperatures, more frequent extreme weather events, and shrinking polar ice caps. The impacts of climate change affect the environmental, societal, economic, and health sectors across many nations and territories. According to a study published in the prestigious journal Nature, there has been an approximate 0.9°C increase in global temperatures over the last century, with the rate of this increase accelerating, highlighting the growing threat of climate change (Hansen et al., 2006). This rise in temperature poses direct and indirect risks to natural ecosystems and socio-economic structures, leading to inconsistent food supplies, heightened natural disasters, ecological degradation, and rising sea levels that threaten island nations like Taiwan.

In response, countries worldwide have developed strategic initiatives. Taiwan has taken significant steps by implementing policies aimed at reducing greenhouse gas emissions, adapting to climate changes, and transitioning to a low-carbon economy. However, effectively tackling Taiwan's unique climate challenges requires careful examination of its policies and constructive feedback on their effectiveness.

Taiwan's crucial role in addressing climate change

Located at the confluence of tropical and temperate zones on Asia's northeast coast, Taiwan is home to a rich tapestry of ecological assets and a myriad of biodiversity. Yet, as the global climate transformation accelerates, Taiwan's vulnerability to its effects increases. A research article in the esteemed journal, Science, suggests that since 1981, Taiwan's temperature trajectory has exceeded the global average rate, placing Taiwan in a heightened vulnerability bracket concerning future climate shifts (Hsiang et al., 2011). This underscores Taiwan's critical role in combating climate change and highlights the urgent need for effective mitigation strategies. The threat of climate change could unleash a range of repercussions on Taiwan, including more frequent extreme weather patterns, unstable water reserves, ecological changes, damage to agriculture and fishing sectors, and socio-economic disruptions. These transformations could significantly hinder Taiwan's economic progress, disrupt societal balance, and alter its ecological harmony. Therefore, it is crucial for Taiwan to develop and implement strong and tailored climate countermeasures.

In response to these impending challenges, Taiwan's governing bodies are actively promoting policies that address climate change—ranging from initiatives to reduce greenhouse gas emissions, adapt to the changing climate, increase energy efficiency, and transition towards a low-carbon economy. However, a thorough analysis

of policy effectiveness and constructive critiques are essential to assess the strength of these strategies and strengthen them against the complex challenges that climate change imposes on Taiwan.

Research background and motivation

As the intensity of global climate change escalates, nations face increasing threats including erratic weather patterns, ecological shifts, and fluctuating water resources. Taiwan, with its advanced development and dense population, is particularly vulnerable to these climate-induced challenges. Acknowledging this, Taiwan's government is actively promoting adaptation strategies to mitigate the multifaceted impacts of climate change on its economy, society, and ecology. In the academic realm, much of the previous research has focused on the empirical and technical aspects of climate change, including climate projections and strategies for reducing greenhouse gas emissions. However, climate change is not solely a scientific issue; it involves complex interactions among political, economic, social, and ecological dimensions. This highlights a gap in the examination of government policies and strategies to address climate change.

This research aims to bridge this gap by analyzing and providing insights into Taiwan's approach to climate change, examining the effectiveness and challenges of the region's policy frameworks, goals, and mechanisms. Through a detailed assessment of existing policies and their implementation, we seek to gain a deep understanding of Taiwan's current climate change strategies and offer tailored policy recommendations. Ultimately, this study intends to enhance the Taiwanese administration's ability to develop robust and sustainable climate-focused policies, thereby strengthening Taiwan's resilience against the increasing challenges posed by climate change (Hsu & Chen, 2002).

Research objectives and research questions

Amid the escalating consequences of global climate change, governmental bodies face increased risks, such as more frequent extreme weather events, ecological shifts, and water resource volatility. Taiwan, with its advanced development and dense population, is not exempt from these challenges. In response, Taiwan's leadership has been proactive in developing adaptive policies to address the economic, societal, and environmental effects of climate change.

Much of the existing literature has focused on the empirical and technical aspects of climate change, resulting in a noticeable gap in policy-oriented discourse. This research aims to shed light on Taiwan's policy landscape regarding climate change, exploring the effectiveness, complexities, and potential pitfalls of the strategies, objectives, and instruments utilized by the Taiwanese government. Specifically, our study will focus on the following critical questions: 1) What strategies has the Taiwanese government implemented to combat climate change, and how effective have they been? 2) What obstacles has the administration faced in implementing these climate-

centric policies? 3) Considering the inherent limitations and potential oversights of current strategies, this research will propose forward-looking policy advisories to enhance the government's approach to climate change.

By leveraging international research paradigms and methodologies, this study is set to perform a detailed analysis of Taiwan's climate change policies and subsequently provide actionable recommendations. Through this effort, we aim to offer valuable guidance not only for Taiwan's policymakers but also for other stakeholders striving to enhance their climate resilience (Lai et al., 2021).

Research scope and methodology

The objective of this study is to provide a comprehensive policy analysis and offer recommendations regarding Taiwan's approach to addressing climate change challenges. To achieve this, the research will conduct a detailed examination of Taiwan's climate change policies, utilizing sources such as policy documents, relevant laws and regulations, government reports, and existing academic literature. Qualitative research methods, such as literature reviews and policy document analysis, will be applied to gain insights into the policy-making process, its objectives, and strategies. The findings will inform policy evaluations and recommendations.

To establish an appropriate research scope and methodology, references were made to several international journals and studies that focus on climate change strategies, including one that specifically examines Taiwan's adaptive measures. This particular study provided a multi-layered analysis of both the policy formulation and its implementation phases, offering a comprehensive overview of Taiwan's steps in addressing climate change (Chang et al., 2013). This prior work has significantly informed the organizational structures examined in this research and provided a substantial rationale for the selected focus and methods of this study

Current status and trends of climate change

Overview of global climate change

Climate change is a critical environmental issue in contemporary times. The increase in greenhouse gas emissions, mainly due to human activities, is a primary driver of global climate shifts, leading to rising Earth temperatures. This increase in temperature has triggered various climate disturbances with extensive implications across ecological, societal, and economic dimensions. Authoritative sources such as the IPCC have noted an approximate increase of 1.1°C in global temperatures since the latter half of the 19th century. With the continuous rise in greenhouse gas emissions, future projections indicate an intensification of climate change severity. This trend is expected to lead to more frequent climatic extremes, including storms, droughts, and floods. The effects of these climate changes will leave a lasting impact on socio-economic structures, ecosystems, and the daily lives of people worldwide, with regions like Taiwan being no exception (Schleussner et al., 2016).

Analysis of climate change status and trend in Taiwan

Located off the northeast shores of Asia, Taiwan is confronting the global impacts of climate change. Insights from notable international publications have placed Taiwan's climate trends under close examination. In recent years, the shifts in Taiwan's climate have become increasingly apparent. Research highlights a consistent rise in the nation's average temperature, with notably hotter summers. There has been a significant increase in the number of intensely hot days and prolonged heatwaves, presenting challenges for agriculture, environmental management, and public health. Additionally, changes in Taiwan's precipitation patterns are noticeable. There has been a greater concentration of rainfall and an increase in heavy downpour events, impacting water conservation, urban disaster management, and agricultural irrigation practices. Furthermore, Taiwan's coastal areas are experiencing an accelerated rise in sea levels, posing potential threats to its coastal ecological, social, and economic structures. If these climatic changes are not addressed, they could significantly affect Taiwan's socio-economic and ecological stability in the future, highlighting the need for thorough policy evaluations and adaptive measures (Lin et al., 2022)

Analysis of Factors Affecting Climate Change in Taiwan

Taiwan’s experience with climate change is influenced by a complex mix of natural and human factors. Internationally recognized research highlights that these factors significantly shape Taiwan's climatic patterns and trajectories. From a natural standpoint, global climatic changes, evidenced by rising average global temperatures, are reflected in Taiwan's climate records. Additionally, variations in significant atmospheric dynamics, such as the Asian monsoon and key circulation patterns like the Eurasian and Pacific Highs, influence Taiwan's climate characteristics, impacting its rainfall distribution and frequency of cyclonic events.

On the human side, activities such as industrial production and transportation contribute to climate change by increasing greenhouse gas concentrations in the atmosphere, thereby exacerbating global climate anomalies. Given its status as a rapidly industrializing center, Taiwan's carbon footprint is particularly significant. In summary, Taiwan's climate narrative is shaped by inherent factors like global climate shifts and atmospheric circulation changes, as well as by human-induced factors, primarily greenhouse gas emissions. A detailed examination of these influences is crucial for gaining a deeper understanding of Taiwan's climatic challenges and trends. Such insights are essential for stakeholders to develop effective, climate-focused policies (Chen et al., 2021).

Climate change issues facing Taiwan

Consequences of climate alterations in Taiwan: from elevated sea levels and temperatures to severe weather events

Taiwan, as an island, is inherently vulnerable to the effects of climate change. Insights from prominent international research indicate that the factors influencing Taiwan's climate shifts are a combination of natural and

human-related causes. Naturally, Taiwan's location within the Asian monsoon belt makes it susceptible to monsoonal patterns, which significantly affect its precipitation patterns and overall climate variations. Recent times have seen an increase in extreme weather events in Taiwan, such as prolonged droughts and powerful typhoons, posing challenges to agriculture, water supply, and infrastructure.

On the human side, Taiwan's role as a major industrial center contributes significantly to greenhouse gas emissions, exacerbating the global climate crisis. Additionally, human activities such as changing land use, increasing urban sprawl, and expanding transportation networks lead to secondary climate impacts in Taiwan, including the urban heat island effect and challenges in water management. In conclusion, Taiwan's climate dynamics are shaped by a blend of environmental factors and human interventions. A thorough understanding of how these factors interact is crucial for policymakers and stakeholders to develop effective strategies that enhance Taiwan's resilience to the impending climate challenges (Hung & Chen, 2013).

Potential economic, social, and ecological ramifications of climate change for Taiwan

Taiwan, facing the ongoing challenges of climate change, finds itself at a critical juncture where economic, societal, and environmental impacts intersect. Research from respected international publications highlights a range of consequences, including economic difficulties, societal vulnerabilities, and ecological degradation. Economically, unpredictable weather events like typhoons and heavy rainfall endanger Taiwan's agricultural and marine industries. The consequences include crop destruction, declining fish populations, and damage to fisheries infrastructure, leading to reduced productivity and fewer job opportunities in these sectors. Furthermore, the integrity of vital infrastructure such as transportation, energy, and water systems could be compromised, challenging Taiwan's economic stability and growth prospects.

From a societal perspective, the emerging patterns of climate change may foster unrest. Extreme weather events, from droughts to floods, could compromise public health, lower life quality, and affect the well-being of the population. Particularly vulnerable are the elderly, economically disadvantaged, and rural residents, who may disproportionately suffer from these changes. Ecologically, Taiwan is at risk of significant environmental decline. Climate change threatens to diminish biodiversity, disrupt ecosystems, and disturb the ecological balance, thereby undermining the provision of ecosystem services. The expected rise in sea levels could transform ecological patterns, land use, and human settlements in coastal areas. Ultimately, Taiwan faces a complex climate challenge that intertwines economic, societal, and environmental concerns. A deep understanding of these interconnected impacts is essential for Taiwan's government to develop effective and responsive strategies.

Taiwan's current climate change response policies

Various measures taken by the Government of Taiwan

The Taiwanese government, as documented in renowned international journals, has implemented a

comprehensive range of strategies to combat the effects of climate change. These strategies encompass climate risk evaluations, adaptive measures, and mitigation efforts. Initially, the government undertook extensive climate risk assessments to identify and assess the vulnerabilities and threats posed by climate change across various sectors and regions. Research highlights Taiwan's efforts in conducting detailed climate change risk assessments, focusing on vulnerable territories and industries, which helps in prioritizing relevant policies (Yang & Ge, 2020). In terms of adaptation, the state has supported initiatives specifically designed to address the tangible impacts of climate change. These include promoting water stewardship through rainwater harvesting systems and enhancing water conservation efforts to safeguard against potential droughts and water shortages. Additionally, in response to urban challenges, there has been an emphasis on adjusting land use and urban planning to accommodate rising sea levels and erratic weather patterns (Tu & Yu, 2023).

On the mitigation front, the government has concentrated on reducing greenhouse gas emissions to slow climatic changes. This has involved fostering an energy transformation, increasing the use of sustainable energy sources, and enhancing energy conservation practices. Moreover, Taiwan actively participates in the global climate dialogue, setting emission reduction targets that align with international standards. In summary, Taiwan's proactive approach is evident in its comprehensive response to climate change, which includes risk assessments, adaptive strategies, and mitigation plans. These efforts are crucial not only for reducing the impact of climate change on Taiwan but also for strengthening its socio-economic and ecological resilience and fulfilling its international climate obligations.

Applicable legal frameworks, directives, strategies, and initiatives

Addressing climate change through policy interventions is crucial for Taiwan, involving a range of legislative frameworks, policy directives, and actionable plans. In an effort to proactively mitigate the impacts of climate change and promote sustainable growth, Taiwan has made significant legislative progress in recent years. Notably, the Climate Change Adaptation Act was introduced in 2015, quickly followed by the development of comprehensive strategies in 2016 aimed at mitigating the effects of severe weather events such as typhoons and rising sea levels. Additionally, the Taiwanese government has actively promoted sustainable growth models, as demonstrated by initiatives like the National Renewable Energy Action Plan and the blueprint for the National Center for Global Change Research, both aimed at reducing greenhouse gas emissions and encouraging sustainable development.

However, the process of translating these policy goals into effective outcomes faces several challenges. Some climate-responsive policies struggle with effective enforcement and are hindered by inadequate oversight mechanisms, leading to weakened impacts on the ground. Furthermore, the isolated nature of some policies can cause resource inefficiencies and suboptimal results. Therefore, there is a critical need to thoroughly examine these policies, assess their actual effectiveness, and suggest improvements. An article from the respected Climate Policy

journal highlights several key recommendations for global policymakers. It calls for the harmonization of policies and the promotion of inter-departmental collaboration to ensure seamless policy implementation. It also stresses the vital role of grassroots involvement, ensuring that policies meet local needs and gain community support. Additionally, the journal emphasizes the importance of robust oversight and evaluation mechanisms, advocating for transparency and effectiveness throughout the policy lifecycle. By incorporating these insights, Taiwan can refine its policy frameworks, making them more robust and effective in addressing the ongoing challenges of climate change.

Policy implementation and effectiveness evaluation of government agencies

The Taiwanese government has implemented a detailed strategy including laws, regulations, policies, and tactical plans to combat climate change. Nonetheless, the effectiveness of these measures in practice has sparked debate and scrutiny regarding the capabilities of governmental agencies. Scholarly research has been conducted to evaluate the efficiency and fidelity of execution by these agencies in relation to their climate change objectives. A significant study in 2020 by Chen and Lin explored the complexities of policy implementation in Taiwan. Their research highlighted various obstacles that hinder effective policy implementation, such as limited resources, poor inter-ministerial collaboration, and inconsistent policy alignment.

While the study recognized the significant progress made by government bodies in introducing relevant legislative frameworks and strategies for both mitigation and adaptation, it also identified critical bottlenecks. These include fragmented policy harmonization and uneven resource distribution across agencies. In essence, although Taiwan’s plan for addressing climate change is comprehensive on paper, the actual execution by governmental entities faces significant challenges. Addressing these issues is crucial for achieving the desired outcomes of Taiwan's climate policies (Su et al., 2013).

Analysis of the advantages and disadvantages of policy measures

Taiwan has developed a comprehensive framework to tackle climate change, incorporating a range of policy tools including laws, regulations, policies, and strategic initiatives. However, a thorough evaluation is essential to determine the effectiveness and practicality of these measures. According to global research findings, Taiwan's current policies on climate change exhibit distinct strengths across the spectrum of policy instruments. The government has introduced significant legislative measures such as the Climate Change Response Law and the White Paper on Sustainable Energy Policy, which aim to guide and enhance climate-responsive actions. Furthermore, initiatives like the National Action Plan for Climate Change Adaptation and its counterpart for Mitigation provide clear directives for governmental bodies and stakeholders to coordinate their efforts in addressing climate challenges.

Despite these positive steps, there are noticeable gaps in the implementation of these policies. A lack of

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synchronization and unity in policy deployment is apparent, with isolated efforts by various government entities sometimes leading to redundant actions and inefficiencies. The absence of a strong oversight mechanism complicates the evaluation of the policies' effectiveness at the ground level. Additional challenges include funding shortages, technological limitations, and varying levels of public support, all of which can affect the tangible outcomes of these policies. In summary, while Taiwan's framework for responding to climate change is supported by well-established laws, regulations, and plans, the implementation process is fraught with difficulties such as poor coordination, monitoring issues, and resource constraints. To strengthen its climate resilience, it is crucial for Taiwan to address these critical issues (Lee et al., 2022)

Assessment of measured potency, potential hurdles, and issues

In Taiwan, addressing climate change involves a comprehensive array of instruments, including laws, regulations, policies, and tactical plans. Understanding the real-world impact of these interventions requires thorough assessment. However, this evaluation process is fraught with complex challenges. The inherent complexity of climate change policies, due to their long-term scope and interconnected nature, means that the outcomes of these initiatives may not be visible for some time. Moreover, these policies are subject to a myriad of ever-changing factors, both temporally and geographically, necessitating a sustained and detailed analytical approach to accurately measure their effectiveness over extended periods.

The evaluation process is further complicated by the need for cross-disciplinary scrutiny and a robust data infrastructure, particularly in socio-economic areas where data may be limited or unreliable. This lack of data can affect the reliability and impartiality of the evaluation. Additionally, the political landscape plays a significant role, as climate change policies often disrupt established political and economic balances. The varied perspectives and vested interests of numerous stakeholders, including government bodies, interest groups, the corporate sector, and the general public, can influence the outcomes of policy assessments. To encapsulate, while it is vital to assess the effectiveness of Taiwan's climate change strategies, the task is complex, involving multi-dimensional policy issues, challenges with data, and the influence of stakeholder dynamics. Successfully navigating these complexities is crucial for conducting an unbiased and accurate evaluation of policy efficacy (Berkes et al., 2021).

Examination of Taiwan's strategies in addressing climate change

Dissecting the genesis and execution of Taiwan's climate change strategies, including policy background, aims, and instruments.

The research entitled "Policy Analysis and Suggestions for Taiwan's Climate Change Response Policies" explores the comprehensive strategy the Taiwanese government has implemented to address climate change. This study highlights the methods used in formulating and deploying policies, identifying their foundational elements: the policy background, objectives, and implementation tools. An article cited within the research suggests that the basis

for these policies likely stems from Taiwan's immediate and future climate challenges. These challenges include extreme weather events, rising sea levels, and decreasing water reserves, along with a commitment to meeting international climate change mitigation standards.

The goals of these policies include reducing greenhouse gas emissions, enhancing adaptive capabilities, protecting ecosystems and climate-vulnerable areas, and promoting a sustainability-focused development agenda. The mechanisms for achieving these goals encompass legislative measures, financial incentives, advancements in science and technology, widespread information sharing, and building international collaborations to fulfill the outlined objectives. The policy-making process, from development to execution, is influenced by various internal and external factors. These include the ideological orientations of the policy makers, the current political environment, stakeholder involvement and influence, and the logistics of funding and resource distribution. The government faces the challenge of balancing these dynamic factors to achieve policy goals while ensuring effectiveness, equity, and sustainable results (Hsu & Lin, 2013).

Assess the strengths and weaknesses of these strategies, Including the efficacy, practicality, and long-term viability

Drawing from analytical insights into Taiwan's climate change response policies, it is clear that the government has taken proactive steps in devising comprehensive measures to address the complex challenges posed by climate change. A key example of these efforts is the Environmental Protection Department of the Executive Yuan's 2015 blueprint, which outlined a national adaptation strategy to climate change, accompanied by supportive policies to mitigate environmental, societal, and economic impacts. On the positive side, Taiwan's climate-focused policies have made significant progress in specific sectors. The government has effectively reduced greenhouse gas emissions by promoting a shift towards more sustainable energy practices, enhancing energy efficiency, and encouraging the adoption of green energy sources. Additionally, the government has prioritized ecological conservation and disaster preparedness to protect both the environment and society from climate-related adversities.

However, the implementation of these policies is not without its challenges. The practical application of some policies requires substantial financial investments and technological expertise, which raises questions about their economic viability. Moreover, the long-term sustainability of these initiatives is vulnerable to the changing political landscape and societal dynamics. Factors such as policy consistency across different government tenures, societal acceptance, and public engagement play critical roles in determining the durability and effectiveness of these strategies (Shih, 2016).

Stakeholder analysis and evaluation

Within the scope of analyzing Taiwan's climate change response policies, stakeholder evaluation plays a

critical role. Stakeholders include all entities affected by or having influence over policy directions, ranging from government bodies and corporate entities to non-profit organizations, academic institutions, and the broader civil society. Conducting thorough stakeholder scrutiny can reveal how policies impact different groups, identify potential areas of conflict, and enhance the likelihood of policy durability and practicality. Research from an international academic journal emphasizes that government agencies are central to climate response strategies, overseeing policy design, financial support, and implementation. It is crucial for governmental units to engage proactively with all stakeholders during the policy formulation phase, taking into account their perspectives and needs, thus strengthening the fairness and credibility of the policies. Simultaneously, the corporate sector and NGOs play critical roles in the implementation phase, contributing their technical expertise, resources, and on-the-ground strategies.

However, the landscape is not without its conflicts. Corporations may primarily focus on economic benefits, while NGOs typically concentrate on ecological conservation and social fairness. This divergence necessitates governmental mediation to align these sometimes conflicting interests to ensure comprehensive policy outcomes. By conducting in-depth stakeholder evaluations, the government can refine its policies to better align with the expectations and concerns of all parties involved. Additionally, it is essential to establish lasting frameworks for collaboration, encouraging continuous dialogue and building rapport with stakeholders to prevent potential disputes and ensure unified efforts. Such collaborative engagements are fundamental to enhancing the strength, sustainability, and effectiveness of policies, which are crucial for the success of climate adaptation strategies (Shih & Tseng, 2014).

Issues and challenges in policy development and implementation

Taiwan's efforts to develop and implement climate change response policies are fraught with complexities and challenges, as highlighted by various international academic discussions. A significant challenge facing the Taiwanese government is the complexity involved in coordinating and integrating these policies. Common issues include unclear role definitions, overlapping responsibilities, and lackluster collaboration between agencies, which lead to fragmented and inconsistent policy planning and execution. Furthermore, the process of realizing these policies often faces resistance, either from opposition or lobbying by various stakeholder groups, which can significantly hinder the smooth implementation of policy initiatives. These obstacles underscore the need for more streamlined and effective policy management to overcome barriers and ensure the successful execution of Taiwan's climate strategies (Dupuis & Biesbroek, 2013).

Evaluation of policy effectiveness and efficiency

Within Taiwan's climate change mitigation framework, the importance of evaluating the effectiveness and efficiency of policies is paramount, necessitating thorough scrutiny and assessment. Numerous international academic publications have provided valuable insights into this area. Notably, one study applied system dynamics

methodology to analyze the effectiveness and efficiency of Taiwan's climate-related strategies. This research highlighted the need for government levels to skillfully manage the complex interplay of diverse objectives—encompassing economic prosperity, societal welfare, and environmental stewardship—to create a well-balanced policy framework. Furthermore, the study emphasized the critical need for continuous monitoring and evaluation of policies to ensure wise resource distribution and sustained policy implementation.

A detailed and methodical evaluation of policies facilitates ongoing improvements, ensuring that strategies remain responsive to the dynamic nature of climate change. This evaluation framework not only identifies successful strategies that could be applied in other regions facing similar climate challenges but also promotes a culture of constant policy review and adaptation. Such an approach is crucial in enhancing policy outcomes and achieving the broader goals of climate change mitigation.

Global insights and comparative studies

In Taiwan's climate change response policies, leveraging international experiences and conducting comparative research are instrumental for effective policy development and implementation. Numerous international studies offer valuable insights and recommendations through comparative analyses of climate change policies and measures adopted by various countries. For example, a study performed a global comparative analysis of climate change response policies and measures. The findings indicated that countries prioritize and implement diverse policy measures tailored to their specific needs, including strategies for reducing greenhouse gas emissions, managing climate-related risks, and enhancing climate risk communication. Furthermore, the study underscores the importance of cross-border cooperation and knowledge sharing in bolstering the effectiveness and innovativeness of climate change response policies. Such comparative research is invaluable in helping Taiwan refine its strategies by understanding and integrating best practices from around the world, thereby enhancing the efficacy and innovation of its own climate change policies.

Conclusions

To summarize, this research has conducted an in-depth examination of Taiwan's strategies for tackling climate change, highlighting the challenges present in current policies. It recognizes the achievements of the Taiwanese government in developing comprehensive climate change countermeasures, evidenced by the establishment of relevant statutes, regulations, directives, and operational frameworks, as well as mitigation and adaptation measures. However, the analysis also reveals several obstacles that compromise policy implementation, including the fragmentation of efforts, limited public involvement, and weak oversight mechanisms. To address these complexities, the study recommends several corrections: strengthening the unity of policy initiatives, enhancing risk management, increasing public engagement, improving execution and monitoring mechanisms, and

creating a supportive environment for industrial advancement. These recommendations aim to enhance the effectiveness of Taiwan's climate change strategies, better equipping the nation to handle future climatic challenges. The insights and advice provided in this research are intended not only for Taiwanese policymakers but also as valuable guidance for global leaders engaged in climate change mitigation.

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System dynamics engineering cost management strategy from the perspective of supply chain management: an effective method to control the cost of construction projects

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Abstract

With the rapid development of the construction industry and the increasing market competition, the effectiveness of project cost management is becoming more and more important for the economic feasibility and sustainable development of the project. The purpose of this paper is to discuss the key measures to improve the level of project cost management from the perspective of supply chain management and system dynamics and put forward the strategies for effective cost control in all stages of construction projects. Firstly, the importance of scientific budgeting and optimal design in controlling the initial project cost is emphasized, and the long-term impact of the system dynamics model is analyzed. Secondly, the cost monitoring and management of the construction phase is discussed, with a focus on schedule control, material procurement, and site management, with the aim of using a system dynamics approach to predict cost changes to avoid budget overruns. In addition, rational planning of contract management and bidding processes is also seen as a key factor in controlling costs, and system dynamics can help evaluate the effectiveness of different strategies. Finally, it is suggested to improve the professional ability of project management personnel through team building and emphasize the role of system thinking in improving the overall level of project cost management. Through the implementation of these measures, it is expected to enhance the effectiveness of project cost management, achieve effective control of project costs, and promote the sustainable development of construction projects.

Keywords: Construction Project, Project Cost Management, Cost issues and countermeasures

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Introduction

Project cost management background

With the rapid development of the global construction industry, effective cost management in engineering projects has received increasing attention. As projects grow in size and complexity, controlling costs has become one of the main challenges faced by construction companies. Many construction projects often suffer from budget overruns and uncontrollable costs, which not only reduce the company's profits, but also lead to contract disputes, which can affect the reputation of the business (Harris et al, 2021). In order to meet these challenges, it is particularly important to improve the level of project cost management and implement strict cost control measures. Scientific budgeting, rational optimization of design, meticulous construction management and effective contract management are the key strategies to reduce project costs, which can ensure the rational use of funds while meeting quality and schedule requirements. However, traditional cost management models are often inadequate in dealing with the complex nature of modern construction projects. Therefore, combining the supply chain management perspective with the system dynamics approach can significantly improve the effectiveness of engineering cost management and promote the sustainable development of construction projects (Hanioglu, 2022).

Recent literature has highlighted the significant impact of Building Information Modelling (BIM) technology in improving project schedules and cost control and can provide scientific decision support through data analysis (Katke, 2020). In addition, from the perspective of system dynamics, dynamic models can be established to simulate various factors that affect costs to achieve effective cost prediction and control (Liu et al., 2020). The purpose of this study is to explore how to improve the level of project cost management from the perspective of supply chain management and system dynamics, and to put forward specific strategies for effective cost control at all stages of construction projects.

Engineering cost management from the perspective of supply chain

In today's highly competitive construction market, engineering cost management from a supply chain perspective has become critical. With an emphasis on collaboration and integration, supply chain management aims to optimize the entire process from material procurement to project delivery. By improving the efficiency of each link, enterprises can effectively reduce costs, shorten construction periods, and improve resource utilization (Luo et al., 2020). In a construction project, the supply chain includes not only material suppliers, but also design teams, construction units and supervision agencies, and the coordination of these links is the key to achieving cost control.

System dynamics provides a powerful tool for analyzing the behavior of complex systems, helping companies understand and predict the interactions between elements in the supply chain. In the context of cost management, system dynamics models can be used to simulate the long-term impact of different decisions, helping managers identify possible cost risks and potential cost savings opportunities (Ghadgeet et al., 2022). For example, by building simulation models, companies can analyze the impact of factors such as material price fluctuations,

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supplier delivery delays, and construction schedule uncertainties in the supply chain on overall costs.

Using the system dynamics mindset, construction companies can integrate cost data from different stages from a macro supply chain perspective and make adjustments for key links. Such integration not only helps to improve the project's budget accuracy but also identifies and resolves potential issues in a timely manner, leading to more effective cost control (Kazancoglu et al., 2021).

In conclusion, the combination of supply chain management and system dynamics can provide a new perspective and method for engineering cost management, so that enterprises can better respond to challenges in a rapidly changing market environment and improve the economic efficiency and sustainability of projects.

Objectives of the Study

The purpose of this study is to explore the engineering cost management strategy from the perspective of supply chain management, especially the application of system dynamics analysis tools to improve the cost control ability of construction projects. The specific objectives are as follows:

1. Analyze the current status of engineering cost management: Through literature review, evaluate the current challenges and problems of engineering cost management, especially the shortcomings of supply chain collaboration and cost control.
2. Explore best practices in supply chain management: Examine industry success stories to identify and summarize effective supply chain management strategies that can lead to resource optimization and cost reduction for construction projects.
3. Establish a system dynamics model: Design and implement a system dynamics model to simulate the impact of each link in the supply chain on project costs, and then analyze the long-term effects and potential risks of different management decisions.
4. Practical suggestions: Based on the research results, this paper provides practical suggestions for construction enterprises to help them effectively apply the methods of supply chain management and system dynamics in actual operation, so as to improve the overall efficiency and effectiveness of project cost management.

Research gaps and academic contributions

Research gaps

In the interdisciplinary field of engineering cost management and supply chain management, although many studies have explored their respective theories and practices, there is still a lack of understanding of how to effectively integrate the perspectives of the two to improve the cost control ability of construction projects. The existing literature focuses on individual aspects of cost management, such as budgeting, contract management, or material procurement and the lack of integrated analysis of system dynamics has led to a lack of comprehensive understanding of the impact of various links in the supply chain on project costs. In addition, there is no mature theoretical framework for how to simulate and evaluate the effects of different management

strategies through system dynamics models. Therefore, this study fills this gap and aims to provide an integrated perspective to explore the intrinsic relationship between supply chain management and engineering cost management.

Academic Contributions

The main academic contributions of this study are:

1. Theoretical innovation: By introducing the system dynamics model, this study provides a new analytical tool for engineering cost management, promotes an in-depth understanding of supply chain management, and expands the theoretical basis of related literature.

2. Practical application: This study puts forward specific supply chain management strategies for the actual cost control problems in construction projects, which provides valuable guidance for construction enterprises to apply supply chain management in actual operations.

3. Interdisciplinary integration: The organic combination of engineering cost management, supply chain management and system dynamics provides new ideas for future research in related fields and promotes interdisciplinary exchanges and cooperation.

Through these contributions, this research can not only enhance the academic understanding of the intersection of engineering cost management and supply chain management, but also provide practical solutions for practical construction projects, thereby promoting the sustainable development of the construction industry.

Literature review

Supply chain management of project cost management

Supply chain management plays a key role in project cost management. According to research, the efficiency of the supply chain has a direct impact on the overall cost and delivery time of the project (Tezel et al., 2021). In construction projects, the procurement, storage and transportation of materials belong to the scope of the supply chain, and the management quality of these links is crucial to control the project cost. Many scholars have pointed out that significant costs can be reduced by strengthening the selection and management of suppliers and optimizing the procurement process of materials (Sharma & Joshi, 2023). For example, using a supply chain integration strategy can ensure the availability of necessary resources before a project starts, thereby reducing additional costs due to material shortages or delays.

In addition, the transparency of the supply chain is also considered to be an important factor in improving the ability to control costs. When project teams have real-time access to information in the supply chain, they can respond more quickly to market changes and adjust procurement strategies and materials management (Benton Jr, 2020). In this process, the application of information technology, such as BIM (Building Information Modeling) technology and the Internet of Things (IoT), has been found to have a significant impact on improving the efficiency of supply chain management and reducing costs (Mannino et al., 2021). Therefore, the effectiveness of supply

chain management not only improves the efficiency of project cost management but also provides a guarantee for the successful implementation of the entire project.

Application of system dynamics in engineering cost management

System dynamics is a theory and method for studying complex systems and their interrelationships, which has important application potential in engineering cost management. By building a system dynamics model, managers can simulate and predict cost changes in a project, so as to formulate more effective cost control strategies (Chen et al., 2023). The system dynamics model can help analyze the interaction between various project elements, identify the root causes of cost changes, and adjust management strategies through dynamic feedback.

For example, system dynamics is used to analyze cost fluctuations during construction and their long-term impacts, thereby helping companies to make better budgeting and resourcing during the design and construction phases (Ford & Lyneis, 2020). This approach can reduce cost overruns due to uncertainty and improve project economics. In addition, system dynamics can also help enterprises evaluate the effectiveness of different management strategies and provide data support for decision-making (Jahan et al., 2022). Through these applications, system dynamics not only improves the accuracy of engineering cost management, but also promotes the sustainable development of the project.

In short, the combination of supply chain management and system dynamics provides a new perspective and method for project cost management, which is helpful to improve the efficiency of cost control and promote the successful implementation of engineering projects.

Research Methodology

This study adopts a comprehensive research method combining literature analysis and case study method, aiming to deeply explore the existing theory and practical application of engineering cost management. Firstly, through a systematic literature review, the core theories, research progress and practical cases in the field of engineering cost management are sorted out and summarized, and the research results in the relevant literature are critically analyzed to identify the shortcomings of the current research and the future research direction.

Secondly, in order to strengthen the combination of theory and practice, this study selects representative practical construction projects as cases, and collects and analyzes the data and experience in the process of cost control. Specifically, this study focuses on the following aspects:

1. Material procurement: In the material procurement process, system dynamics models are applied to simulate the dynamic behavior of the material supply chain. Consider using an inventory control model (e.g., an economic order quantity model) to analyze the impact of inventory levels in the supply chain on procurement costs. By establishing a feedback loop of supplier selection and price fluctuations, we explore how to reduce total

costs and improve project efficiency by optimizing procurement strategies.

2. Cost management in the design stage: Using the method of system dynamics, the impact model of design changes on costs is established, and the feedback effect of design decisions is discussed. Specifically, you can use a feedback loop diagram to show the impact of design changes, such as the cost increase caused by delaying the design. Mathematical models can use methods such as linear programming to predict cost outcomes under different design choices.

3. Tender design: In the tender design phase, system dynamics is applied to analyze the interaction of different strategies in the bidding process. An overall bidding efficiency model can be established to explore the impact of quotation strategy, supplier capacity and market competition on the final bidding cost. Conduct sensitivity analysis to understand how different variables affect overall cost-effectiveness.

4. Cost monitoring throughout the construction process: System dynamics tools (such as Vensim or Stella) are used to model the cost of each project activity and its impact on the overall budget. By establishing a feedback system for monitoring indicators, it is possible to identify and respond to possible financial risks in a timely manner.

From a supply chain perspective, there is a relationship between the above four stages. The efficiency of material procurement will have a direct impact on the cost of the design phase, as inappropriate material selection can lead to design changes; Design changes can trigger additional material requirements, further impacting sourcing strategies and cost control. In addition, the quotation in the tender design will rely on prior material procurement and design decisions, thus creating a continuous feedback loop. Through the discussion of system dynamics, we can better understand the interaction between these stages, so as to formulate a more holistic management strategy.

This study will deeply analyze the best practices presented in the case studies and put forward corresponding management countermeasures and suggestions based on the research results, in order to provide empirical support for the theoretical construction and practical operation of project cost management.

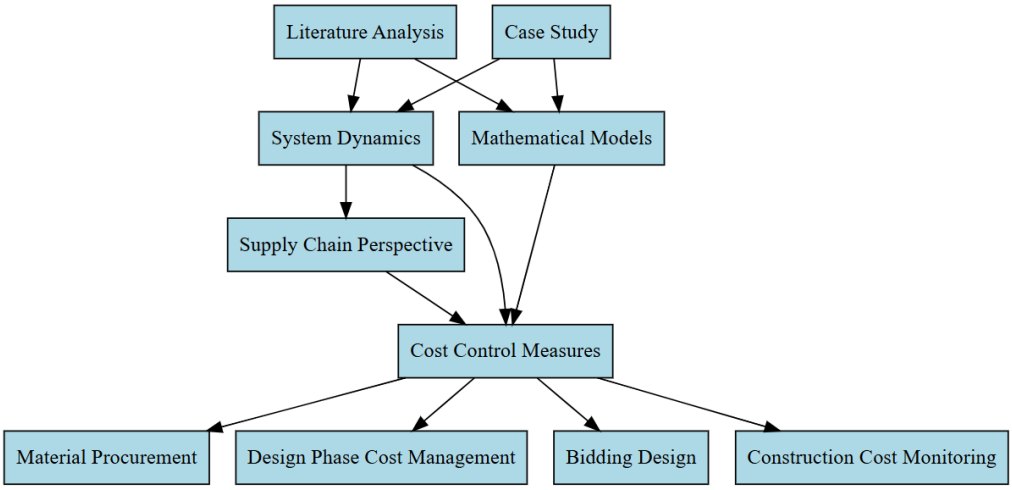

Figure 1 Conceptual framework of this study

Results and Discussion

Engineering manages the variables associated with each stage of the supply chain

Material procurement stage

During the material procurement phase, several key indicators need to be closely monitored. The first is inventory levels, which include real-time inventory levels compared to forecasted inventory needs to ensure supply chain stability. The second is the procurement cost, which covers the cost of raw materials, transportation and storage. The selection of suppliers is also crucial, and reliability and delivery time are among the core elements in evaluating supplier performance. In addition, price fluctuations are also variables that affect purchasing decisions, especially changes in the market price of raw materials. Basic variables include inventory control parameters (e.g., economic order quantities), supplier performance metrics (e.g., lead times and quality), and cost fluctuations (e.g., effects due to seasonal changes).

Cost management in the design phase

During the design phase, there are several key metrics to focus on. The first is the frequency of design changes, which involves the number of design changes and their impact on the project. This is followed by the proportion of cost increases, which reflects the extent to which design changes affect the budget. In addition, design delay time is also an important indicator, and the delay has a direct impact on the cost of the project. The basic variables include the factors influencing the design change, such as the complexity of the design and the number of participants, the parameters of the cost prediction model (such as the results of linear programming), and the impact factor of the delay on the overall cost of the project.

Tender design stage

There are a number of metrics to consider when developing a quoting strategy. The first is the quotation strategy, which involves comparing the quotation strategy of competitors with their own quotation to ensure competitiveness. The second is the supplier capability, which evaluates the supplier's technical level and its position in the market. In addition, market competitiveness is also a key indicator that reflects the number of competitors in the market and their influence on the market. Basic variables include bidding efficiency metrics such as bid success rates, competitive market indices, and quote model parameters, which cover data such as minimum and average bids, which are used to optimize the bidding strategy

Cost supervision stage of the whole construction process

In financial management, several key metrics need to be closely monitored. The first is the budget overrun rate, which reflects the ratio of actual costs to budget and helps assess whether the project is over budget. The second is the financial risk indicator, which mainly includes the current ratio and the debt ratio, which are used to measure financial risk. In addition, oversight indicators focus on the timeliness of project activities and their impact on overall schedules and costs. Basic variables include budget execution metrics, such as actual vs. budgeted spending, predictive model parameters for financial risk, and feedback loops for monitoring metrics to improve management processes.

System dynamics model

From the above variables, we can build a system dynamics model, which includes the following steps. Firstly, a feedback loop is established to present the interaction between the indicators in the form of a feedback loop, so as to clearly show the correlation of each variable. Secondly, mathematical modeling is carried out, using linear programming and other mathematical methods to simulate the changes of different variables and analyze their impact on the overall system. Next, tools such as Vensim or Stella are used to conduct simulation analysis to explore the stability and performance of the supply chain under different scenarios.

Here are some examples of feedback loop models: First, supply chain cost feedback loops, where inventory levels affect procurement costs, which in turn affect inventory decisions. The second is the design change feedback loop, where design changes directly affect cost increases, which in turn prompt further design evaluation and adjustments. In addition, in the feedback loop of bidding efficiency, the supplier's ability will affect the quotation strategy, which in turn will affect the degree of market competition, and then affect the bidding cost. Such a model helps to analyze the stability of the engineering management supply chain, identify potential risks and identify opportunities for improvement.

Mathematical model of cost management in the four stages of engineering supply chain

The mathematical equations of the four-stage reference model and the meanings of the variables in each equation.

Material Procurement Model

Equation:

$$Cp = Cf + (D \times Cu) / Q+S \quad (1)$$

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Variable Help:

- Cp: Procurement Cost
- Cf: Fixed Costs (e.g. Procurement Overhead)
- D: Quantity required (quantity of material required per unit time)
- Cu: Cost per unit of material (may be affected by market price fluctuations)
- Q: Quantity per order (i.e. economic order quantity)
- S: Inventory carrying costs (including storage, insurance, etc.)

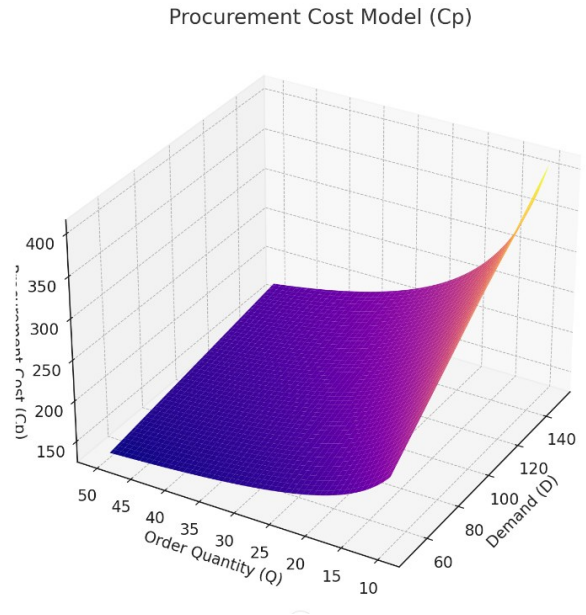

Figure 2 3D view of the material procurement cost management model

Here is the 3D surface plot representing the Procurement Cost Model (CpCpCp) based on the equation:

$$Cp = Cf + (D \times Cu) / Q+S$$

Description of the Plot:

- X-axis: Represents the demand (D), which indicates the quantity of materials required within a unit of time.
- Y-axis: Represents the order quantity (Q), which refers to the quantity ordered each time (Economic Order Quantity).
- Z-axis: Represents the total procurement cost (Cp), calculated based on fixed costs, demand, unit material cost, and inventory holding cost.

This graph illustrates how the procurement cost varies with changes in demand and order quantity, providing valuable insights for optimizing purchasing strategies.

Cost management model in the design phase

Equation:

$$Cd = C0 + \alpha \cdot (X - X0) + \beta \cdot T \quad (2)$$

Variable Help:

- Cd: The total cost of the design phase
- C0: Base cost (forecast cost without change)
- α\alpha: the cost increment factor caused by each design change
- X: The number of changes to the current design
- X0: Number of base design changes
- β\beta: Additional costs due to delays (e.g., schedule delays)
- T: Design delay time

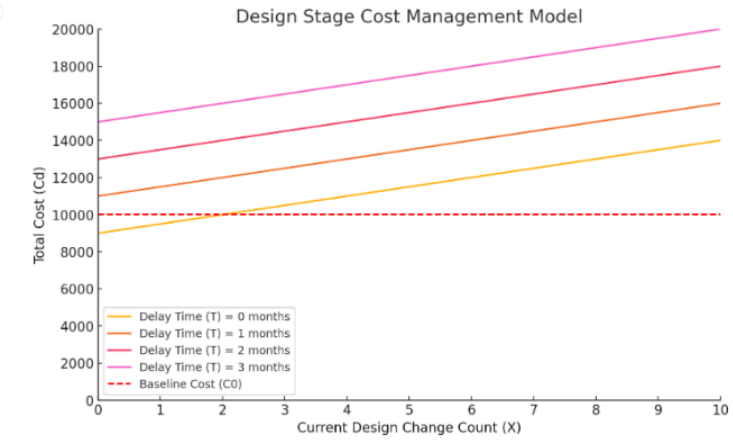

Figure 3 Cost management model diagram in the design phase

Here is the graph illustrating the Design Stage Cost Management Model based on the provided equation:
Graph Description

- X-axis: Represents the current design change count (X), ranging from 0 to 10.
- Y-axis: Represents the total cost (Cd), ranging from 0 to 20,000.
- Curves: Each line corresponds to a different delay time (T):
  - T = 0 months: Represents the total cost without any delays.
  - T = 1, 2, and 3 months: Each subsequent line shows the increase in total cost due to design changes and delays.
- Red Dashed Line: Indicates the baseline cost (C0), which serves as a reference point for cost predictions without any design changes or delays.

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This visualization helps illustrate how the total cost increases with both the number of design changes and the associated delays.

Tender Design Model

Equation:

$$Ct = C_{b+}\gamma \cdot (Qs - Q_d) + \delta \cdot M \quad (3)$$

Variable Help:

- Ct: Total cost at the tender stage
- Cb: Base cost (e.g. cost of basic requirements of the project)
- γ\gamma: The cost impact factor between the supplier's capacity and the quoting strategy
- Qs: Supplier's Offer (Average Quote in the Market)
- Qd: Expected Quote (Reasonable Expectation Based on Historical Data)
- δ\delta: the coefficient of the impact of market competition
- M: Market competition index (e.g. number of competitors and intensity of competition)

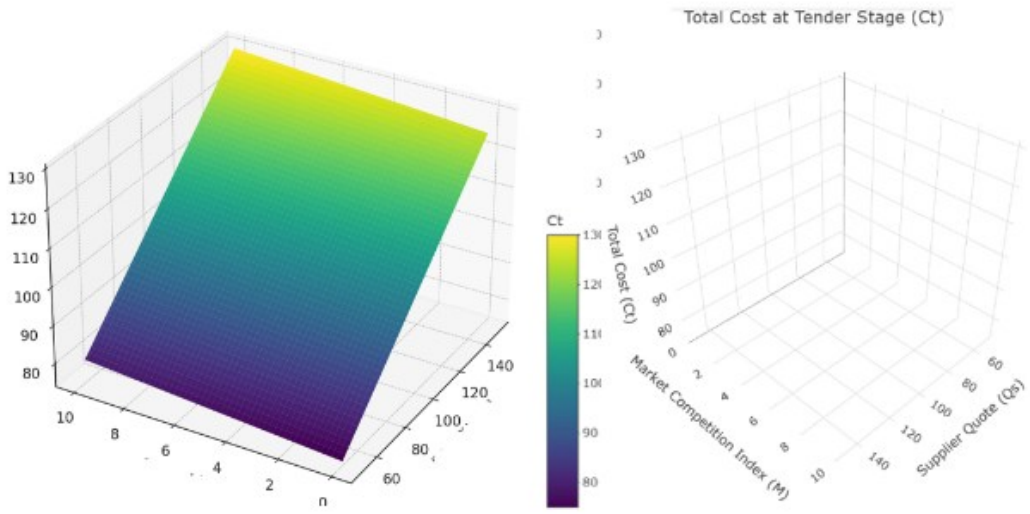

Figure.4 Mathematical model diagram of cost management in the bidding design stage

This is a three-dimensional graph showing the total cost Ct at the tender stage in relation to the supplier's offer Qs and the market competition index M.

- X-axis represents the supplier's quotation Qs.
- The Y-axis represents the market competition index M.
- The Z-axis shows the total cost Ct.

As you can see from the graph, the total cost Ct will change accordingly as the supplier's quotation and

the market competition index change. This helps to understand the trend of costs in different quotations and competitive situations.

Construct a cost supervision model for the whole process

Equation:

$$Cm=C_{initial}+\sum(Ca)+R \quad (4)$$

Variable Help:

- Cm: The total cost of the construction process
- Cinitial: Initial budget or forecasted cost
- Ca: Cost by project activity (e.g., itemized cost of construction, materials, etc.)
- R: Sum of financial risk indicators (e.g., additional costs for budget overruns)

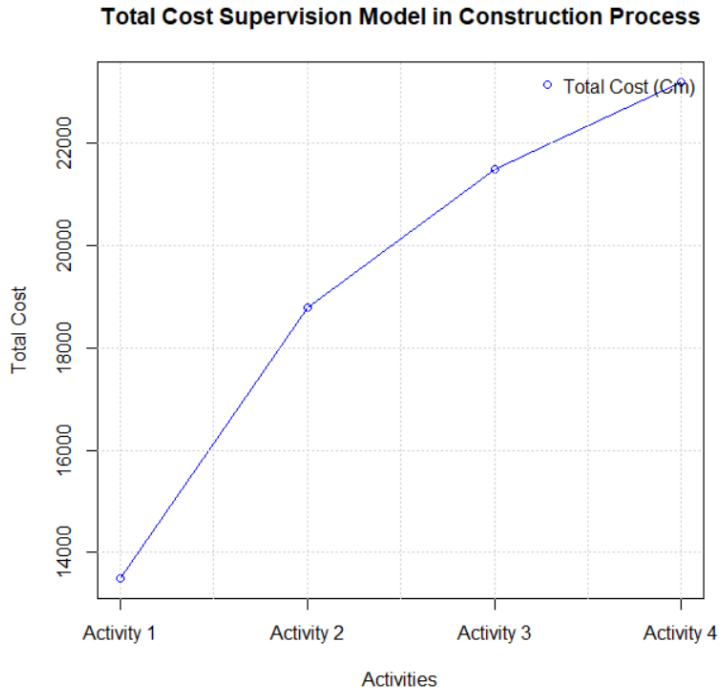

Figure 5 Cost supervision model diagram of the whole construction process

Integrated system dynamics model

In the equations for each of these stages, we can integrate them into a holistic system dynamics model to assess the stability of the overall supply chain. This can be achieved by setting up feedback loops that influence each other

The overall supply chain cost equation is as follows:

$$Ctotal = Cp + Cd + Ct + Cm \quad (5)$$

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Here, Ctotal represents the total cost of the entire supply chain, which is the sum of the costs of the various stages. The interactions and feedback between the individual costs can be further analyzed by parameter tuning for sensitivity analysis to determine how to optimize costs at various stages and improve the stability of the supply chain.

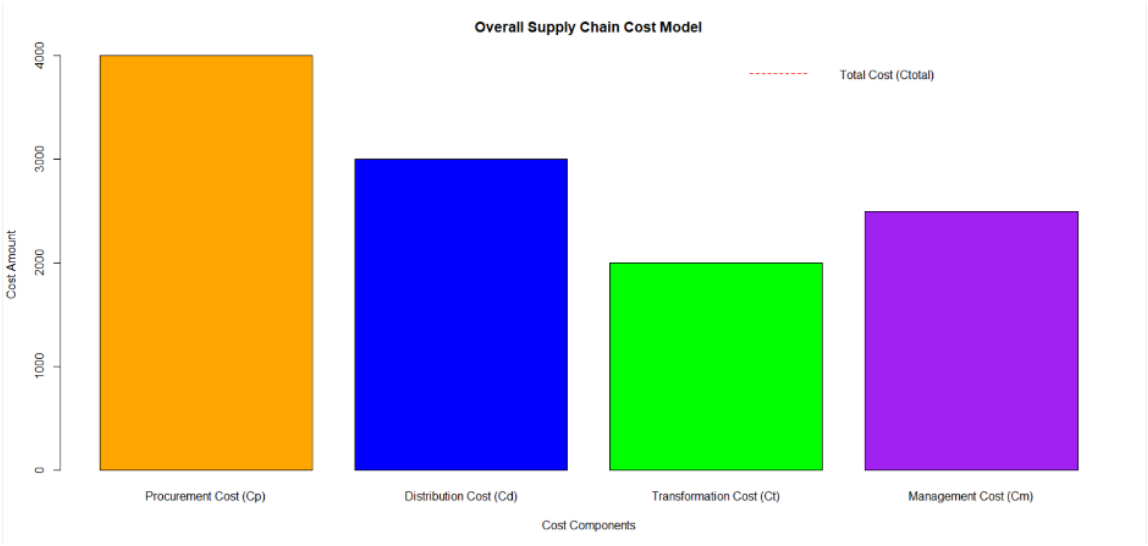

Figure 6 Diagram of the overall supply chain cost management model

These mathematical equations can help us build system dynamics models that assess the performance and stability of the overall supply chain by simulating changes in individual variables. By conducting a sensitivity analysis, you can identify potential areas for improvement and develop strategies to reduce total costs and improve project effectiveness.

Related actions of project cost management

Material procurement cost control

The high amount of material consumed and the frequent price fluctuations during the construction process pose a great challenge to cost management. In the procurement stage, the price of materials must be strictly controlled and forecasted, and a reasonable procurement strategy must be implemented according to market conditions to ensure the effectiveness of cost control.

Improve cost management with modern and intelligent technology

In the digital era, construction enterprises must rely on modern information technology and BIM technology to conduct data analysis and improve the level of cost management. The growing role of these technologies in cost control has helped to significantly reduce production costs.

Cost management in the design phase

Cost management during the design phase plays a key role in ensuring the economics of the project. Through design optimization and the involvement of technicians, costs can be controlled and economic benefits can be improved while achieving design goals.

Strengthen cost supervision

Strengthening the cost supervision of the whole process of the project can ensure the quality and safety of the project while reducing costs. Assembling a professional supervisory team and maintaining transparency in project management is essential to achieve effective cost control.

Figure 7 Conceptual diagram based on the system dynamics model

The diagram above illustrates the variables and their causal relationships at each stage of the engineering management supply chain.

Case Study

Cost management in construction is a complex and dynamic process that is influenced by a variety of internal and external factors. Building a system dynamics model can help understand and analyze the interactions between these factors, thereby providing decision support for cost management.

The following is a dynamic model building process based on the theme of "Construction Cost Management", with model diagrams and flowcharts attached to help readers understand.

Define the system boundaries and scope

First, we need to determine the scope and main variables covered by the model. Cost management of construction projects involves many factors such as labor, material costs, construction time, design changes and management expenses, etc.

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System Scope:

- Direct costs: labor, materials, equipment, etc
- Indirect costs: overheads, insurance, taxes
- External factors: market volatility, interest rates, changes in laws and regulations

Identify the main variables

In dynamic models, state and flow variables are important elements to describe the system. We can divide the core variables of a construction cost management system into the following categories:

State Variables:

- Total Construction Cost (TCC): The expected cost of the overall project.
- Progress: The progress of the completion of the construction project.

Flow Variables:

- Labor Cost: The change in personnel wages with time and human resources input.
- Material Cost: Varies with fluctuations in material demand and market prices.
- Equipment Cost: Depends on the time and frequency of use.

Parameter:

- Construction Efficiency: The ratio of construction speed to quality.
- Material Price Volatility: The market volatility of material prices.

Establish causal relationships between variables

In construction projects, the interaction between cost variables is very important. For example, changes in construction efficiency affect construction schedules, which in turn affect the total cost. Fluctuations in material prices can also directly change the cost of materials, which in turn affects the overall cost.

Example causality:

- Relationship between labor and material costs and total costs: As construction progresses, labor and material costs accumulate and drive up total costs.
- Design changes and delays: Design changes can delay construction schedules, which in turn can increase overheads and overall costs.

Mathematical description of the model

Based on the causal relationship between variables, we can use a set of equations to describe the dynamic behavior of the system.

Example Mathematical Models:

1. Total Cost Model:

$$TCC = LC + MC + EC + IC \quad (6)$$

Thereinto:

- LC: Labor Costs
- MC: Material cost
- EC: Equipment cost

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- IC: Indirect Costs (Overheads, Insurance, etc.)

2. Changes in Labor Costs Over Time:

$$dLC/dt = \text{number of people in the labor force} \times \text{wage rate} \quad (7)$$

Change in material costs over time:

$$dMC/dt = \text{material usage} \times \text{material unit price} \quad (8)$$

The unit price of materials may be adjusted according to market volatility:

Material Unit Price = Initial Price × (1 + Market Volatility)

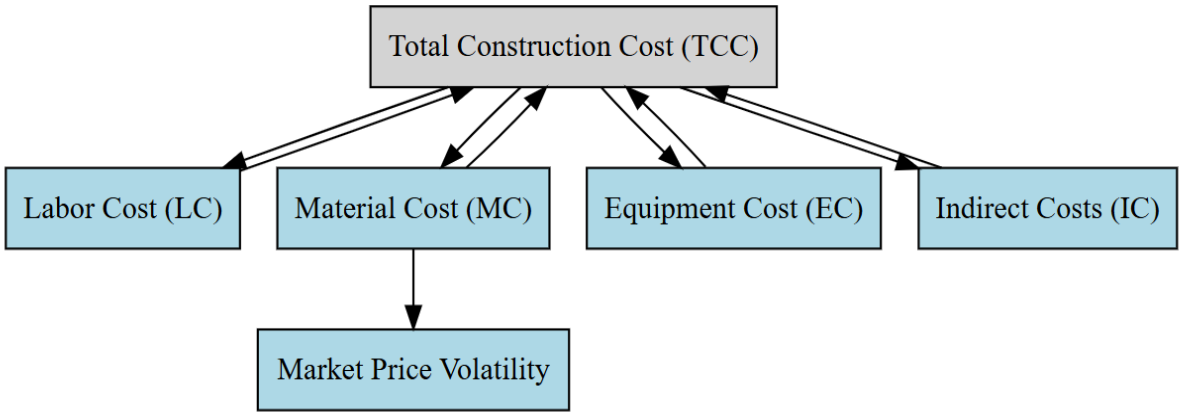

Figure.8 Interaction of dynamic analysis factors of engineering cost management system

Conclusions and Recommendations

Conclusion

From the perspective of supply chain management, combined with system dynamics, this paper discusses the key measures and strategies to improve the level of construction project cost management. The study shows the importance of scientific budgeting and optimal design in controlling the initial project cost, and using the system dynamics model to analyze its long-term impact, which can help to improve the accuracy of cost forecasting. In the construction stage, this paper emphasizes the key roles of schedule control, material procurement, and site management in order to ensure the effectiveness of cost monitoring and management, and proposes a system dynamics approach as an important tool for predicting cost changes. In addition, rational planning of contract management and bidding processes is considered to be a key factor in cost control, and the application of system dynamics enables the evaluation of the effectiveness of different strategies. Finally, improving the professional ability of project management personnel through team building and emphasizing the importance of system thinking can significantly improve the overall level of project cost management.

In general, the implementation of the above measures can not only enhance the effectiveness of project cost management, achieve effective control of project costs, but also promote the sustainable development of construction projects. The results of this study provide valuable guidance for construction enterprises in the current competitive market environment, which is helpful for them to cope with the challenges of engineering cost management.

Recommendations for future research

1. Expand the application scope of the system dynamics model: Future research may consider expanding the application scope of the system dynamics model to explore the characteristics of different types of construction projects and their impact on cost management, so as to provide more targeted cost control strategies.
2. Empirical research and case analysis: It is recommended to conduct an empirical study to deeply explore the specific application effects of supply chain management and system dynamics in engineering cost management through case analysis, so as to provide practical support for theoretical research.
3. Integrating new technologies: With the development of new technologies such as Building Information Modelling (BIM) and the Internet of Things (IoT), future research can explore how these technologies can be combined with supply chain management and system dynamics to further improve the efficiency and accuracy of cost management.
4. Interdisciplinary research: It is suggested that future research can start from an interdisciplinary perspective, combining knowledge from the fields of economics, management, and engineering to form a more comprehensive research framework for cost management.
5. Policy and management recommendations: Further research can explore government policies and their impact on construction project cost management and put forward corresponding management recommendations to promote the healthy development of the construction industry.

These suggestions will help deepen the research on supply chain management and system dynamics in engineering cost management, promote academic exchanges in related fields, and provide more forward-looking solutions for practice.

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A Corporate Role Model in Climate Action: A Case Study of O'right's Net-Zero Emission Practices in Supply Chain Management

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Abstract

In contemporary business operations, green economy and sustainable development have increasingly become the core of corporate strategies. As global environmental issues continue to grow, consumer demand for eco-friendly and sustainable products is increasing, forcing companies to rethink their business models. Steven Ko, Chairman of the Board of Directors of O'right, said in the Economist Forum that carbon emissions can be considered as an asset to companies, a view that highlights the challenges and potential business opportunities faced by companies in the process of tackling climate change. At the Sustainability Week Forum in Singapore 2023, Steven Ko shared O'right's practical experience in tackling climate risks and promoting sustainable transformation, highlighting the importance and potential of SMEs in achieving net zero emissions. His presentation not only showcased how O'right combines innovation with eco-friendly practices, but also emphasized that sustainability is not only a responsibility, but also the key to business success. These perspectives provide inspiration for many beauty brands, especially in the process of driving the green transition. This research will delve into how Steven Ko's leadership has made O'right a benchmark for green businesses and analyze what its business model has implications for other beauty brands. Through case studies, this study aims to provide specific reference and practical guidance for enterprises to formulate effective environmental protection strategies, and promote more enterprises to actively participate in the green economy and contribute to sustainable development.

Keywords: Net Zero Emissions, Corporate Social Responsibility, Sustainable Development, Supply Chain, Management, Steven Ko

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Introduction

Background

Green economy and sustainable development play an increasingly important role in the business strategies of contemporary enterprises. As global environmental issues become more severe, businesses and consumers are increasingly taking environmental issues seriously and actively seeking solutions related to sustainability (Sachs, 2015). Steven Ko, chairman of O'right, pointed out in the Economist Forum that "Carbon emissions can be both liabilities and assets of companies" (Aurora Group, 2023), which reveals the challenges and potential opportunities for companies in climate action today.

In 2023, the second edition of The Economist Asia Sustainability Week was held in Singapore from 7 to 9 February, bringing together more than 90 sustainability leaders from the world to discuss sustainability related topics in depth. As a beauty brand representing Taiwan's small and medium-sized enterprises, Chairman Steven Ko attended the forum to share the practical experience of enterprises in addressing climate risks and seizing opportunities. Chairman Ko was invited to give a keynote speech in the Singapore to share his experience and insights on corporate sustainability transformation, with a view to guiding more decision-makers to engage sustainability commitments into concrete actions (Tatler Asia, 2023).

In the context of climate risks increasingly impacting market demand, corporate disclosure of climate risks has become crucial. Climate risk disclosure not only protects corporate reputation and value, but also becomes one of the core strategies of enterprises to address environmental challenges (Board, 2017). The forum focused on how companies identify, measure, manage and report on environmental, social, governance (abbreviated as ESG) issues and climate-related risks, and how to use existing technologies to generate transparent reports and demonstrate non-financial results. Addressing these issues can help companies better adapt to the challenges of future climate change and advance the achievement of the Sustainable Development Goals (Upward & Jones, 2016).

Research Question and Purpose

This study aims to explore how Steven Ko can effectively integrate corporate operations and environmental protection concepts in the process of promoting corporate sustainability and green innovation, and deeply analyze O'right's business model and its influence in the beauty industry. Specific questions include:

1) How Steven Ko pushed O'right to become a benchmark for green companies; 2) What inspiration does the company's sustainable development concept have for other enterprises; 3) how to influence consumer behavior through practice and further promote green consumption.

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Significance:

This case study has important theoretical and practical value. At the theoretical level, this study can provide a new perspective for corporate sustainability and green innovation, through the analysis of O'right's development process under the leadership of Steven Ko, especially in the consumer goods industry. On a practical level, O'right is a successful business case that provides companies with concrete methods and practical experience in implementing environmental strategies so to understand the new trend of industrial transformation, helping enterprises' development under the green economy.

Research gaps and research contributions:

In the past, the literature generally considered that the achievement of net-zero emissions was only for large enterprises with sufficient capital, however, the possibility of achieving the goal for SMEs was rarely discussed. Therefore, a small beauty company, O'right, is the first in the world to achieve carbon neutrality, which challenges conventional wisdom. Steven Ko's story was featured in an interview with The Economist, which even featured alongside with Google and Apple, highlighting the importance of the company's drive for net-zero emissions. This not only changes the perception of small and medium-sized enterprises to achieve net-zero emissions, but also proves the possibility that environmental protection and economic benefits can coexist. The success of this model is a unique contribution which will be further explored in depth.

Literature Review

CSR and ESG

Corporate Social Responsibility (abbreviated as CSR) and ESG frameworks have become core competences of corporate sustainability strategies in recent years. CSR has traditionally focused on corporate social and environmental obligations, including charitable giving, employee welfare, and community engagement (Carroll, 1999). However, with the intensification of global climate change and environmental challenges, ESG standards are prioritizing indicators for companies to evaluate sustainability and provide investors with a basis for decision-making by quantifying the performance of enterprises in environmental protection, social responsibility and governance structure (Eccles & Stroehle, 2018).

This study is mainly based on the evolving theory of sustainable development and CSR framework, which was supplemented by the analysis of carbon neutrality and green innovation theory. Green innovation theory argues that companies can achieve sustainable development while achieving economic benefits and reducing their negative impact on the environment through innovative technologies and processes at the same time (Chen, 2008). O'right explains the theory perfectly by chairman Steven Ko made green innovation as core corporate strategy, driving the company's commitment to reducing its environmental footprint along with its supply chain management, product design and production processes. By incorporating CSR concepts to achieve carbon

neutrality, it is in line with the carbon neutrality goal set up in the Paris Agreement, which requires companies to reduce their carbon emissions gradually and achieve net zero emissions eventually.

According to the Triple Bottom Line (TBL) theory of sustainable development, companies must take social and environmental responsibilities while pursuing economic benefits (Elkington, 1999). This triple TBL includes the comprehensive balance of economy, people, and environment. It is based on this theory that O'right formulates its sustainability goals, and achieves long-term sustainable development of the company by continuously reducing environmental impact and improving social responsibility. Especially in the beauty industry, the company has pioneered the promotion of non-toxic, biodegradable products and the full use of green energy technology for production (O'right, 2023)

In addition, the combination of CSR and ESG framework also enables O'right to respond to higher demands from investors and consumers. Enterprises should not only focus on short-term economic benefits, but also regard sustainability as a core competitiveness. This has been recognized by a growing number of companies in the global market, especially those committed to leading the transformation of the industry (Parmar et al., 2010).

Net zero emissions in the supply chain

Net Zero Emissions has become an important goal in today's global corporate strategy. Many multinational companies such as Google, Apple and Microsoft have committed to net-zero emissions and have achieved this through technological innovation, policy support and the adoption of renewable energy (Blanco, 2021). However, O'right, as the first beauty brand to achieve carbon neutrality certification, provides innovative experience and inspiration for small and medium-sized enterprises compared to these large enterprises. Steven Ko, Chairman of O'right, emphasized that the green economy is not limited to large enterprises with abundant resources, and that companies of any size can achieve sustainable development through innovation and commitment (Tatler Taiwan, 2021).

Traditionally, many studies have focused on how large multinationals use technological innovation and government policies to achieve net-zero emissions (Sachs, 2015), but there is relatively little research on how SMEs can achieve the same goals with limited resources. O'right's success has proven that SMEs can also reduce carbon emissions by optimizing their supply chains, improving operational efficiency, and implementing innovative technologies, which is a model for other businesses. By redesigning its product production processes, adopting eco-friendly materials, and integrating green logistics management, O'right has successfully minimized carbon emissions across its entire supply chain and ultimately achieved carbon neutrality (Nabais, & Franco, 2024).

Supply chains play a key role in a company's net-zero ambitions. Every part of the supply chain – from raw material sourcing and product production to transportation and logistics – can be an opportunity to reduce your carbon footprint. According to the study, O'right adjusting the supply chain process, from supplier selection and green logistics to the use of renewable energy, O'right has effectively reduced carbon emissions in its

operations and established a good social responsibility image inside and outside the industry, which attracts more consumers and investors.

In addition, collaboration in the supply chain is crucial. Companies need to work with suppliers, partners and customers to develop emission reduction strategies to more effectively promote the sustainable development of the entire supply chain. O'right works hand-in-hand with its suppliers and customers to drive the green transformation of the supply chain, which is seen as a breakthrough action in the industry and inspires more companies to move towards net-zero emissions (Chen et al., 2012).

In summary, net-zero emissions practices in the supply chain cannot be achieved by individual technological innovations alone, but requires collaboration and integration within the entire supply chain system. O'right's success not only demonstrates the potential of small and medium-sized enterprises, but also underscores the importance of working together with partners, which has far-reaching implications for driving global climate action and corporate sustainability.

Methodology

Study Design

This study uses a qualitative case study approach to provide an in-depth analysis of the leadership of O'right and its founder, Steven Ko. The qualitative case study method is a research method that explores a single individual, organization or event in depth, especially when exploring complex social phenomena or multifaceted issues (Yin, 2018). By compiling existing public sources, literature, and media reports, this study seeks to understand how Steven Ko has led O'right's efforts to achieve net zero, the challenges he faced, and his achievements. When addressing issues such as corporate social responsibility (CSR), sustainability and carbon neutrality, case studies can effectively demonstrate the depth and detail of people's behaviors in specific contexts, and provide reference for other corporate practices.

Case Selection

O'right and its founder, Steven Ko, were the subject of research because they are a global leader in environmental innovation and carbon neutrality as a small and medium-sized company, despite its relatively limited resources. O'right is the first beauty company in the world to be certified carbon neutral, demonstrating its innovative performance in reducing its carbon footprint and promoting a green economy, as well as setting an example for other small and medium-sized enterprises. In addition, Steven Ko has been interviewed several times for his leadership in corporate sustainability and is recognized as a promoter of small and medium-sized enterprisesPioneers in the journey to net zero. This makes O'right a case study of global significance that deserves to be explored in depth. As the first zero-carbon enterprise in the global beauty industry, O'right was selected as one of the RE100 Top 15 Global Green Leaders along with TSMC and Apple. In addition, O'right has won the France Paris Sustainable Beauty Award for six consecutive years, won the world's three major design

awards and three major invention gold medals, and has also been interviewed and reported by Forbes, Bloomberg Business Week, and The Economist for many times.

Data Sources

This study uses secondary data as the main data source, mainly from media reports, the company's official annual report and sustainability report, academic literature and interviews. Media reports provide the background of O'right's development and the practice of carbon neutrality, while academic literature further deepens the theoretical elaboration of related concepts. For example, in an interview with Steven Ko, details how O'right is achieving sustainability and net-zero emissions through innovative strategies with limited resources, and these data provide a rich background and analytical basis for this study.

Data Analysis Methods

This study will use content analysis for data analysis. Content analysis is a systematic and objective analysis tool that can help researchers extract core concepts and themes from large amounts of textual data (Krippendorff, 2018). This approach is particularly well suited for identifying recurring themes in texts, especially key points related to corporate social responsibility, carbon neutrality practices, and sustainable development. By encoding and categorizing this data, this study can further distill O'right's strategy in driving net-zero emissions and its implications for small and medium-sized enterprises.

The content analysis will collate O'right's green innovation practices, supply chain optimization and carbon reduction strategies, and explore how these measures can effectively promote its competitiveness in the global market. Through this approach, we are able to not only showing in detail how O'right is achieving net zero emissions, but also providing practical references for other SMEs to demonstrate the feasibility of achieving sustainability goals with limited resources. These findings will provide guidance for future academic research and corporate practice.

Results and Discussion

Case Description

O'right Background information

Steven Ko is the founder and current CEO of O'right, a famous Taiwanese company known for its eco-friendly hair products. O'right was established in 2002, started as a small business, but under the leadership of Steven Ko, it has gradually transformed into a global brand with sustainability at its core. Steven Ko not only focuses on the quality of its products, but also strives to improve the company's environmental performance throughout the production chain, especially to achieve carbon neutrality goal. These measures make O'right the first hair brand in the world to achieve net-zero emissions, highlighting its leadership in eco-friendly innovation.

O'right's organizational structure is relatively simple, with a small-scale, high-performance operation that supports its flexibility and innovation in the market. This allows the company to quickly adapt to market changes

and actively drive the process of sustainable development. Through his green beauty brand, Steven Ko is not only practicing corporate social responsibility, but also driving the green revolution and strengthening the global awareness of sustainable beauty products. Since 2006, he has led O'right to become the world's first carbon neutral certified beauty company with the concept of "green, sustainable and innovative", which has had a profound impact on the beauty industry and the entire sustainable economy system.

In terms of sustainability, O'right launched the Green Sustainability Innovation Program 17 years ago. The company conducted a carbon footprint inventory in 2010 and was certified by the United Kingdom Standards Institution (BSI) in 2011, becoming the world's first shampoo to achieve carbon neutrality certification (Zhou &Zhou2020). At the same time, since 2020, O'right has achieved carbon neutrality for all product lines, factories and organizations for three consecutive years, including direct emissions, indirect emissions and Scope 3 (supply chain) levels. These achievements make O'right one of the first beauty companies in the world to reach zero carbon. In addition, in December 2022, the company completed its commitment to RE100 (100% Green Electricity Initiative for Global Enterprises), achieving its goal of 100% green electricity.

O'right's shows how a small and medium-sized enterprise can become a global leading sustainable business in a competitive market through innovative technology and disciplined management practices with limited resources. These achievements not only help to enhance brand value, but also inspire the whole industry to drive toward sustainability and net zero emissions direction (see Table1 for details).

Table 1 Important milestones of O'right

year	Important Events
2002	Founded by Steven Ko and Rena Huang, O'right is committed to developing hair care products with eco-friendly and natural ingredients.
2007	For the first time, the company launched a product with the theme of "green packaging" to demonstrate the company's commitment to environment protection.
2010	The launch of the "Caffeine Plant Scalp Activator" by O'right has been widely acclaimed, marking the improvement of its product innovation capabilities.
2013	Obtained international green certification, which strengthens the brand's environmental image.
2016	Receiving the Green Factory label from Taiwan's Ministry of Economic Affairs further strengthens its leadership position in sustainability.
2017	Winning the Sustainable Leadership Award at the Sustainable Beauty Awards highlights the brand's influence in the industry.

Table 1 (cont.)

year	Important Events
2018	Winner of several international awards, including the Pure Beauty Global Awards and the Sustainable Beauty Awards.
2020	Launched a carbon neutrality program and began to implement carbon offset projects on a large scale.
2021	It continues to receive environmental and social responsibility awards, including the Carbon Peaking and Carbon Neutrality Model Enterprise Award at the International Green Zero Carbon Festival.
2023	To become a well-known eco-friendly brand in the international market and praised on multiple international platforms.
2024	Won the National Environmental Education Award for Excellence in the Individual Category and a number of international green awards, cementing its position in the industry.

With a focus on sustainability and environmental protection, O'right has continuously launched innovative products and won several awards at home and abroad, demonstrating its leadership and influence in the beauty industry.

O'right's green development history and main features

O'right has faced many challenges in the development of the company, especially in achieving the goal of carbon neutrality. With a small scale and limited resources, how to stand out in the highly competitive market for hair products and lead the global sustainability wave has become one of the biggest challenges. By strict control of carbon emissions and energy use, O'right successfully overcame these difficulties and achieved carbon neutrality through innovative technologies, they had received well response internationally and wide exposure to media attention. The Economist remarked O'right alongside with Apple and Google, emphasizing that despite its small size, the company is at the forefront of the world in achieving net-zero emissions, demonstrating strong environmental awareness and execution.

O'right effectively demonistrated to the current question of whether SMEs have the ability to achieve net-zero emissions by taking concrete measures to achieve carbon neutrality. It's philosophy and sustainability strategy significantly illustrate the O'right brand value and inspired the SMS businesses can implemented the eco-friendly green policy in environmental innovation, even with limited resources. O'right promotes organic products to educate consumers for the long-term health and environmental benefits of natural products, despite at their high prices. The strategy enhances the brand value throughout the heart of consumers and awaked that of their green awareness.

In this study, we have researched and identify through O'right's public information, and extracted their management focus by following keywords, which reflect its main achievements and influence to the industry. These keywords reveal the company's value proposition as their business strategy and values and showed their influences on the sustainability to the world, how Steven Ko's, forms up his business philosophy, and put into the effective implementation (See table 2).

Table 2 Ten key cultural characteristics of the company

keyword	illustrate
green	Steven Ko promotes the concept of environmental protection and sustainable development, emphasizing the production and use of green products.
Sustainability	O'right are committed to promoting sustainable management and achieving balanced development of environment, society and economy.
innovation	Innovation-driven development, creating the world's first bottle of zero-carbon shampoo and series of products by an unique business models, showing the industry's cutting-edge technology and design capabilities.
quality control	Through high standards of quality control to ensure the excellent quality of products and services, to win the trust of the market. Improve the quality of products and services through high standards of quality control.
Zero carbon	Focus on the production and promotion of low-carbon and zero-carbon products and strive to reduce the carbon footprint of business operations.
Environmental Commitment	Committed to follow the principles of environmental protection in the course of business operation and actively participating in environmental protection activities.
Social responsibility	Attach importance to corporate social responsibility and actively promote the sustainable development of industry and society.
Industry leadership	Widely regarded as an environmental leader, he serves as a role model for hair industry and throughout the world.
National Quality Award	Won the National Quality Award in recognition of its outstanding achievements in quality management and business performance.
Supply chain management	Partnering with valuable suppliers to advance environmental protections, transform the value creation process, and improve the sustainability of the entire supply chain.

Resource

Business philosophy:

The era of GDP has passed, and the future is the advent of the GEP era

As the founder of O'right, Steven Ko is committed to environmental protection with the business philosophy of "Green, Sustainable and Innovative". Throughout the challenges of climate change, he insists the entrepreneurs leadership in driving sustainable development through his innovative business model.

Steven Ko believes that the era of GDP (Gross Domestic Production) has passed, and the future will belong to the era of GEP (Here refers as Gross Ecosystem Product). GEP represents the sum of the value of final products and services for human well-being and sustainable economic and social development. GEP can make up for the cost of GDP that cannot reflect the consumption of natural resources and the destruction of the ecological environment. Steven Ko pointed out that if a country's GDP comes mainly from gasoline vehicles in the petrochemical industry, its economic potential will be neglected by that of a company with a small GEP that focuses on green energy and electric vehicles, even if the overall GDP is high. He cited Tesla and Toyota as examples, emphasizing that Musk is focusing on the manufacture of electric vehicles (Here abbreviated as EV), making good use of the income from carbon credit trading to cope with high-cost green investments, and ultimately achieving profit and leading the growth trend of the EV market. Toyota, on the other hand, is facing an existential crisis due to its slow transformation, and is redefining its vision as a "service company for transportation and mobility".

Through O'right's public reports, we can gain insight into his business philosophy. For example, in a presentation at the Economist Conference, Steven Ko spoke about the role of business in changing climate risks. He pointed out that O'right's corporate business goal is "net zero carbon emissions", and emphasized that starting from the carbon inventory, O'right would identify carbon emission hotspots in the process of product raw material acquisition, manufacturing, production, transportation, consumption and waste recycling, and build a green supply chain to comprehensively promote green transformation.

Concept presentation: The documentary "Tales of the Arctic": a visual journey through climate change

In the summer of 2022, Steven Ko launched the "Thaw Greenland" project, visiting the Arctic and filming a documentary on climate change, witnessing the profound impact of global warming on people and the environment. The documentary, titled "The Story of the Arctic," won CDP | RE100 supported by the World Climate Foundation (WCF) and invited to the world premiere of the United Nations General Assembly (UNGA77), New York Climate Week, the COP27 Global Climate Summit in Egypt and the Economist Forum Asia Sustainability Week as panel speaker.

The documentary aims to present the impact of climate change on the Arctic ecosystem, where it shows the magnificent landscape of the Arctic region has been melting, and the film introduced the team delving into the climate change facts happening in Arctic had been seriously affected in local organisms and ecological

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balance. The film highlights the urgency of climate change and inspires viewers to take action to protect the environment. By telling the stories of local residents, the film shows how they are directly affected by climate change, with melting glaciers and changes in the ecological environment, and this emotional resonance gives viewers a deeper understanding of the seriousness of environmental problems. Coincidentally, this film has the same message as the film of " Chasing Ice" saying about how the global warming effect has been severely compounded in recent 10 years, compared with the same damage as the previous century caused.

In addition, O'right urged its efforts the audiences to act upon the net-zero emissions actions immediately in the film, highlighting the responsibility and potential of businesses in tackling the climate challenge. The film, which combines corporate action and social awareness, has been praised by many environmental organizations and the media, further enhancing O'right's reputation in the field of sustainability. Through a visual storytelling, O'right make its brand awareness, as well as the climate change issues to the public.

O'right's sustainability strategy

The company has taken a number of operational material measures to implement the sustainability strategy, such as:

- Green raw materials

By fully de-sourcing and replacing petrochemical components with agricultural by-products, this initiative meets United States Department of Agriculture (USDA) standards for bio-based products, promotes the use of green raw materials, and reduces environmental impact.

- Green packaging

The company has established a green supply chain for PCR (Post-Consumer Recycled) packaging, and since 2017, it has successfully prevented 5 million plastic bottles and plastic indenters from entering streams, seas or incinerators. This not only reduces the generation of plastic waste, but also promotes a circular economy.

- Green Factory

Oride has the first GMP (Good Manufacturing Practice) green cosmetics factory in Asia, and completed the use of 100% green electricity in the use of green energy ahead of schedule last year. In addition, the company has achieved Scope 1, 2 and 3 carbon neutrality in its corporate organization and product production, demonstrating its commitment to the environment.

- Investment benefit management of carbon

Oride manages carbon emissions data and joins the Science Based Targets initiative (SBTi) to implement carbon reduction targets. The company has developed a carbon pricing strategy and implemented sustainability management measures such as climate-related financial disclosures (TCFD), social return on investment (SROI) and carbon return on investment (CROI) to ensure a balance between its business operations and environmental protection.

- Carbon books and carbon credit assets

Ored has stored carbon credits for the next five years, becoming the first company in Taiwan to obtain a KPMG visa to include carbon credit assets in its financial statements, marking its innovation and leadership in carbon asset management.

- Corporate sustainability management

The company has set up a specific sustainability task project team, established a cross-departmental sustainability circle, and allocated one professional sustainability manager for 100 employees to further strengthen the sustainable development of its enterprise. O'right regularly publishes Corporate Social Responsibility (CSR) reports to demonstrate its commitment to social and environmental responsibility to its stakeholders. The main purpose is to enhance O'right's market competitiveness but also set a standard for promoting the practice of corporate social responsibility.

Discussion on the sustainable strategy of O'right

Marginal benefits of achieving net-zero emissions for O'right

The company's strategy to achieve net zero emissions throughout the supply chain has brought benefits to the company in a number of ways:

a. Enhance brand image and market competitiveness: Through a sustainable business model, Oraide's brand image has been successfully shaped into an environmentally friendly brand and attracted consumers who are concerned about environmental issues. According to reports, many consumers are willing to pay higher prices for eco-friendly products, which not only strengthens customer loyalty, but also boosts their market share. Net-zero strategies are often accompanied by improved energy efficiency and more efficient use of resources, reducing long-term operating costs. For example, by using renewable energy and reducing waste, OLED has significantly reduced its energy bills in its production processes.

b. Comply with government policies and regulations: As stricter environmental regulations are pushed around, companies that can adapt to these changes ahead of time will be able to avoid future legal risks and associated fines. By implementing net-zero emissions, O'right is able to comply with policy requirements early, thereby reducing the cost of compliance and ensuring a competitive advantage in policy changes.

c. Strengthening the resilience of the supply chain: The introduction of sustainable measures has made the supply chain more stable in the face of environmental challenges and reduced the risk caused by environmental factors, which is essential to maintain stable production and supply.

d. Attracting investors and partners: More and more investors and businesses are looking for partners who meet environmental and social responsibility standards. Oled's sustainability strategy makes it even more attractive when looking for partnerships and financing opportunities, which not only contributes to the company's long-term growth, but also facilitates the inflow of capital.

These benefits not only enhance the economic benefits of L&D, but also strengthen its leadership position in the industry, further driving the global focus on sustainable development.

Insight and Revelation and Limitations

Steven Ko's way of doing business offers important lessons for other businesses, especially when it comes to balancing environmental protection and business interests. Through the team's journey into Greenland to shoot a documentary on climate change, Steven Ko not only demonstrated the company's responsibility to social issues, but also highlighted the far-reaching global impact of climate change. This corporate culture, which emphasizes social responsibility, encourages more companies to participate in sustainable development practices.

However, the success of Steven Ko and his company does not mean that all businesses can imitate their model. The uniqueness of its business model and its high focus on green technology make it difficult for many companies to replicate. In addition, the production cost and market acceptance of environmentally friendly products pose challenges, which requires companies to find a balance between innovation and economic efficiency. These discussion points provide a basis for an in-depth discussion of the contributions and challenges of Steven Ko and his company, and can be further analysed from a practical and theoretical perspective.

Conclusions and Recommendations

Conclusion

This study delves into the remarkable contribution of Steven Ko and his company, O'right, in driving net-zero emissions, particularly in the areas of supply chain management and CSR. The results show that O'right has achieving its net-zero emissions target successfully, he is also a pioneer in the industry, inspiring many companies to go towards sustainability direction bravely. Through concrete actions plans and bring up the awareness to the consumers, industries to climate change. Steven Ko had demonstrated a role model what companies can contribute in global environmental challenges.

This study fills a gap in the literature, particularly in highlighting how SMEs can successfully implement net-zero strategies. While past research has focused on the case of large corporations, the success story of O'right proves that even smaller companies can play a key role in sustainability, providing new perspectives for future research.

Recommendations

In the future, it is suggested that the challenges and opportunities faced by other SMEs in achieving net-zero emissions can be further explored. In addition, a focus on how companies can coordinate and work together in global supply chains to address climate change and environmental challenges will help deepen our understanding of corporate sustainability strategies. Through these efforts, the study will shed a more comprehensive light on the role and impact of companies of different sizes in tackling environmental issues.

In addition, future research should actively explore more SMS practical cases with outstanding performance in environmental protection and social responsibility, which will give more courage to those who is think of yet no action taken parties, to promote the environmental accumulation and diffusion of carbon net-Zero knowledge and promote to all sectors of society to work together for the climate challenge. These findings

highlight the success stories of O'right and the importance of corporate action taken for driving sustainable development in the current global climate crisis.

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A Systematic Approach to ESG Integration and Crisis Management Systems in Supply Chains: A Theoretical Framework and Mathematical Models

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Abstract

This study explores systems thinking that integrates environmental, social and corporate governance (ESG) frameworks and crisis management in the supply chain, introducing mathematical models for analysis. First, we analyze how the three levels of ESG are intertwined to form an overall sustainable development framework. System dynamics models are used to model the interactions and risk dynamics between these layers, highlighting the existence of systemic risk. Next, we examine how companies can use ESG frameworks for crisis management in the face of environmental disasters, social issues, or governance scandals. The decision tree model helps to analyze the choice of ESG measures and their consequences in crisis situations, while revealing the effectiveness of ESG as a risk mitigation strategy. In addition, the game theory model explores the behavioral interactions between firms, governments, investors, and society and analyzes the strategic choices and impacts of each role in crisis situations. Finally, the carbon footprint calculation model is applied to assess the impact of enterprises in environmental challenges, emphasizing the importance of ESG frameworks in reducing environmental impact and promoting sustainable development. Overall, this study provides a systematic approach to help companies effectively integrate ESG and crisis management strategies in a complex supply chain environment.

Keywords: Environmental, Social and Governance (ESG), Crisis Management, Systems Thinking Mathematical Modelling, Sustainable Development

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Introduction

Background

In the context of global challenges such as climate change and social inequality, environmental, social and corporate governance (ESG) has become a core issue for corporate and social development (Eccles, Ioannou, & Serafeim, 2014). Meanwhile, effective crisis management is equally as important when it comes to sustainable development for a company, especially in an era that uncertainty and risk have been brought up more frequently, where companies are supposed to demonstrate flexibilities (Boin &'t Hart, 2003). To address these two issues, the purpose of this article is therefore to explore how to enhance the efficiency of crisis management and further improve the ESG performance of enterprises through systems thinking and mathematical models. First, we analyzed the application of systems thinking in crisis management and explore how it can contribute to the development of a holistic perspective to better identify potential risks (Harris, 1990). Then, through the construction of mathematical models, we will show how to quantify and evaluate the effectiveness of crisis management measures and make actionable recommendations to improve the decision-making process of enterprises (Pal Vorstel, 2007). It is hoped that this research can provide theoretical support and practical guidance for the sustainable development of enterprises, while contributing new insights to academic research in related fields.

Research status

With the ever-increasing awareness global climate change and socio-economic instability, companies are stressing more often the importance of integrating environmental, social and governance (ESG) concepts into their business operations. According to the Global Sustainability Report, a company's ESG performance not only affects its social responsibility, but is also directly related to its financial performance and market competitiveness (Khan et al., 2016). Research shows that companies which actively pursue ESG strategies are more resilient to external risks (Eccles et al., 2014). However, despite the fact that many companies have begun to pay attention to ESG, many of such practices still suffer from systemic deficiencies and lack of integration, which greatly reduces the effectiveness of the crisis management (Mchiri, 2022).

The existing research mostly focuses on a single dimension of ESG performance, and there is still a lack of discussion on how to apply systems thinking to crisis management and ESG integration. With the increasing application of systems thinking and mathematical models in many fields, incorporating them in the scope of crisis management would not only improve the efficiency of response, but also improve the overall performance of enterprises in terms of ESG. Based on this, the present article will discuss how to use systems thinking and mathematical models to strengthen enterprises' crisis management capabilities, improve their performance in ESG indicators, and provide new perspectives and solutions for the sustainable development of enterprises.

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Research Objectives

The main objective of this research is to explore how systems thinking and mathematical models can be effectively integrated into the crisis management process of enterprises, and further improve their performance in environmental, social and corporate governance (ESG) indicators. Specifically, this study aims to achieve the following objectives:

1. Analyze the application of systems thinking in crisis management: Discuss how systems thinking can help organizations better understand the complexity and dynamics of crisis management, and improve their crisis response capabilities (Sturman, 2000).
2. Establish mathematical models to support decision-making: Design mathematical models for crisis management to help companies make more scientific and rational decisions in different crisis scenarios (Forrester, 1961).
3. Assessing the impact of ESG performance: Analyze the specific impact of systems thinking and mathematical models on corporate ESG performance, especially in the areas of risk management and sustainability (Eccles et al., 2014).
4. Recommendations on best practices: Based on the results of the study, we provide specific strategic recommendations for companies to effectively integrate ESG concepts into their crisis management to achieve their sustainability goals (Khan et al., 2016).

Through the integration of systems thinking and mathematical models, this study hopes to provide enterprises with more forward-looking and practical crisis management solutions in the face of the current complex and uncertain economic environment.

Research gaps and academic contributions

Research gaps

Although the application of systems thinking and mathematical models in crisis management has attracted the attention of academia and industry, there are still several obvious research gaps in the current literature. First, there is a lack of research on the specific application of systems thinking in corporate crisis management and its impact on the decision-making process. Second, although some studies have explored the application of mathematical models in risk management, there is a lack of systematic discussion on how to effectively integrate these models with systems thinking to improve enterprises' crisis response capabilities (Wang et al.,2022). Finally, there is relatively little research in the existing literature on the integration of environmental, social, and governance (ESG) indicators into crisis management, especially in the context of mathematical models (Khalil et al., 2024). Therefore, this study aims to fill these gaps and provide new insights into related fields.

Academic Contributions

The academic contributions of this study are mainly reflected in the following aspects. First, this study integrates systems thinking and mathematical models to provide a new framework for analyzing complexity in

corporate crisis management, which provides a theoretical basis for future research (Sturman, 2000). Second, by an in-depth analysis of the specific application of systems thinking in crisis management, this study will aid the academic community to understand how the theory can have an impact in practice (Senger, 2006). Thirdly, this study provides specific strategic recommendations on how to integrate ESG concepts into crisis management, which not only fills the gap in the existing literature, but also provides guidance for corporate practice (Eccles et al., 2014). Finally, the results of this study will promote future research on the application of systems thinking and mathematical models in other management fields, and promote the development of this field.

Literature review

Systems Thinking and Mathematical Models

In recent years, the application of systems thinking and mathematical models in the field of enterprise crisis management has received more and more attention. In 2021, Bi et al. explores how systems thinking can help companies make effective decisions in the face of disruption. They point out that systems thinking can improve the resilience of firms by facilitating cross-sector collaboration (Bi et al., 2021). In addition, the study highlights the importance of systems thinking in analyzing complex systems, providing strategic recommendations for companies in the face of uncertainty.

In the same year, Skovsmose published research focusing on the application of mathematical models in risk management, especially model optimization in crisis situations. They use simulation methods to assess corporate risk in different crisis scenarios and propose the effectiveness of mathematical models in supporting decision-making processes (Skovsmoss, 2021). This study not only confirms the potential of mathematical models in crisis management but also provides an empirical basis for future research.

Broadstock et al. (2021) further examined the role of environmental, social and corporate governance (ESG) indicators in corporate crisis management. Their research shows that integrating ESG considerations during a crisis can significantly improve their image and social responsibility, thereby enhancing their long-term sustainability (Broadstock et al., 2021). This suggests that integrating ESG concepts into crisis management is critical to the strategic intent of companies.

Recently, in 2023, some researchers have focused on how the combination of systems thinking and mathematical models can improve the efficiency of corporate crisis management. They propose a comprehensive framework that highlights the importance of systems thinking in developing mathematical models and explores how the interaction between the two affects the decision-making process (Abdel-Latif et al., 2023). This research provides an important perspective for future academic discourse and calls for the academic community to explore this topic more deeply.

Based on the above literature, it can be seen that the application of systems thinking and mathematical models in corporate crisis management has received increasing attention, and most of the current research

focuses on the balance between theoretical discussion and empirical support. These studies not only enrich the relevant literature, but also provide practical guidance for enterprises to cope with the crisis.

Application of mathematical models in supply chain ESG integration and crisis management

Mathematical programming models

Mathematical programming models are widely used in supply chain management, especially in resource allocation and decision support. In recent years, Jayarathna et al. proposed a multi-objective optimization model to balance economic benefits and environmental impacts. Their research shows that through effective mathematical programming, companies can achieve ESG goals by reducing their environmental impact while increasing profitability (Jayarathna et al., 2021). This study highlights the importance of mathematical programming models in responding to supply chain crises, especially when decisions need to be made quickly.

Risk assessment model

In supply chain crisis management, risk assessment models can help companies identify and assess potential risks. Díaz-Curbelo et al. (2020) developed a risk assessment framework using fuzzy mathematics methods to focus on environmental and social risks in the supply chain. Their model is able to quantify uncertainty and provide risk-based decision support to businesses, thereby increasing their resilience in crisis situations (Díaz-Curbelo et al., 2020). This study shows the potential of risk assessment models to integrate ESG considerations, especially when dealing with complex and uncertain supply chain environments.

System dynamics model

System dynamics models excel in analyzing the dynamic behavior of complex systems. Alameru and Brishaud (2020) discussed the application of a systemadynamic approach to supply chain ESG integration, by building models to simulate the impact of different strategies on corporate ESG performance. Their research shows that system-dynamic models can help firms understand the long-term consequences of their decisions on social and environmental impacts (Alamerew & Brissaud, 2020). This provides a new perspective on the decision-making process in crisis management, emphasizing the need for continuous monitoring and evaluation in an ever-changing environment.

Statistical and machine learning models

Statistical and machine learning models are also becoming important tools in supply chain management. Aljohani (2023) used machine learning algorithms to develop a predictive model designed to predict the occurrence of a supply chain crisis (Aljohani, 2023). Their research shows that through data analysis, companies are able to identify potential crises in advance and thus take proactive measures. This model not only improves the accuracy of forecasting, but also emphasizes the importance of data-driven decision-making in supply chain management.

Research Methodology

This study adopts a systematic methodology and focuses on analyzing the feasibility of different mathematical models in environmental, social and corporate governance (ESG) integration and supply chain crisis management. The research method mainly includes the following steps:

1. Literature review

First, a comprehensive literature review was conducted to identify the main challenges and research status of ESG integration and supply chain crisis management. The literature review focuses on relevant research in the last three years, especially in the application of mathematical models and machine learning methods, to understand the advantages, disadvantages and applicability of different methods.

2. Construction of theoretical framework

Based on the results of the literature review, a theoretical framework is constructed that aims to integrate ESG indicators in supply chain management, especially in crisis situations. This framework covers a variety of mathematical models, including:

- Optimization model: Explore ways to find the best resource allocation under different constraints, taking into account environmental and social impacts.
- Simulation model: By simulating different scenarios, analyze the responsiveness and potential risks of the supply chain, and provide decision support.
- Machine Learning Models: Evaluate their feasibility in demand forecasting, supply chain disruption and risk identification, and analyze their impact on supply chain flexibility.

3. Analysis of mathematical models

Conduct a detailed analysis of the advantages and disadvantages of the constructed mathematical model. Discuss the applicability of each model in ESG integration and crisis management and its potential limitations. This process includes:

- Model comparison: Compare the ability of different mathematical models to respond to supply chain crises and their environmental and social impacts.
- Feasibility assessment: Analyze the feasibility of each model in practical applications, especially the constraints of enterprise resources, data availability, and technical level.

4. Discussion of methodology

On the basis of the analysis of various mathematical models, the theoretical basis of these models and their methodological significance in practical application are further discussed. This study will consider the following aspects:

- Method selection basis: Analyze how to choose the appropriate mathematical model according to different supply chain characteristics and crisis scenarios. For example, in industries with a high environmental impact, an optimization model may be more effective, while a machine learning model may provide

better prediction accuracy in a scenario where demand fluctuates.

- Model Integration: Explores how to combine multiple mathematical models to form an integrated decision support system to more comprehensively evaluate ESG integration and crisis management strategies.

5. Methods of statistical analysis

Although this study does not involve the collection of empirical data, the statistical analysis methods that may be used by various mathematical models will be discussed to support future research and applications. These include:

- Descriptive statistics: used to summarize and describe the basic characteristics of various ESG indicators in the supply chain, such as mean, standard deviation, distribution, etc.
- Regression analysis: It can be used to examine the impact of ESG factors on supply chain performance, helping to identify key variables and their relationships.
- Factor analysis: Used to explore and confirm the underlying structures that influence supply chain decisions, especially in multivariate situations.
- Scenario Simulation Analysis: By simulating different environmental and market conditions, evaluate the behavior and response of the supply chain in crisis situations, and then adjust strategies.

6. Conclusions and Recommendations

Finally, based on the analysis results of various mathematical models, the research findings are summarized, and the direction and practical suggestions for future research are put forward to help enterprises effectively integrate ESG indicators in supply chain management and improve their ability to cope with crises.

Results and Discussion

Overview: A systems dynamics perspective on the impact of ESG in crisis management

ESG implications of crisis management

When faced with crises such as environmental disasters, social issues, or governance scandals, companies can use ESG frameworks to respond effectively. The main arguments here include:

- ESG as a risk mitigation strategy: ESG frameworks can help companies prevent and respond to potential crisis events. By integrating environmental, social and governance factors, companies can better identify risks and develop response plans.
- Post-crisis resilience: Companies that adopt ESG policies typically show greater resilience after experiencing a crisis. Good ESG practices can promote the resilience of companies and help them recover quickly from challenges.

A. Application of mathematical models for the environmental dimension

Exploring how companies can reduce their environmental impact through ESG frameworks, especially

when addressing environmental challenges such as climate change and resource consumption, the application of mathematical models can provide effective solutions.

B. Application of mathematical models for the social dimension

The social dimension covers employee welfare, community relations and labor rights, etc., and analyzes how to use mathematical models to evaluate the impact of corporate social responsibility, and formulate corresponding policies and measures on this basis.

C. Corporate Governance and Risk Management

Explores the central role of corporate governance in ESG and analyzes how good corporate governance can help prevent and manage corporate risks. By establishing a transparent governance structure, companies can respond more effectively to crises.

D. ESG metrics and data analysis

Analyze how to use data to quantitatively evaluate ESG and use mathematical models to predict its long-term impact on companies. Through systematic analysis of ESG indicators, companies can develop more effective strategies to support sustainable development.

F. Systems thinking for ESG frameworks

The three main dimensions of ESG (environmental, social, and corporate governance) are intertwined to form an overall sustainability framework. This architecture not only considers the impact of a single dimension, but also emphasizes the interaction between them. Key arguments include:

- Systemic risk: Failure at any single level, such as an environmental breach, can have a profound impact on the entire system. This risk underscores the linkages between the various levels of ESG and points to the need for a holistic management strategy.
- Dynamics: Changes in environmental factors, social expectations, and governance standards over time will affect the effectiveness of ESG strategies. Companies need to adapt their strategies to the changing external environment.

Figure1 Schematic diagram of the system dynamics model of ESG

Model 1: System Dynamics Model

A system dynamics model is a systematic model designed to analyze the interactions between multiple variables, which can help researchers model the cascading effects between different levels. This model uses differential equations to describe the feedback mechanisms within the system and shows how the variables affect each other over time, resulting in complex behavioral patterns. In particular, in the context of ESG (Environmental, Social and Governance) framework, system dynamics models can be used to deeply understand the interaction between internal decision-making and the external environment when responding to external challenges, such as environmental change or social unrest.

ESG implications of crisis management

When faced with crises such as environmental disasters, social issues, or governance scandals, companies must effectively use ESG frameworks to respond. An ESG framework can not only help companies identify potential risks, but also provide a set of guiding principles to facilitate the effectiveness of their response strategies.

- ESG as a risk mitigation strategy: By integrating environmental, social and governance factors, companies can develop a more comprehensive risk management strategy. These strategies can help companies prevent and respond to potential crisis events, for example, by reducing the risk of environmental pollution by establishing a sound environmental management system, or by strengthening social responsibility to improve relationships with stakeholders. When faced with a crisis, these preventive measures can effectively reduce losses and improve response efficiency.
- Post-crisis resilience: Research shows that companies that adopt ESG policies typically show greater resilience after experiencing a crisis. These companies are often able to rebuild their brand image more quickly, restore market confidence, and get back to normal operations quickly after a crisis. For example, a company that has established a good social image before a crisis can rely on this trust to quickly restore customer support when faced with difficulties. At this time, ESG policy has become not only a tool for risk management, but also an important cornerstone of the long-term competitiveness of enterprises.

In summary, the application of system dynamics models in the analysis of ESG impact and crisis management can help enterprises understand the challenges they face more comprehensively and design more effective response strategies to cope with the changing market environment and social expectations.

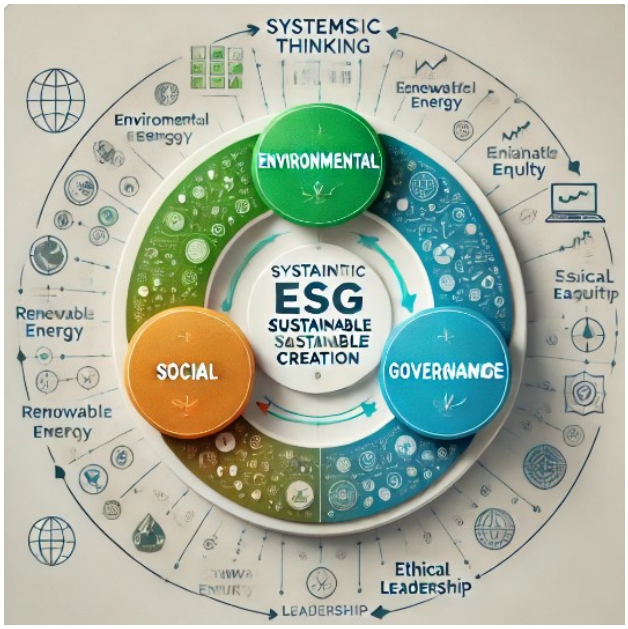

Figure2 the application of system dynamics models in the analysis of ESG

Model 2: Decision Tree Model:

The decision tree model can be used to analyze the decision points and their results of ESG measures under different crisis scenarios

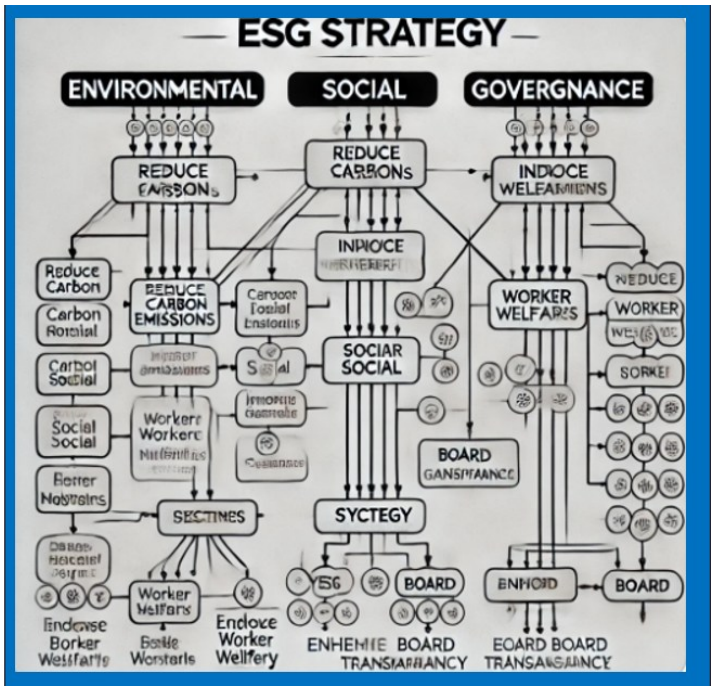

Figure 3 Diagram of the decision tree model applied to the dynamics of ESG systems

The above figure is a decision tree model diagram applied to the dynamics of ESG system, starting from the "ESG strategy" as the root node, and divided into three major areas: environmental, social and corporate governance, each of which has corresponding decision points and possible actions, showing the results or feedback loops of each decision. This graph can help you visualize the dynamic interactions in the ESG decision-making process.

Below is a table that uses decision tree models to solve ESG (Environmental, Social, Governance) system dynamics problems, showing the options and possible outcomes of different decisions:

Table 1 ESG strategy decision-making impact assessment tree

Nodes/decision points	description	choose	Results/Impacts
Root node: ESG strategy decision-making	Develop an overall ESG strategy	Environmental	Take environmental protection measures to reduce pollution and waste of resources
		Social	Improve social welfare, such as employee welfare, labor rights
		Governance	Enhance corporate transparency and shareholder governance
Environment: Reducing carbon emissions	Take steps to reduce your carbon footprint	be	Reduce carbon footprint, enhance corporate image, and comply with policy requirements
		not	Increased environmental risks, which may result in fines or negative publicity
Social: Improving employee welfare	Enhance employee compensation and benefits	be	Enhance employee satisfaction, attract talent, and increase productivity
		not	Employee turnover increases and job morale is low
Governance: Increase transparency	Increase board transparency and openness in corporate decision-making	be	Increase investor trust and improve corporate governance ratings
		not	Investors rebounded, downgrading corporate governance ratings

Table 1 (Cont.)

Nodes/decision points	description	choose	Results/Impacts
Outcome of the decision: Environmental impact assessment	Whether the environmental protection measures taken by the enterprise meet the emission reduction target	be	Reduce long-term operating costs and improve environmental evaluation
		not	Further strategic alignment and policy compliance are needed
Outcome of decision-making: Social impact assessment	The effect of improved employee benefits	be	Improve corporate social responsibility ratings and enhance employee cohesion
		not	Facing social risks such as employee strikes or labor shortages
Outcome of the decision: Governance assessment	Whether the transparency of corporate governance affects the long-term development of the company	be	The company's share price rises, attracting more investment
		not	The company's reputation has been damaged and it is facing scrutiny from regulatory authorities

This table shows how to use a decision tree model to analyze various aspects of ESG and derive the corresponding outcomes or impacts based on different choices.

Model 3: Game Theory Model

Game theory models can be used to study the behavioral interactions between firms and stakeholders, especially in the face of crisis. Game theory models provide a framework for analyzing the behavior and strategy choices of different participants, helping to understand the interaction process of companies, governments, investors, and society in driving ESG systems. Through these models, conflicts of interest and opportunities for collaboration between different actors can be analysed to find the best strategy to improve sustainable development.

The following is a table of game theory models applied to solve the dynamics of ESG (environmental, social, corporate governance) systems, showing how different actors influence each other through strategic choices and achieve or fail to achieve sustainability goals

Table 2 Table of game theory models applied to ESG systems

role	Policy options	Consequences of the act	Types of games	interpretation
enterprise	1. Invest in sustainable technologies	2. Maximize short-term returns	1. Gain long-term profits and reputation	2. Immediate profit increases, but long-term risk increases
government	1. Implement strict environmental protection policies	2. Relax environmental regulations	1. Improved environment, but may reduce corporate investment	2. Short-term and long-term environmental benefits
investor	1. Support ESG-friendly businesses	2. Invest in high-return, high-risk companies	1. Stable long-term returns and reduced risks	2. High-return short-term investment, but exposed to policy risks
Social/Consumer	1. Buy ESG-friendly products	2. Buy products that are less expensive but have a high environmental impact	1. Businesses are gradually transforming into sustainable development	2. Enterprises continue to engage in high-polluting activities, and social costs increase
Non-Governmental Organizations (NGOs)	1. Promote strict ESG standards	2. Take a neutral stance on ESG issues	1. Increase social awareness and promote ESG policies	2. ESG issues are being ignored and companies may continue to behave irresponsibly

Description of the form

1. Roles: Each role involved in the ESG system has different interest drivers, including corporations, governments, investors, consumers, and NGOs. The interaction of these roles is crucial in determining the outcome of an ESG system.

2. Strategy Options: Each character's strategic choices in the game affect their own and other characters' outcomes. Game theory models allow these roles to make choices under the influence of each other.

- Businesses may choose to invest in sustainable technologies or maximize returns in the short

term.

- Governments can choose to implement environmental policies or relax regulations, affecting the entire economic ecosystem.
- Investors are faced with investing in ESG-friendly companies or those that pursue high risk and high returns.
- Consumers' choices directly affect a company's product strategy and have a significant impact on market demand.

3. Behavioral outcomes: Each strategy choice has a corresponding outcome, and different choices will affect the sustainability of the ESG system.

- If a company invests in sustainable technology, it will gain long-term benefits and reputation, but if it chooses short-term benefits, it may face environmental risks and negative reputation.
- The implementation of strict environmental protection policies by the government may reduce short-term investment by enterprises, but it will benefit long-term environmental protection.
- Investors support ESG-friendly companies with reduced long-term risks, while investing in high-risk companies may face policy risks.

4. Game Type: This column describes the type of game that each character interacts with. Different game models can be used to simulate interactions between characters.

- The prisoner's dilemma: the choice between short-term and long-term benefits. Cooperation is good for sustainable development, but individual behavior tends to be maximized in the short term.
- Social contract game: The contractual relationship between the government and society determines the balance between the environment and the economy.
- Public Wealth Game: Consumers' choices affect the use of public resources, and individual decisions affect society as a whole.
- Coordination game: NGOs and other organizations need to coordinate with companies and governments to promote the achievement of ESG goals.

Model 4: Carbon Footprint Calculation Model

The mathematical model of the environmental dimension can be applied to explore how companies can reduce their environmental impact through ESG frameworks when responding to environmental challenges such as climate change and resource consumption. The carbon footprint calculation model is used to assess the carbon emissions of a company during production and operations. It helps companies and organizations quantify their carbon emissions at all ESG levels, so as to formulate corresponding emission reduction measures. The model not only helps companies understand their own carbon emissions and those of their supply chains, but also helps them make greener business decisions and drive overall sustainability. This approach reduces environmental risks and enhances social responsibility, promoting transparency in corporate governance and long-term profitability.

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The following is a table of how the Carbon Footprint Calculation Model is applied to solve the dynamics of ESG (Environmental, Social, Governance) systems, showing how the carbon footprint can be measured and managed at different levels of ESG, and the impact on sustainability:

Table 3 A table in which the carbon footprint calculation model is applied to the ESG system

ESG dimension	Carbon Footprint Measurement Project	Calculation Method/Model	Results & Impact	Application note:
environment	Corporate carbon emissions	GHG Emissions Calculation	Calculate the total carbon emissions of a company from the production of products or services	Help enterprises identify links with high carbon emissions and promote the application of emission reduction technologies
society	Supply chain carbon footprint	Supply Chain Carbon Footprint Model	Calculate carbon emissions at all stages of the supply chain, including transportation, logistics, and material use	Help enterprises choose low-carbon suppliers and improve the environmental benefits of the supply chain
Corporate Governance	The carbon impact of management's decisions	Carbon Footprint Decision Model	Quantify the impact of decisions on carbon emissions and set sustainable development goals	Help enterprises take carbon emissions into account at the strategic decision-making level and promote green governance

Table 3 (Cont.)

ESG dimension	Carbon Footprint Measurement Project	Calculation Method/Model	Results & Impact	Application note:
products	Carbon emissions over the life cycle of a product	Product Carbon Footprint Assessment	Calculate the carbon footprint of a product from production to disposal, including materials, manufacturing, transportation, etc	Help enterprises optimize product design, choose environmentally friendly materials, and reduce carbon emissions throughout the product life cycle
Employee Behavior	Carbon emissions from employee travel and the working environment	Employee Carbon Footprint Model	Calculate the carbon footprint of your employees' commuting, traveling, and office environments	Help enterprises implement remote work, low-carbon commuting, and create a low-carbon working environment
Energy use	Renewable energy use	Energy Carbon Intensity Model	Calculate the carbon intensity of energy use compared to renewables versus conventional energy sources	Encourage companies to use low-carbon energy sources and gradually reduce their dependence on fossil fuels
Waste management	Carbon footprint of waste disposal	Waste Carbon Footprint Model	Calculate carbon emissions in the waste treatment process, including recycling, incineration, landfilling, etc	Helping companies develop more effective waste reduction and recycling programs

Table 3 (Cont.)

ESG dimension	Carbon Footprint Measurement Project	Calculation Method/Model	Results & Impact	Application note:
Green procurement	Purchases of low-carbon products and services	Green Procurement Carbon Model	Calculate the carbon footprint of the procurement process to drive the procurement of low-carbon products and services	Helping companies implement sustainable procurement policies and reduce their overall carbon footprint

Description of the form

1. ESG Dimensions: The table covers different aspects of ESG, including environmental, social, corporate governance, and related specific application areas (e.g., products, employee behavior, energy use, etc.), showing how to calculate carbon footprints at each level.

2. Carbon Footprint Measurement Programs: Each ESG level has a corresponding carbon footprint measurement program, which helps companies and organizations accurately calculate the sources of their carbon emissions and develop emission reduction strategies.

- The environmental dimension focuses on the direct carbon emissions of the company.
- The social dimension focuses on the management of carbon emissions in the supply chain.
- Corporate governance, on the other hand, emphasizes how corporate decisions affect the overall carbon footprint.

3. Calculation Methodology/Model: Different carbon footprint calculation models are used to quantify carbon emissions at each ESG level. These models include:

- GHG Emission Formula: Used to calculate a company's carbon emissions.
- Supply Chain Carbon Footprint Model: Used to track supply chain carbon emissions.
- Product Carbon Footprint Assessment: Analyze the carbon emissions of the whole life cycle of a product.
- Employee Carbon Footprint Model: Calculated for carbon emissions from employee travel and work environments.
- Energy Carbon Intensity Model: Calculates the carbon intensity of renewable and conventional energy sources.

4. Results & Impacts: The results of carbon footprint calculations have a direct impact on your company's

decision-making and strategy implementation.

- Reducing carbon emissions can reduce the negative environmental impact of a company and improve its social responsibility rating.
- Controlling the carbon footprint of the supply chain can help companies achieve greener procurement and supply management, and drive supplier transformation.
- The low-carbon transformation of employee behavior can reduce carbon emissions at work and improve sustainability within the organization.

5. Description of the app:

- At the environmental level, companies can use carbon footprint calculations to identify high emission segments and promote emission reduction technologies, such as energy-saving technologies or the use of renewable energy.
- At the societal level, carbon emission management in the supply chain is becoming more and more important, and companies should choose low-carbon suppliers and improve logistics links.
- At the corporate governance level, the carbon footprint decision evaluation model helps management integrate carbon emission considerations into long-term strategies and achieve more transparent sustainability goals.

Model 5: linear programming

It can be applied to optimize the allocation of resources, such as how to minimize environmental costs while meeting production needs. Below shows a table of how linear programming models can develop their role in ESG integration and crisis management, and provides specific mathematical models and expected effects to help better understand their application in the supply chain.

Table 4 Analysis of mathematical models of supply chain sustainability and resource optimization

Applications	Specific applications	Mathematical models	What to expect
Resource allocation	Optimize resource allocation in the supply chain and balance environmental and economic benefits	Maximize/minimize the objective function, subject to resource constraints	Improve resource efficiency and reduce environmental impact
risk management	Evaluate and adjust supplier selection to reduce risk in crisis scenarios	A risk minimization model that takes into account supplier performance and stability	Enhance the resilience of your supply chain and respond quickly to emergencies

Table 4 (Cont.)

Applications	Specific applications	Mathematical models	What to expect
Environmental Impact Assessment	Quantify carbon emissions and other environmental metrics from supply chain activities	Carbon Minimization Model	Comply with ESG standards and enhance corporate image
Social Responsibility Management	Evaluate and improve the performance of suppliers in terms of social responsibility	Social Responsibility Maximization Model	Enhance social trust and improve the overall sustainability of the supply chain
Integrate supply chain strategies	Integrate environmental, social and governance factors across the supply chain to optimize operational processes	A model that integrates minimizing costs and maximizing social value	Promote the synergy of all links in the supply chain and improve the overall performance

Model 6: Social Impact Model

Social impact models can simulate the positive or negative impact of a business on a local society. The social aspects include employee welfare, community relations, labor rights, etc., and explore how to use mathematical models to evaluate the impact of corporate social responsibility.

The following table demonstrates the application of social impact models in ESG integration and crisis management, and provides a specific model framework and expected effects to help understand their impact in the supply chain.

Table 5 Analysis of supply chain social impact and responsibility assessment model

Applications	Specific applications	Model framework	What to expect
Community involvement	Assess the impact of supply chains on local communities and promote community engagement and support	Stakeholder analysis model	Enhance community trust and brand image

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Table 5 (Cont.)

Applications	Specific applications	Model framework	What to expect
Employment opportunities	Quantify the impact of supply chain operations on the creation and disappearance of local jobs	Job opportunity growth forecasting model	Promote economic development and enhance social stability
Education & Training	Evaluate the contribution of supply chain companies to education and training in terms of social responsibility	Educational Impact Assessment Model	Improve the quality of the workforce and promote sustainable development
Health & Safety	Analyze the impact of supply chain activities on worker health and safety	Health risk assessment model	Reduce the accident rate and improve the working environment
social welfare	Quantify the supply chain's investment and return on social welfare programs	Analytical model of social welfare benefits	Enhance social well-being and enhance the image of corporate social responsibility
Poverty alleviation	Assess the contribution and impact of supply chains to poverty alleviation	Poverty Impact Assessment Model	Improving living standards and promoting social equity

Model 7: Multi-objective Optimization Model

A multi-objective optimization model can analyze how to balance multiple social factors such as benefits, compensation, training, etc. The following table demonstrates the application of multi-objective optimization models in ESG integration and crisis management, and provides a specific model framework and expected effects to help understand its impact in the supply chain.

Table 6 Analysis of multi-objective optimization model for supply chain operation and ESG integration

Applications	Specific applications	Model framework	What to expect
Environmental and economic balance	Balance environmental sustainability with economic benefits to optimize supply chain operations	Environmental-economic dual-objective model	At the same time, environmental protection and cost control are achieved, and the overall efficiency is improved
Risk & Efficiency Management	Balance risk minimization with maximizing operational efficiency in crisis management	Risk-efficiency multi-objective optimization model	Enhance supply chain resilience and responsiveness
Social Impact Assessment	At the same time, we consider social responsibility and economic benefits to achieve the optimization of social impact in the supply chain	Socio-economic dual-objective model	Enhance corporate image and promote social development
Resource placement	Optimize resource allocation under multiple sustainability goals, such as energy use, material recycling, etc	Multi-objective optimization model for resource allocation	Improve resource efficiency and reduce environmental impact
Long-term vs. short-term goals	Consider both short-term profits and long-term sustainability goals to develop a balancing strategy	Short-term and long-term equilibrium optimization model	Achieve long-term sustainability and competitiveness of your business
Integrate ESG metrics	Balance ESG (Environmental, Social and Governance) indicators and develop an integrated strategy	ESG integration multi-objective optimization model	Ensure balanced development across all ESG dimensions to improve overall performance

Model 8: Risk Analysis Model

Corporate governance must understand the central role of ESG and how to prevent and manage corporate risks through good corporate governance. A risk analysis model uses mathematical methods to calculate risks in corporate governance, such as potential risks in the board structure or internal control system. The following table shows the application of risk analysis models in ESG integration and crisis management, and provides a specific model framework and expected effects to help gain a deeper understanding of their impact in the supply chain.

Table 7 Analysis of supply chain crisis management and ESG risk identification and response model

Applications	Specific applications	Model framework	What to expect
Crisis identification	Assess potential sources of crisis and risk factors in the supply chain, and establish a risk identification system	Risk Identification Model	Improve risk early warning capabilities and reduce the probability of crises
risk assessment	Quantify the likelihood and impact of risk to provide data support for decision-making	Quantitative risk assessment model	Empower managers to make informed decisions based on data
Risk prioritization	Prioritize risks based on their severity and probability of occurrence, and develop priority response strategies	Risk prioritization model	Allocate resources efficiently and focus on high-risk projects
Contingency planning	Develop a crisis response plan based on a risk analysis to ensure rapid response capabilities	Contingency planning model	Enhance the resilience of your supply chain and ensure business continuity
Risk monitoring	Establish a continuous monitoring system to regularly assess the risk profile and adjust response strategies	Risk monitoring and assessment model	Adjust your strategy in a timely manner to respond to the changing risk environment

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Table 7 (Cont.)

Applications	Specific applications	Model framework	What to expect
ESG-related risk analysis	Conduct specific analysis of environmental, social and governance (ESG) risks to ensure compliance with relevant standards	ESG risk analysis model	Improve corporate ESG compliance and reduce potential legal and reputational risks

Model 9: Monte Carlo Simulation

Monte Carlo simulations can be used to simulate the risk of corporate governance decisions under multiple random variables. Table 8 showcases the application of Monte Carlo simulation in ESG integration and crisis management and provides a concrete model framework and expected effects to help better understand its impact in the supply chain.

Table 8 Application analysis of Monte Carlo simulation in the integration of supply chain management and ESG

Applications	Specific applications	Model framework	What to expect
risk assessment	Use Monte Carlo simulations to assess the impact of uncertainties in the supply chain on risk	Uncertainty risk assessment model	Obtain probability distributions of risk ranges to support the decision-making process
Resource placement	Simulate the operational results under different resource allocation scenarios to find the optimal solution	Resource allocation optimization model	Determine the best resource allocation to improve operational efficiency
Environmental impact analysis	Assess the potential environmental impact of supply chain operations and consider uncertainties	Environmental Impact Assessment Model	Predict environmental impacts in different operating scenarios

Table 8 (Cont.)

Applications	Specific applications	Model framework	What to expect
Demand forecasting	Stochastic simulations based on market changes to predict fluctuations in product demand	Demand forecasting models	Improve demand forecasting accuracy and inventory management
Investment decisions	Analyze the return risk of different ESG investment solutions, and provide the distribution of risk and return	Return on investment risk assessment model	Help businesses make more informed investment decisions
Crisis response strategies	Simulate the effects of different crisis response options to find the most effective response strategy	Crisis response simulation model	Enhance resilience to ensure supply chain continuity

Model 10: Regression Analysis

ESG indicators are the best basis for data analysis and can be used to model the relationship between ESG indicators and corporate performance, so researchers must understand how to use data to quantitatively evaluate ESG and predict its long-term impact on enterprises through mathematical models. Table 9 demonstrates the application of regression analysis in ESG integration and crisis management, and provides a specific model framework and expected effects to help better understand its impact in the supply chain.

Table 9 Application of regression analysis model in ESG forecasting and supply chain performance management

Applications	Specific applications	Model framework	What to expect
ESG performance forecasts	Use regression analysis to predict your organization's environmental, social, and governance (ESG) performance	ESG performance forecasting model	Understand the factors influencing ESG performance and inform your improvement strategy

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Table 9 (Cont.)

Applications	Specific applications	Model framework	What to expect
Supply chain performance analysis	The key variables affecting supply chain performance were analyzed, and a regression model of supply chain performance was established	Supply chain performance regression model	Identify key factors to improve supply chain efficiency
Evaluation of the effectiveness of crisis response	Evaluate the impact of crisis management measures on business performance and quantify the effectiveness of response strategies	Regression model of crisis response effect	Improve the effectiveness of responses to support future crisis management decisions
Cost and benefit analysis	Analyze the relationship between the costs and benefits of supply chain operations and optimize resource allocation	Cost-benefit regression analysis model	Achieve cost control and improve resource allocation efficiency
Market demand forecast	Based on the historical data analysis of the influencing factors of market demand, a market demand regression model was established	Market demand forecasting regression model	Improve the accuracy of demand forecasts and optimize inventory management
Social Impact Assessment	Analyze the impact of corporate activities on society and quantify the contribution of social responsibility to corporate performance	Social Impact Assessment Regression Model	Promote socially responsible investment and enhance the social image of enterprises

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Model 11: Structural Equation Modeling (SEM)

Structural equation models can analyze the interrelationships between ESG indicators and their overall impact on corporate performance. Table 10 demonstrates the application of structural equation modeling in ESG integration and crisis management, and provides a specific model framework and expected effects to help understand its impact in the supply chain. These themes and mathematical models can help managers explore the multi-dimensional approach to systems thinking about ESG frameworks and crisis management, and highlight how the interaction between different levels affects the overall performance of the organization.

Table 10 Application analysis of structural equation model (SEM) in ESG integration and supply chain crisis management

Applications	Specific applications	Model framework	What to expect
ESG factor relationship analysis	Use SEM to analyze the interrelationship between ESG factors (environmental, social, governance).	Structural equation model of ESG factors	Identify the key factors influencing ESG performance and their interactions
Evaluation of crisis management strategies	Evaluate the impact of different crisis management strategies on supply chain performance, and analyze the causal relationship between strategies	SEM model of crisis management strategy	Improve the effectiveness of crisis management strategies and optimize resource allocation
Factors influencing supply chain performance	The influencing factors of supply chain performance were analyzed, and a structural equation model was established to evaluate its overall impact	SEM model of supply chain performance	Provide comprehensive performance reviews to help develop improvement strategies
The relationship between social responsibility and performance	Explore the relationship between corporate social responsibility (CSR) and business performance, using SEM for quantitative analysis	SEM model of social responsibility performance	Understand the impact of CSR on business performance and promote socially responsible investment

Table 10 (Cont.)

Applications	Specific applications	Model framework	What to expect
Consolidate metrics	Integrate different ESG metrics into a single model and analyze their impact on supply chain management	ESG metrics are integrated with SEM models	Improve the systematization and integrity of supply chain management
Simulate future scenarios	Use SEM to simulate future scenarios to assess the potential impact of different policies or action options on the supply chain	Scenario simulation SEM model	Help managers anticipate and respond to future risks and challenges

Advantages of using structural equation modelling studies

There are several advantages using the SEM for modeling. The analysis of latent and observed variables offers several significant advantages, including the following advantages over other research methods:

1. Analyze the relationship between multiple variables at the same time

SEM is able to consider multiple latent variables (e.g., ESG factors, crisis management strategies, supply chain performance, etc.) and observed variables (e.g., specific indicator data) at the same time, and can evaluate the causal relationship between them. This comprehensiveness allows researchers to understand the complex interactions between different factors, whereas other methods, such as regression analysis, typically focus on a single causal relationship.

2. Ability to deal with latent variables

SEM can effectively deal with latent variables that cannot be directly observed, which is particularly important in the research of ESG and crisis management. For example, latent variables such as corporate social responsibility or environmental awareness cannot be directly measured, but can be estimated through relevant observed variables (e.g., employee surveys, implementation of environmental policies, etc.). This property makes SEM very useful when exploring and quantifying these abstractions.

3. Provide model fit evaluation

SEM provides a variety of metrics to evaluate the fit of the model (e.g., CFI, TLI, RMSEA, etc.), which enables researchers to intuitively understand the fit of the model and make adjustments accordingly. In contrast, many traditional statistical methods, such as single regression analysis, often fail to provide such a comprehensive fit assessment, and it is easy to overlook the overall applicability of the model.

4. Recognize the impact of measurement errors

SEM can take measurement errors into account, which means it can provide more accurate estimates.

In ESG and crisis management research, SEM can help researchers better control the impact of these errors due to possible bias in data sources and collection methods, thereby improving the reliability of results.

5. Build complex causal models

SEM allows researchers to build and test complex causal models, which is particularly important when exploring the relationship between ESG integration and crisis management. For example, consider how environmental, social, and governance factors work together to impact supply chain resilience and performance. Other research methods may not be able to deal with such multi-level causation at the same time.

6. Adaptable

SEM has a high degree of flexibility, and researchers can adjust the model structure according to the research needs, and conduct multiple tests and optimizations, so as to continuously improve the explanatory power and prediction ability of the model. This adaptability makes SEM particularly well-suited to the rapidly changing supply chain environment and ESG requirements.

The advantages of structural equation modeling in ESG integration and crisis management research, especially in its ability to effectively deal with the complex relationship between latent variables and observed variables, evaluate model fitting, control measurement errors, and construct multi-level causal models, provide researchers with powerful analytical tools and insights, making it a more effective research method in exploring the sustainability and resilience of supply chains.

Model 12: Machine Learning Model

Machine learning models are methods developed by artificial intelligence. The application of machine learning models in ESG integration and supply chain crisis management not only improves efficiency and accuracy, but also enhances the ability of enterprises to respond to uncertainty and risk, thereby promoting sustainable development.

There are several advantages to using machine learning models:

1. Efficient data processing capabilities: Machine learning models can process large volumes and complex data, which is especially important in supply chain management. These models are able to collect data from a variety of sources, including suppliers, consumers, environmental impacts, and more, and quickly analyze that data to derive insights.

2. Prediction accuracy: Through training on historical data, machine learning models are able to identify trends and patterns to provide accurate predictions. For example, these models can predict changes in demand, supply chain disruptions, and their potential impacts, helping companies adjust their strategies in a timely manner.

3. Real-time responsiveness: Machine learning models have the ability to learn and adapt in real time, continuously updating their predictions and recommendations based on the latest data. This is crucial in crisis management, as being able to react quickly reduces losses and risks.

4. Multi-dimensional analysis: Machine learning is able to consider multiple variables and complex interrelationships at the same time to conduct multi-dimensional ESG assessments. This capability enables businesses to gain a more comprehensive understanding of the environmental and social impacts of their operations.

5. Enhanced decision support: By generating actionable insights, machine learning models are able to support management in making data-driven decisions. These insights are not limited to forecasting, but also include recommendations for optimal resource allocation and policy adjustments.

6. Continuous improvement: As the amount of data increases and the model is further trained, the predictive ability and accuracy of the machine learning model will improve, and continuous improvement will be achieved, which will have a positive impact on the long-term development of the enterprise.

The following is a table of the research applications of machine learning models including the model name, application purpose, key features, and references.

Table 11 Overview of the application of machine learning models in supply chain crisis management and ESG integration

The name of the model	Purpose of application	Key features:	What to expect
Supervised learning models	Anticipate supply chain crises	Trained with labeled data, it is able to identify potential crisis patterns and trends	Identify the key factors influencing ESG performance and their interactions
Unsupervised learning models	Perform data clustering and feature extraction	Clustering algorithms are used to identify similar features and identify potential problem areas or patterns	Improve the effectiveness of crisis management strategies and optimize resource allocation
Reinforcement learning models	Optimize decision-making processes and improve ESG performance	Learn the best strategies through trial and error to adapt to changing environments and dynamic needs	Provide comprehensive performance reviews to help develop improvement strategies
Deep learning models	Process large-scale data and perform complex pattern recognition	Multi-layer neural networks are used to automatically extract features and deal with nonlinear relationships	Understand the impact of CSR on business performance and promote socially responsible investment

Table 11 (Cont.)

The name of the model	Purpose of application	Key features:	What to expect
Time series prediction models	Anticipate changes in supply chain demand and adjust supply chain strategies in a timely manner	Analyze time series data to forecast future changes in demand and supply	Improve the systematization and integrity of supply chain management
Simulate future scenarios	Use SEM to simulate future scenarios to assess the potential impact of different policies or action options on the supply chain	Scenario simulation SEM model	Help managers anticipate and respond to future risks and challenges

1. Supervised learning model: Trained on labeled historical data, it can effectively predict the occurrence of supply chain crises and help enterprises formulate response strategies in advance.

2. Unsupervised learning model: Through cluster analysis, potential patterns in data can be found and decision support can be provided, especially in ESG assessment.

3. Reinforcement learning models: Ability to continuously adjust decision-making processes to improve ESG performance and adapt to dynamic supply chain environments.

4. Deep learning models: Suitable for processing large-scale and complex data, it can automatically identify nonlinear relationships and improve the accuracy of predictions.

5. Time series forecasting models: Leverage historical data to forecast future demand for more precise resourcing and risk management.

This table briefly summarizes the application of machine learning models in supply chain ESG integration and crisis management, and provides relevant references.

Conclusions and Recommendations

Conclusion

This paper emphasizes the value of mathematical models in ESG integration and supply chain crisis management and echoes the research goal of exploring the feasibility of different mathematical models and their practicability in crisis management. Through in-depth analysis, we found that mathematical models play a key role in supporting companies in navigating various crisis challenges. These models not only provide a framework for

risk identification and assessment, but also help companies optimize resource allocation to improve the resilience and sustainability of their supply chains. The need for ESG integration has become more prominent, and the application of mathematical models provides a clear path for companies to make informed decisions in the midst of uncertainty.

In the discussion of methodology, we analyze the advantages and disadvantages of various mathematical models, including optimization models, simulation models and machine learning models. Each model exhibits different advantages in specific scenarios, for example, optimization models have good performance in resource allocation and cost control, while machine learning models have shown strong potential in predicting future risks and trends. These analyses not only provide theoretical support for ESG integration in the academic community, but also provide practical reference for the industry when implementing relevant strategies.

Recommendations for future research

Future research should focus on the integration and empirical validation of these mathematical models to further deepen the understanding of ESG integration and its impact on supply chain management. With the increasing attention of ESG factors in global supply chain management, how to effectively use mathematical models to promote sustainable development will become an important research topic. In particular, consideration should be given to combining the strengths of different mathematical models to develop a comprehensive framework to adapt to changing market conditions and needs. In addition, future research can also explore the adaptability and effectiveness of mathematical models in different industrial contexts, so as to provide specific strategic suggestions for enterprises in different industries.

To sum, this study not only provides a rich theoretical basis for academic discussion in related fields but also provides practical guidance for decision-making in enterprise practice, and lays a solid foundation for future supply chain management. Further research and empirical evidence will help enhance the resilience of enterprises in the face of uncertainties and risks and promote a more sustainable development path.

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Cross-border e-commerce service quality model construction and variable relationship analysis

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Abstract

The study aims to explore the relationship between cross-border e-commerce service quality and consumer loyalty. With the goal of improving the service quality of cross-border e-commerce, combined with the theory of consumer behavior and cross-border e-commerce, the service quality model was constructed, and the relationship between the variables was analyzed. The specific issues related to the relationship between the quality of cross-border e-commerce services and consumer loyalty, switching costs, and perceived value. Utilizing quantitative analysis methods, this paper designs a variable relationship model and a questionnaire that includes measures of service quality, switching costs, perceived value, and loyalty. A total of 500 questionnaires were distributed to consumers with experience in international online commerce, and 470 valid responses were collected and analyzed. The results indicate a positive relationship between service quality in international online commerce and consumer loyalty, perceived value, and switching costs. Based on these findings, the study provides relevant research suggestions in the context of current international online commerce marketing practices.

Keywords: International Online Commerce, Quality of Service, Model Building, Variable Relationships

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Introduction

Research status

With the continuous development of global digital technology and applications, the cross-border e-commerce industry is booming, attracting many traditional enterprises to transform. The quality of cross-border e-commerce services has become an important criterion for evaluating the competitiveness of enterprises. The research of Wolfgang ULaga et al. shows that the role of service quality in customer value is much greater than that of price, so this study draws on the SERVQUAL model proposed by Parasuraman et al. to explore the current status and influencing factors of cross-border e-commerce service quality.

Research Motivation

The rapid development of the international online commerce industry and the importance of service quality to the competitiveness of enterprises prompted this study to construct a model and analyze the variable relationship between international online commerce service quality. Although many scholars have made contributions in the field of service quality, no research can fully represent the current situation of international online commerce service quality, so this study aims to deeply explore the current situation of international online commerce service quality and its related factors in combination with the actual situation.

Research Objectives

This paper aims to improve the service quality of international online commerce enterprises, and analyzes the variable relationships of service quality, switching cost, perceived value and customer loyalty of international online commerce enterprises, so as to further enrich the theory of international online commerce

Research Questions

The main research questions of the paper are as follows:

1. How does the quality of international online commerce services affect the switching cost of consumers?
2. How does the quality of international online commerce services affect consumers' perceived value?
3. How does the switching cost of consumers affect their loyalty to international online commerce?
4. How does consumers' perceived value affect their loyalty to international online commerce?
5. How does the quality of international online commerce services affect consumer loyalty?
6. How does the quality of international online commerce services affect consumers' loyalty through their switching costs?
7. How does the quality of international online commerce services affect consumers' loyalty through their perceived value?

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Literature review

Brief description of the principle

The increasing global digital technology and applications have provided huge growth opportunities for cross-border e-commerce, and many traditional enterprises have transformed into the e-commerce industry. At present, the technology of cross-border e-commerce is becoming more and more developed, and the government monitoring market mechanism is becoming more and more mature. In the context of a favorable cross-border e-commerce environment, the quality of cross-border e-commerce services is an important basis for evaluating enterprises and the cornerstone of enterprise competition. Therefore, the construction of a cross-border e-commerce service quality model and variable relationship analysis are of far-reaching significance to promote the development of cross-border e-commerce and foreign trade.

Empirical research confirms that among the drivers of customer value, the active role of quality is much greater than that of price, with the former being 63.3% and the latter being 36.7%. Therefore, this paper draws on the most representative definition of Parasuraman et al. (1985) Quality of Service Model (PZB Model), which is widely cited in academic practice.

The PZB model uses exploratory research to identify ten dimensions of consumer service quality. The 1988 SERVQUAL scale reduced the original 10 components of the PZB model to five, and formed the SERVQU AL scale (22 measurement items).

Although the SERVQUAL model is limited to a kind of ex-ante research, the proposed five dimensions affecting service quality are still widely recognized by experts in the international service quality research community(Joseph et al., 1993). The five facets of the Self's model are as follows: Tangibility, Reliability, Reactivity, Guarantee, and Caring. Although many scholars have carried out research on service quality in different fields, they cannot represent the current situation of cross-border e-commerce services, so this paper analyzes and discusses the construction of cross-border e-commerce service quality model and the relationship between variables based on the current situation of cross-border e-commerce service quality.

Concept of relevant variables

Quality of Service

Gronroos (1984) defines quality of service as the difference between what consumers expect in advance and what they perceive after receiving it. Service quality is the consumer's perception and measurement of service performance, that is, the customer's perception of the quality of the various services provided, when the perception degree is high, it represents good service quality, and conversely, when the perception degree is low, it indicates poor service quality

Conversion costs

Consumer switching cost is an important factor affecting the basic consumer group of international online commerce. Therefore, companies need to do everything possible to reduce consumers' willingness to switch products (Jackson & Schuler, 1985) proposed the concept of switching cost, which explains the economic

and psychological costs that customers must face when switching suppliers. Switching costs can lead to customer dependence on service providers.

Perceived value

Zaithaml (1988) first proposed the theory of perceived value from the perspective of the customer in 1988. Consumer behavior theory is the theoretical basis that explains all business and marketing activities, and international online commerce is no exception. The comprehensive evaluation of a service or product by a consumer is based on the perception of pay and benefit, and the perceived value of a consumer refers to the result of the consumer's perceived evaluation of a product or service. In addition to paying more attention to the quality of their own consumption experience, people are also affected by other factors such as perceived value (Ma et al., 2022).

Loyalty

Customer loyalty refers to how loyal a customer is to a business. Customer loyalty refers to the psychological tendency to trust, continue and repeat purchases of products or enterprises due to satisfaction, and is the continuous expression of customer purchase behavior. Jill Griffin, a senior marketing expert in the United States, believes that customer loyalty refers to the degree to which customers frequently repeat purchases due to their preference for a business or brand.

Personalization factors such as high-quality products, low-priced selling prices, convenient and fast websites, fast delivery logistics, and secure payment systems can help businesses ensure customer satisfaction and customer loyalty (Sujay et al., 2022).

Research framework design

The SERVQUAL evaluation model is a pre-study of the benefits of a service product that the customer experience. In the process of exploring the relationship between service quality, perceived value, satisfaction and loyalty, it is found that there is a positive relationship between each aspect.

Drawing on the SERVQUAL scale, this paper divides the service quality of international online commerce into five dimensions to quantitatively evaluate the service quality. Referring to the literature on consumer switching cost, consumer perceived value, and consumer loyalty, and based on the research of previous scholars, the model was constructed and a formal questionnaire was formed

The consumer loyalty model of international online commerce is constructed as follows (see Figure 1):

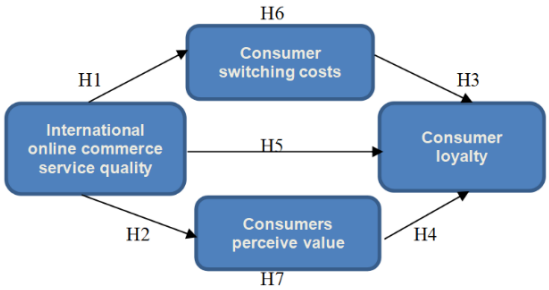

Figure 1 The relationship between international online commerce service quality and consumer switching cost, consumer perceived value, and consumer loyalty. Source: Compiled from the study

The research framework of this paper sets up the following seven path relationships, namely: first, the relationship between service quality and consumer switching cost; second, the relationship between service quality and consumers' perceived value; third, the relationship between consumer switching cost and consumer loyalty; fourth, the relationship between consumer perceived value and consumer loyalty; fifth, the relationship between service quality and consumer loyalty; Sixth, consumer switching cost has a mediating role in the relationship between service quality and consumer loyalty; Seventh, consumer perceived value plays a mediating role in the relationship between service quality and consumer loyalty.

Research Methodology

Questionnaire design and

Based on the literature review of consumer behavior theory, international online commerce theory and other literature, the research framework is designed, the research hypothesis is proposed, the variable definition is found and the variable measurement is carried out. Drawing on the design ideas of mature questionnaires in the past, the research framework was designed based on the reference questionnaires used by previous scholars, and the research framework was designed according to the literature review. Formal questionnaires were designed according to the variables and scales of the theoretical model. The research questionnaire is discussed from the following aspects: the questionnaire consists of the following three parts: first, the questionnaire subjects are filtered, that is, adult consumers who meet the requirements of "international online commerce shopping experience" are allowed to fill in the questionnaire; Secondly, the descriptive questions in the three questionnaires of the three models all have 7 common items, namely, the gender, age, education level, occupation, monthly income, international online commerce shopping time, and average monthly expenditure of the respondents. Thirdly, the descriptive questions of variables in the model questionnaire; This questionnaire is mainly based on a seven-point Likert scale to measure the scores of each construct, and expresses the respondents' agreement in terms of strongly disagree, disagree, somewhat disagree, generally agree, somewhat agree, agree, and strongly agree. A total of 500 questionnaires were distributed and 480 questionnaires were recovered, of which 470 were valid, with a total effective recovery rate of 98%.

Questionnaire Questions

Taking international online commerce service quality, consumer perceived value, and consumer switching cost as independent variables and consumer loyalty as dependent variables, the survey was carried out in the form of a structured questionnaire, including the following contents:

1. Demographic characteristic variables. Demographic variables mainly include: gender, age, education level, occupation, monthly income, international online commerce shopping time, average monthly expenditure, etc.

2. International online commerce service quality. In the part of the international online commerce

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service quality measurement scale, drawing on the SERVQUAL scale, according to the references, the scale items are revised for the research purpose of the paper, and the service quality is divided into five dimensions, namely reliability (1-5 questions), responsiveness (6-9 questions), guarantee (10-13 questions), care (14-18 questions), and tangibility (19-22 questions), and the quantitative evaluation of service quality is implemented. According to the relevant description of each question and their own situation, the test participants subjectively scored and judged the questions one by one, and the scores were set in 7 levels, from 1 to 7, and the degree of agreement gradually increased.

3. Consumer Switching Costs

1) Definition of operational:

Switching costs are the costs that consumers must pay when they change the products they buy from a business, as well as the various losses, tangible or intangible, that consumers lose when they switch to alternative merchants.

2) Measurement method:

Drawing on the references, this paper researches and designs an international online commerce consumer switching cost measurement scale, and puts forward a total of five measurement items.

Perceived value

1) Definition of operational type. Perceived value refers to the overall utility measurement and evaluation made by consumers in the process of purchasing products or services, comparing "what they get" and "what they pay", that is, consumers' perceived evaluation of products or services, that is, the result of the exchange between perceived benefits and perceived costs (Zeithaml, 1988) This paper examines the gap between perceived costs (both monetary and non-monetary) paid by consumers and the perceived benefits obtained.

2) Measurement method. According to the questions used by Yang and Peterson (2004) as the basis for measurement, and then modifying, deleting, and revising the questionnaire according to the characteristics of international online commerce, a total of four questions were proposed.

5. Consumer loyalty

1) Definition of operational: Consumer loyalty refers to the willingness of consumers to continue shopping at a international online commerce company and to recommend them to their relatives and friends.

2) Measurement method: Referring to the research literature on consumer loyalty, the loyalty facet question scale was designed.

Model assumptions

1) The relationship between service quality and consumer switching costs Only by clarifying that service quality is the influencing factor of customer switching costs, can we better formulate an effective strategy to manage customer switching costs. Based on the 1995 research, analyzed the customer conversion behavior of online service enterprises and discussed the factors affecting the conversion behavior of online customers, which is of great reference value for the study of international online commerce consumer switching costs. Patterson

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and Smith added a cultural element to the study of customer switching behavior, revealing the differences in customer switching costs in different countries. Therefore, the following hypotheses are proposed:

Hypothesis H1: The quality of international online commerce services has a positive impact on consumers switching costs.

2) The relationship between service quality and consumers' perceived value

From the perspective of marketing, a company's high-level service, and high-efficiency and high-quality production can enhance consumers' perceived value. Consumers demand high-quality goods for a more convenient and high-quality life. Doney and Cannon (1997) trust refers to the characteristics of brand trust possessed by consumers, such as consistency of brand quality and service, authenticity, reliability, honesty, and responsibility. Fang et al. (2008) argue that the research on corporate strategy focuses on the influence of consumers on the development of enterprises, which is manifested in perceived value, corporate innovation, and corporate performance improvement.

American scientist Parasuraman studied the quality of e-commerce service The initial view was that the quality of service depends on the degree to which the e-commerce website can meet the needs of consumers for efficient browsing, shopping, and delivery, and after the pre-purchase is turned to the purchase, he believes that the quality of service depends on the convenience of the website's purchase and delivery, the speed and efficiency of transactions.

Quality of service and perceived value are high-dimensional attribute variables. Zeithaml (1998) pointed out that in the research model of perceived value and purchase intention, service quality will positively affect perceived value. That is, in the research on the relationship between service quality, customer satisfaction, perceived value and customer loyalty, it is confirmed that service quality has a significant positive impact on customer perceived value.

Therefore, the following hypotheses are proposed:

Hypothesis H2: International online commerce service quality has a positive impact on consumers' perceived value.

The relationship between consumer switching cost and consumer loyalty

Fornell (1992) was the first to introduce the concept of switching cost into the interpretation of consumer loyalty in the field of marketing and introduced switching cost into the conversion relationship between consumer satisfaction and consumer loyalty. Kotler et al. (2022) point out that there are two basic ways to retain loyal consumers, namely improving consumer satisfaction and increasing consumer switching costs.

The available research literature suggests that higher switching costs lead to higher consumer loyalty. When consumer satisfaction rises to a certain level, it has the effect of weakening consumer loyalty, and in this case, the impact of switching costs on consumer loyalty will play a leading role.

From a practical point of view, the implementation of customer switching cost management strategies to cultivate customer loyalty can provide a good way for enterprises to develop and implement customer loyalty programs. Therefore, the following hypotheses are proposed:

Hypothesis H3: International online commerce consumer switching cost has a positive impact on consumer loyalty.

The relationship between consumer perceived value and consumer loyalty

The theory of perceived value of customers, proposed by Zaithaml (1988) takes consumers' perceived value as the key element, and defines perceived value as the consumer's feeling of measuring gains and losses in the process of purchasing goods, that is, the overall evaluation of gains and costs. Zaithaml advocates a comprehensive innovation in the overall quality of goods and services, which is particularly important to improve competitiveness and maintain existing customers. Sustainable visual merchandising will also largely influence the variation of retailers' store loyalty (Kseniya et al., 2022). Sophisticated and efficient online platform shopping apps are particularly important ways to increase customer satisfaction and loyalty (Kathrin et al., 2022)

It can be seen that perceived value dynamically influences consumers' choice of products and services. Utilitarian consumers, on the other hand, are more focused on perceived value. Consumers with a higher level of perceived value can perceive higher utilitarian value because they have more information about the service costs and benefits of international online commerce enterprises, such as product price, service quality, and shopping time. Make more efficient decisions. Therefore, the following hypotheses are proposed:

Hypothesis H4: International online commerce consumer perceived value has a positive impact on consumer loyalty.

The relationship between service quality and consumer loyalty

Regarding the relationship between service quality and consumer loyalty, most scholars believe that service quality has a direct impact on customer loyalty. Boulding (2023) showed that repeat demand and willingness to recommend are positively affected by the quality of service. Zeithaml (1988) found that service quality has a positive impact on consumer loyalty. Parasuraman et al. (1994) found that the association between service quality and consumer perceived preferences varies across industries. Allred and Lon Addams (2000) point out that service quality is an important variable that affects the perceived value of customers, and it is also a necessary condition for customer loyalty.

Therefore, the following hypotheses are proposed:

Hypothesis H5: International online commerce service quality has a positive impact on consumer loyalty.

Service quality affects consumer loyalty through consumer switching costs

According to Bolton (2000) , loyalty depends on the quality of services that customers provide to those that serve their own businesses compared to those that serve them. Dick and Basu (1994) define switching cost as the time, money, and mental cost of switching customers to a service provider, so that they become dependent on the service provider. The reasons for customer dependence in the above two studies are, on the one hand, the cost of switching service providers; On the other hand, there is the quality service of the service provider.

Bitner (1990) shows that loyal consumers usually use service quality and interaction effect as the judging criteria, and recommend or praise companies with good service quality to others that when customers feel

that the quality of service is poor and the switching costs are low, they will switch to other companies to find another service.

Therefore, the following hypotheses are proposed:

Hypothesis H6: International online commerce service quality positively affects consumer loyalty through consumer switching cost (consumer switching cost plays a mediating role in the relationship between service quality and consumer loyalty).

Service quality affects consumer loyalty through consumers' perceived value

The review of consumer behavior theory and framework, this paper analyzes the influencing factors of consumers' behavior and attitude from multiple dimensions by taking cognitive attitudes and emotions as mediators, and then uses consumption intention as the measurement outcome variable, so as to make a good research on the impact of online marketing on consumption intention.

A good brand image can reduce the purchase risk of consumers, help enterprises obtain a good image, love and trust the company's products and services, enhance product quality and service perception, and make customers have a positive association with service quality, thereby stimulating customer purchase behavior and enhancing customer loyalty (Park et al., 1986). Romaniuk and Sharp (2003) believe that customers have a positive image perception of product and service quality, which can increase the perceived value of corporate image, and then affect customers' purchase intention and loyalty.

Therefore, the following hypotheses are proposed:

Hypothesis H7: International online commerce service quality positively affects consumer loyalty through consumer perceived value (consumer perceived value plays a mediating role in the relationship between service quality and consumer loyalty).

Research Results

Statistical analysis of data

The results showed that the responsiveness and care of service quality had the most significant impact on consumer loyalty, and the tangible impact of service quality was moderate, while the assurance and reliability of service quality had no significant impact on consumer loyalty. Therefore, the responsiveness, care and tangibility of international online commerce service quality, international online commerce service quality, consumer perceived value and consumer switching cost can have a significant positive impact on consumer loyalty. However, the reliability and guarantee of service quality did not have a significant impact on consumer loyalty.

Focusing on the influence and relationship between model variables can help solve the problem of international online commerce service quality. SPSS27.0 was used to statistically analyze the basic information of the collected questionnaire samples.

Basic population data

From June to August 2023, a total of 44 formal questionnaires will be issued, and 500 valid questionnaires will be distributed to adult consumers with international online commerce shopping experience in Chinese mainland through the Internet, and 470 valid questionnaires will be collected and deleted.

The results of the basic information frequency survey show that the proportion of male and female samples to the total number of adult consumers with international online commerce shopping experience is 45.74% and 54.26%, respectively, which is relatively close to that of men and women, which is within a reasonable range. The subjects of the survey are distributed in multiple age groups, which can clearly express the evaluation and expectations of consumers of different ages on international online commerce service quality, consumer switching cost, consumer perceived value and consumer loyalty.

Table1 Variable reliability analysis results

Variable	Cronbach's alpha	Variable questions
reliability	.871	5
Reactivity	.950	4
Guarantees	.892	4
Caring	.963	5
Materiality	.940	4
Perceived value	.954	4
Conversion costs	.912	5
Service loyalty	.971	6

The data analysis in Table 1 confirmed that the clonch reliability coefficients of the variables were all 0.87 or above, indicating that the internal consistency of the questionnaire was high and it was completely acceptable. The data suggest that the reliability is of high quality.

Table 2 Results of validity analysis

variable	Factor load factor				Commonality (common factor variance)
	factor1	factor2	factor3	factor4	
Characteristic root value (before rotation)	4.741	1.896	1.885	1.758	-
Variance explanation rate % (before rotation)	32.04 9%	13.157 %	12.42 0%	15.79 %	-

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Table 2 (Cont.)

variable	Factor load factor				Commonality (common factor variance)
	factor1	factor2	factor3	factor4	
Cumulative variance explanation rate % (before rotation)	31.602%	45.437%	54.769%	78.547%	-
Characteristic root value (after rotation)	2.378	2.374	2.379	2.364	-
Variance explanation rate % (after rotation)	15.986%	15.941%	15.853%	15.942%	-
Cumulative variance explanation rate % (after rotation)	15.761%	34.763%	42.9642%	79.359%	-
KMO value	0.854				
Bart's spherical value	3897.039				
df	107				
p value	0.000				

From Table 2, it can be seen that the KMO and Bartlett spherical test values, in which the KMO value is 0.854, which is greater than 0.7, and the significance of the Bartlett spherical test is 0.000, less than 0.05, indicating that it is suitable for factor analysis. The construct validity of the questionnaire was good. The 37 questions in the scale were divided into 4 common factors, and the variance contribution rate of the 4 common factors accounted for 79.359%, indicating that the 4 common factors could explain 79.359% of the information of the original variable. The factor load coefficient showed that the factor division with the larger load was consistent with the dimension division preset by the questionnaire. The validity of the questionnaire was good.

Table 3 Discriminative validity: Pearson correlation vs. square root of Average Variance Extracted (AVE)

Variable	Quality of service	Consumers perceive value	Consumer switching costs	Consumer loyalty
International online commerce service quality	0.814			
Consumers perceive value	0.392	0.857		
Consumer switching costs	0.385	0.379	0.837	
Consumer loyalty	0.361	0.368	0.369	0.878

Note: The diagonal number is square root of the AVE

Table 3 analyzes the discrimination validity, and for the quality of international online commerce services, square root of AVE is 0.814, which is greater than the maximum value of the absolute value of the correlation coefficient between factors of 0.392, which means that it has good discrimination validity. For consumers' perceived value, square root of AVE is 0.857, which is greater than the maximum value of the absolute value of the correlation coefficient between factors of 0.392, which means that it has good discriminative validity. For the consumer switching cost, square root of AVE is 0.837, which is greater than the maximum value of the absolute value of the correlation coefficient between factors of 0.385, which means that it has good discriminative validity. For consumer loyalty, square root of the is 0.878, which is greater than the maximum value of the absolute value of the correlation coefficient between factors of 0.369, which means that it has good discriminative validity.

Table 4 Correlation analysis results

	Quality of service	Consumers perceive value	Consumer switching costs	Consumer loyalty
International online commerce service quality	1			
Consumers perceive value	.392**	1		
Consumer switching costs	.285**	.279**	1	
Consumer loyalty	.251**	.256**	.259**	1

**Correlation is significant at a confidence level (double test) of 0.01

The data in Table 4 show that there is a significant positive correlation between service quality, consumer perceived value, consumer switching cost, and consumer loyalty at a significance level of 0.01.

Table 5 Analysis of variance

Model		Sumof Squares	df	Mean Square	F	Sig
1	Regression	223.491	5	44.304	471.392	.000
	Residual	37.798	387	.085		
	Total	261.012	398			

From the F-test results of the model in Table 5 above, it is known that the model passed the F-test (F=471.392, p=0.000<0.05), indicating that the constructed model has existential significance.

Table 6 Regression coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Constant	.091	.092		1.047	.287
	Materiality	.179	.035	.189**	5.851	.001
	reliability	.085	.047	.090	1.682	.093
	Guarantees	.094	.059	.088	1.629	.105
	Caring	.312	.043	.321***	7.224	.000
	Reactivity	.313	.059	.294***	4.968	.000
	International online commerce service quality	.311	.054	.290***	4.769	.000
	Consumers perceive value	.314	.058	.291***	4.993	.000
	Conversion costs	.310	.057	.293***	4.894	.000

Note: *P<0.05, **P<0.01, ***P<0.001

From the above data analysis, it can be seen that the tangibility, caring, and responsiveness of service quality, have a significant positive impact on consumer loyalty. However, the two dimensions of reliability and guarantee have no significant impact on consumer loyalty. Service quality, consumer perceived value and consumer switching cost have a significant positive impact on consumer loyalty.

Mediation effect test analysis

The research model takes the cross-border e-commerce service quality as the independent variable, cross-border e-commerce consumer loyalty as the dependent variable, and cross-border e-commerce consumer conversion cost and perceived value of cross-border e-commerce consumer as the intermediary variables. In this

paper, Hayes (2013) was used to test the mediation effect. The Bootstrap number was set to 5000 and the confidence interval was 95%. If the indirect effect is not included in the confidence interval of 95%, the mediation effect exists. The results of each path coefficient of the model are as follows:

Table7 Results of the mediating effect test of switching costs

Path	Original sample (O)	standard deviation (STDEV)	T-statistic (|O/STDEV|)	95% confidence interval Lower Limit	Upper limit
Direct effects					
Cross-border e-commerce service quality->Consumer loyalty	0.123	0.095	2.201	0.016	0.266
Cross-border e-commerce service quality->Consumer switching costs	0.225	0.063	4.418	0.121	0.383
Consumer switching costs->Consumer loyalty	0.143	0.054	4.790	0.195	0.371
Indirect effects					
Cross-border e-commerce service quality->Consumer switching costs->Consumer loyalty	0.051	0.021	3.901	0.074	0.082
Total effect					
Cross-border e-commerce service quality->Consumer loyalty	0.046	0.018	3.210	0.027	0.094

The mediating effect of switching cost on the impact of service quality on consumer loyalty was analyzed (see Table 7). The mediating effect test showed that the lower bound of the 95% confidence interval of service quality-> switching cost-> consumer loyalty was 0.074 and the upper limit was 0.082. None of them contain 0, indicating that switching cost is used as an intermediary variable to affect the relationship between service quality and consumer loyalty, and the analysis results show that the mediating effect of switching cost is partially mediated.

Table8 Results of the mediating effect of perceived value

path	Original sample (O)	standard deviation (STDEV)	T-statistic (|O/STDEV|)	95% confidence interval	
				Lower Limit	Upper limit
Direct effects					
Cross-border e-commerce service quality->Consumer loyalty	0.183	0.036	2.172	0.139	0.275
Cross-border e-commerce service quality->Consumers perceive value	0.289	0.053	4.381	0.134	0.183
Consumers perceive value->Consumer loyalty	0.274	0.048	4.916	0.148	0.237
Indirect effects					
Cross-border e-commerce service quality->Consumers perceive value->Consumer loyalty	0.072	0.016	3.120	0.023	0.086
Total effect					
Cross-border e-commerce service quality->Consumer loyalty	0.045	0.028	3.142	0.027	0.094

The mediating effect of perceived value on the influence of service quality on consumer loyalty was analyzed. The results of the mediating effect test show that the lower bound of the 95% confidence interval of service quality-> perceived value-> consumer loyalty is 0.023 and the upper limit is 0.086. None of them contain 0, indicating that consumer perceived value is used as an intermediary variable to affect the relationship between service quality and consumer loyalty, and this mediating effect is partially mediated.

According to the above analysis results, the independent variables have a significant impact on the dependent variable and the mediating variable, and the mediating variable has a significant impact on the dependent variable.

The direct and indirect effects of H6 and H7 were significant ($p<0.01$) and the confidence interval did not contain 0, so the mediating effect existed, and H6 and H7 were established.

Hypothesis H6: International online commerce service quality is verified by the positive impact of

consumer switching cost on consumer loyalty (consumer switching cost has a mediating role in the relationship between service quality and consumer loyalty).

Hypothesis H7: International online commerce service quality is verified by the positive impact of consumer perceived value on consumer loyalty (consumer perceived value has a mediating role in the relationship between service quality and consumer loyalty).

The mediating role of perceived value has been divided into three dimensions: perceived usefulness, perceived enjoyment, and perceived value, and the impact on customer intention has been studied. Other literature explores the mediating role of consumers' perceived value on brand relationship performance (Zhao et al., 2022). This paper focuses on the mediating relationship between switching cost and perceived value between service quality and loyalty, and improves the research on the influence relationship between switching cost and perceived value as mediating variables.

Conclusions and Recommendations

combined with the results of questionnaire survey and analysis, suggestions for reference are put forward. Firstly, it is observed that the quality of international online commerce services has a positive impact on consumers' switching costs and consumers' perceived value, indicating that hypothesis H1 and hypothesis H2 are valid. Secondly, it is found that international online commerce service quality, international online commerce consumer switching cost, and international online commerce consumer perceived value have a positive impact on consumer loyalty, which proves that hypothesis H3, hypothesis H4, and hypothesis H5 are valid. Thirdly, there is a partial intermediary relationship between consumer switching cost and consumer perceived value between international online commerce service quality and consumer loyalty, which proves that hypothesis H6 and hypothesis H7 are valid, which further supports the research hypothesis of this paper. These new findings provide an important supplement to the understanding of international online commerce service quality research, and are of great significance for further exploration in this field.

The results of this paper are consistent with some views in the existing literature, especially on the positive impact of e-commerce service quality on consumer loyalty. However, there is also a trend different from previous studies, and the impact of international online commerce service quality reliability and assurance on consumer loyalty is not significant, which may be due to the fact that with the digital development of international online commerce, the reliability and guarantee of international online commerce service quality have been enhanced, and have been fully recognized by consumers, so the impact is not significant. This highlights the uniqueness of the study and the refinement and richness of the knowledge of the field.

Although the study has made some important findings, it is limited by certain reasons. Among them, there are some limitations in the interpretation of causality in the paper due to the single source of data. Due to the large number of parents, the large demand for samples, and the limitations of time and space, the sources of paper data may lack extensiveness. It is suggested that future research should try to overcome these limitations

and explore other aspects of international online commerce service quality research, such as obtaining continuous consumption data of multi-platform customer groups with the help of digital technology, and empirical research on the customer value of multi-platform channels.

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Example: Maslow (1970) asserts that……;…… (Maslow, 1970)

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5. The text must be double-spaced; (a 14-point font Browallia New; italics rather than underlining except for URL addresses); and all illustrations, figures, and tables must be placed within the text at the appropriate points, rather than at the end.

6. The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines.
7. Attached to all submitted articles must be a **150-250 words abstract**, **Keywords** (3-5) and a statement containing the author's present academic or nonacademic position and an address where he or she may be contacted by the editors or interested readers. Authors should place their names on the cover page, but the name should not appear on headers or elsewhere in the body of the article. Full contact details for the corresponding author, including email, mailing address and telephone numbers should also be provided. As the Journal of Supply Chain and Sustainability Research (SCSR) is a peer reviewed journal, the author must be follow the instructions about Ensuring a Blind Review.
8. Make sure that there are no grammatical, spellings, or content errors in articles prior to submitting to the Journal of Supply Chain and Sustainability Research (SCSR).
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