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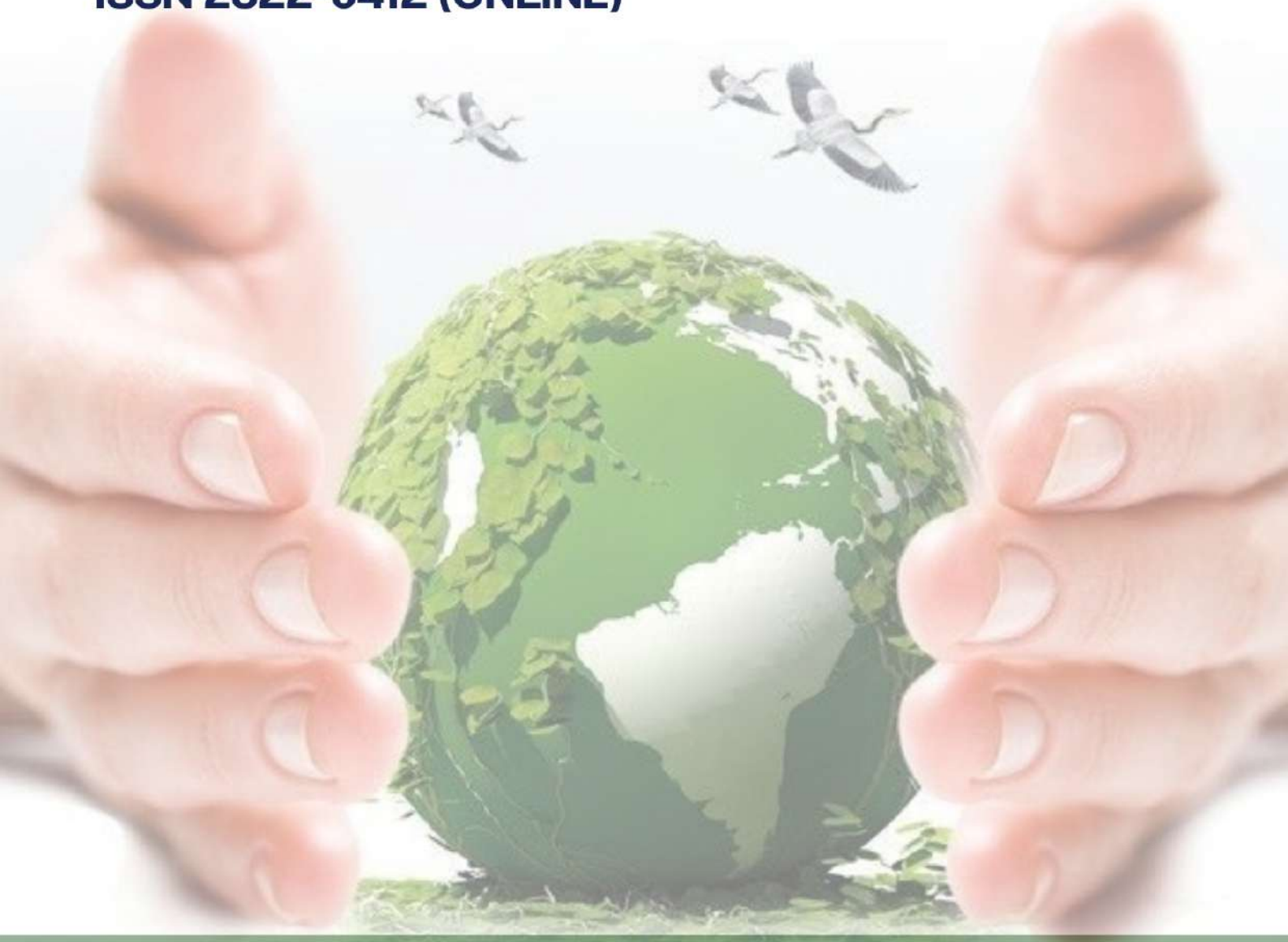

SCSR SUPPLY CHAIN AND SUSTAINABILITY RESEARCH

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SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR

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

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

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

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

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

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

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

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

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

In this issue, 6 research papers are presented.

1) An Impact of Marketing Strategies on University Students' Online Shopping Behavior: A Case Study of Asia Eastern University of Science and Technology, Taiwan

2) Research on Marketing Strategies of Decoration Design Company's Supply Chain

3) Application of MATLAB-assisted Ridge Regression in Weight Reduction and Environmental Protection of Glass Bead Concrete

4) Global Green Logistics: Challenges and Opportunities in Vietnam's Sustainable Development

5) Envisioning the Future of Supply Chain Transportation Management- Exploring Crowd Density Image Recognition with Deep Learning

6) A Review of Research on System Dynamicsin Supply Chain Management

In addition, we would like to inform you about our next issues (Volume 3 No.4,…) in 2024. Recent announcement of the call for papers is accessible on the SCSR website. This issue marks the debut of the SCSR and its birth. It is my pleasure to address you on this occasion. I would like to express a warm welcome to the SCSR readership on behalf of the SCSR Editorial Team. I would like to thank our authors, editors, and anonymous reviewers, who have all voluntarily contributed to the journal's success. Without your participation, this initial issue would not exist.

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We look forward to receiving your contributions.

Jirasek Trimetsoothorn

Editor-in-Chief

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An Impact of Marketing Strategies on University Students' Online Shopping Behavior: A Case Study of Asia Eastern University of Science and Technology, Taiwan

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Abstract

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This research examines the influence of four marketing strategies - product, price, place, and promotion - on the online shopping behavior of university students. The target population consists of undergraduate and graduate students from Asia Eastern University of Science and Technology (AEUST), Taiwan, with a total enrollment of 3,856 students. A total of 374 valid questionnaires were collected. Data were analyzed using descriptive statistics, Pearson's correlation analysis, and multiple regression analysis to assess the impact of each strategy on students' purchasing decisions.

The results show that product strategy has the greatest influence on purchase decisions, with factors such as product details, images, and brand diversity being key drivers (Beta = 0.335, $p < 0.001$). Place strategies, such as free shipping and flexible delivery options, are also significantly impactful (Beta = 0.298, $p < 0.001$). In contrast, price (Beta = 0.158, $p < 0.001$) and promotion strategies (Beta = 0.262, $p < 0.001$) have a comparatively weaker effect on students' decisions. This study highlights the importance of understanding the preferences and behaviors of university students in the online shopping environment, suggesting that e-commerce platforms can improve consumer engagement by focusing on product quality and delivery options. Tailored marketing strategies, especially those that emphasize product variety and delivery convenience, can enhance customer satisfaction and loyalty among this demographic.

Keywords: Marketing Strategies, Online Shopping Behavior, University Students

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Introduction

Online shopping has become a dominant form of commerce, especially among university students who frequently use platforms such as Shopee, PChome, and Momo in Taiwan. These platforms attract young consumers with diverse product offerings, competitive pricing, and convenient shopping experiences. However, businesses aiming to expand their reach in this demographic require a deeper understanding of the factors influencing platform choices and the impact of marketing strategies on university students' shopping behaviors. This study addresses a gap in existing research by focusing specifically on university students at Asia Eastern University of Science and Technology (AEUST), where insights can provide valuable guidance for online retailers. Previous studies (Kotler & Keller, 2016; Armstrong et al., 2019) emphasize the importance of product quality, pricing strategies, and promotional activities in shaping consumer behavior. However, limited research explores how these factors interact uniquely within the university student population.

AEUST, founded in 1968 in Banqiao District, New Taipei City, Taiwan, is known for its educational philosophy of "Creativity, Pragmatism, Macroview, Cooperation, Communication, and Enthusiasm" and emphasizes strong industry partnerships that offer students hands-on learning opportunities (Asia Eastern University of Science and Technology, 2023). This unique academic environment makes AEUST an ideal context for exploring online shopping behaviors, as it combines technological and practical learning settings with a student-centered approach.

This study employs descriptive statistics to examine the importance of marketing strategies—such as product, price, place, and promotion—and their relevance to AEUST students' online shopping preferences. Pearson's correlation coefficient is used to explore the relationship between marketing strategies and university students' online shopping behavior. Finally, multiple regression analysis is conducted to identify which factors have the most significant impact, providing insights for businesses to develop tailored strategies for university students.

Research Objectives

The purposes of this study are:

1. To analyze how product, price, place, and promotion strategies influence online shopping behavior among AEUST students.

2. To identify which marketing strategy has the most significant impact on purchasing decisions.

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Research Questions

1. What is the online shopping behaviors of the university students in of Asia Eastern University of Science and Technology (AEUST) in Taiwan?

2. What are the impacts of marketing strategies influencing the university students' online shopping behavior? Which marketing component (s) is the most inflenetial one?

Literature Review and

Marketing Strategy

Marketing strategy plays a vital role in the modern competitive marketplace. The 4P marketing model proposed by Kotler and Armstrong (2018), which includes Product, Price, Place, and Promotion, provides a basic framework for organizations to develop a marketing strategy. Product strategy focuses on product design, quality, functionality, and brand image, which are effective in attracting consumers and enhancing brand competitiveness (Baker & Sinkula, 2005). Price strategy, on the other hand, should consider consumers' perceived value of the product, and enhance consumers' purchase intention through special offers and discounts (Nagle & Müller, 2017). Place strategy, especially critical for online shopping, includes efficient delivery and user-friendly platforms, which significantly impact consumer satisfaction and repurchase rates (Levy & Weitz, 2012; Solomon et al., 2019). In addition, promotion strategies, particularly those involving social media, can greatly increase brand awareness and promote consumer engagement (Chu & Kim, 2011).

Consumer Purchase Decision Process

Consumers' purchase decision process includes need identification, information search, alternative evaluation, purchase decision, and post-purchase behavior (Kotler & Keller, 2016). During this process, marketing strategies, especially product and price strategies, have a significant impact on consumer choices. Comparison of alternatives, on the other hand, relies on product information, price, and usage evaluation (Blackwell et al., 2006). In addition, consumers' emotional responses also play an important role in purchase decisions, especially in terms of brand loyalty and purchase intention (Bagozzi, 1981).

Shopping Problem Identification

The initial stage in the consumer purchase decision process is shopping problem identification, where consumers recognize a need or problem that requires a solution. According to Solomon et al. (2019), this recognition is often prompted by internal triggers, such as personal desires or necessities, or external influences, such as marketing messages and social interactions. For instance, an effective advertising campaign can

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highlight unmet needs and direct consumers' attention toward specific product categories or brands, creating awareness that drives the subsequent decision-making process.

Recognizing Alternatives

After identifying a need, consumers proceed to recognizing alternatives , during which they begin to consider various options that could satisfy their need. This stage involves recalling familiar brands or exploring new options, which can be influenced by factors such as past experiences and brand loyalty (Engel et al., 1995). As noted by Alba and Hutchinson (1987), the breadth of alternatives recognized is often shaped by the consumer's level of product knowledge, with more experienced consumers typically considering a wider range of options.

Comparing Options

Once consumers have identified a set of alternatives, they move to the stage of comparing options, where they evaluate each choice based on factors like price, quality, and expected functionality (Blackwell et al., 2006). This comparative assessment often relies on a mix of product information, user reviews, and expert opinions to inform their decision (Punj & Staelin, 1983). Additionally, emotional factors, such as brand loyalty and previous satisfaction, play a vital role in shaping preferences and purchase intentions during this evaluation process (Bagozzi, 1981). Marketing strategies that emphasize product differentiation and competitive pricing can significantly influence consumer comparisons and sway their final choice.

Purchase Decision

In the Purchase Decision stage, consumers commit to acquiring a product or service based on their evaluation of options during prior stages. According to research, this stage is influenced by factors such as the ease of transaction, the suitability of the chosen product, and the overall shopping experience. Environmental and situational variables, such as convenience, pricing, and marketing channel preferences, play a significant role in shaping the purchase decision (Milner & Rosenstreich, 2013). Additionally, the integration of omnichannel strategies can enhance the purchase decision process by offering a seamless experience across multiple touchpoints (Pires et al., 2022).

Consumer Post-Purchase Behavior

Consumers' post-purchase behaviors include product use, satisfaction evaluation, repurchase intention, and word-of-mouth communication (Kotler & Keller, 2016). When a product or service meets or exceeds consumer expectations, consumers are more likely to repurchase and recommend the brand to others (Anderson & Srinivasan, 2003). Positive post-purchase experiences help to develop brand loyalty, while negative experiences may lead to consumer dissatisfaction and negative evaluations, which may affect the purchase intentions of other potential customers (Oliver, 2014).

Consumer Online Shopping Behavior

Online shopping behavior refers to the process of searching, comparing, selecting and purchasing goods or services on an online platform (Dholakia & Uusitalo, 2002). Factors affecting online shopping behavior include technical factors, emotional factors, social factors, economic factors, and cultural and personal differences. Technical factors such as platform ease of use, interface design, and payment security have a direct impact on consumers' purchasing experience (Gefen & Straub, 2004), while social factors such as online reviews and social media opinions have a significant impact on consumers' purchasing decisions (Cheung & Thadani, 2012).

Consumer Culture and Online Shopping Platforms in Taiwan

According to Hsu (2019), Taiwanese consumers emphasize on price-performance ratio and brand awareness, and prefer high quality and reputable products. Taiwanese consumers are price-sensitive and often participate in promotions to maximize value (Lin, 2021).Chang (2022) points out that brand loyalty has a significant impact on Taiwanese consumers' purchasing decisions, and consumers tend to choose products with good brand image and guaranteed product quality. In addition, with the popularity of smartphones and mobile Internet, more and more Taiwanese consumers are shopping through mobile apps (Wang, 2022; Huang, 2020).

With the popularity of online shopping, Taiwan's major online shopping platforms such as Shopee, PChome, and Momo have achieved significant success among young consumers; Shopee has attracted a large number of users through flexible promotion strategies and a strong logistics system, and has actively utilized social media for promotion, successfully establishing a young brand image (Lin, 2022). PChome relies on its diverse product choices and fast delivery service, especially 24-hour delivery service, to satisfy consumers' demand for instant shopping (Chang, 2022), while Momo focuses on user experience and product quality, and helps consumers make more informed purchasing decisions through detailed product information and user evaluations (Huang, 2022).

Based on the above literature review and the research objectives of this study, the research framework of this study is as follows:

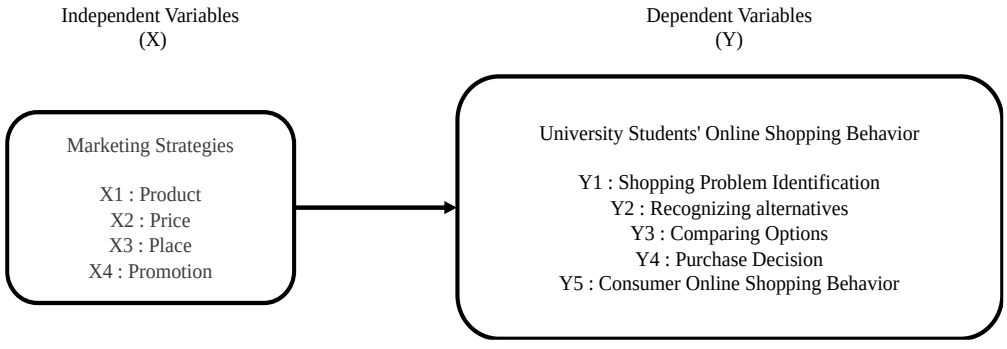

Figure 1 Conceptual Framework

Research Method

This study adopted a quantitative research methodology, aiming to investigate the effects of the four major marketing strategies (Product, Price, Place, and Promotion) on the online shopping behavior of students at Asia Eastern University of Science and Technology (AEUST). The target population consists of the undergraduate and graduate students at AEUST, totaling 3,856 students according to statistics from the Ministry of Education of Taiwan (Ministry of Education Higher Education Institutions Information Disclosure Platform, 2024). Using Yamane's formula to determine the sample size, a minimum of 364 valid questionnaires was required. Ultimately, 374 valid questionnaires were collected, exceeding the minimum sample size needed for reliable analysis.

The data collection was conducted through an online questionnaire, which consisted of two main sections: marketing strategies and online shopping behavior among university students. Each item was measured using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree." The questionnaire was preliminarily tested to ensure clarity before final distribution.

The data analysis begins with descriptive statistics, including mean and standard deviation, to measure the perceived importance of each marketing strategy and the level of agreement regarding online shopping behavior among university students. Next, Pearson's correlation analysis is used to examine the relationship between marketing strategies and students' online shopping behavior, aiming to verify whether these marketing strategies have a positive correlation and influence on students' online shopping behavior.

Finally, multiple regression analysis is conducted to identify which marketing strategy has the most significant impact on students' online shopping behavior. Based on previous research findings and the shopping preferences of Taiwanese students, we hypothesize that the product strategy will have the strongest influence. This step helps to gain a deeper understanding of the individual impact of each marketing strategy on students' online shopping behavior.

Results and Discussion

The purpose of this study is to examine whether marketing strategies have an impact on the online shopping behavior of university students and which marketing strategy has the greatest impact. The final valid questionnaire count collected was 374. The results of the study are summarized below:

Table 1 : Mean and Standard Deviation of Marketing Strategies

Marketing Strategy	n = 374		Level of importance of the strategy
	$\bar{x}$	s.d.	
Product	4.51	0.54	Very important
Price	3.94	0.71	Important
Distribution	4.25	0.68	Very important
Promotion	3.99	0.79	Important
Total Average	**4.17**	**0.55**	**Important**

According to the data results, among the four marketing strategies, product strategy has the greatest influence on purchase decision.

Table 2 Mean and Standard Deviation of Product Factors

Product	n = 374		Level of importance of the strategy
	$\bar{x}$	s.d.	
1. I consider the quality of the product to be very important to me when I shop online.	4.50	0.72	Very important
2. An online shopping platform that offers a wide variety of brands to choose from is more in line with my needs.	4.45	0.75	Very important
3. The detailed description and pictures of the product will influence my choice when shopping online.	4.63	0.64	Very important
4. The variety of brands offered on the e-shopping platform is one of the reasons why I would choose it.	4.39	0.78	Very important
5. I prefer to choose reputable product brands when shopping online.	4.56	0.66	Very important
Total	**4.51**	**0.54**	**Very important**

Among the product strategies, the presentation of product details and pictures ($\bar{x}$ = 4.63, s.d.= 0.64) and brand diversity ($\bar{x}$ = 4.56, s.d.=0.66) were the most influential. These factors indicate that university students emphasize product quality, brand reputation and diversity of choices when choosing shopping platforms, which significantly influences their purchase decisions.

Table 3 Mean and Standard Deviation of Place Factors

Distribution	n = 374		Level of importance of the strategy
	$\bar{x}$	s.d.	
1. I prefer to shop online with a platform that delivers quickly.	4.14	0.95	Important
2. The variety of delivery options offered by a platform will influence my shopping decision.	4.10	1.00	Important
3. I am more likely to shop on an online shopping platform if it offers free shipping.	4.61	0.71	Very important
4. The cross-border shopping option of the online shopping platform will attract me to use it.	4.00	1.07	Important
5. I think an online shopping platform with multiple payment options is more suitable for my needs.	4.33	0.88	Very important
6. I would choose an online shopping platform that offers fast returns and exchanges.	4.33	0.86	Very important
Total	**4.25**	**0.68**	**Very important**

Place strategy is the second most influential factor, especially free delivery service ($\bar{x}$ = 4.61, s.d.= 0761) and variety of payment methods, which suggests that university students have a higher demand for logistics services and shopping convenience.

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Table 4 Mean and Standard Deviation of Promotion Factors

Promotion	n = 374		Level of importance of the strategy
	$\bar{x}$	s.d.	
1. Promotional activities will attract me to click on the online shopping platform to purchase products.	4.20	0.91	Important
2. I am often attracted to daily specials or time-limited promotions offered by online platforms.	3.73	1.18	Important
3. Promotional activities on social media will influence my shopping behavior.	3.84	1.08	Important
4. Push notifications from the online platform keep me informed of real-time promotions and influence my purchasing behavior.	3.72	1.15	Important
5. I will use coupons offered by shopping platforms to reduce my shopping costs.	4.47	0.77	Very important
Total	**3.99**	**0.79**	**Important**

Promotion strategies are less influential but still attractive to university students, especially the use of platform coupons to reduce shopping costs ($\bar{x}$= 4.47, s.d.=0.77). Promotions on social media also have a role to play in increasing purchase intention.

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Table 5 Mean and Standard Deviation of Price Factors

Price	n = 374		Level of importance of the strategy
	$\bar{x}$	s.d.	
1. I will compare prices on different online shopping platforms and choose the best deal.	4.18	0.96	Important
2. Discounts and promotions influence my choice of online shopping platforms.	4.43	0.82	Very important
3. I consider the price of a product to be the deciding factor when shopping online.	4.15	0.92	Important
4. I tend to prefer shopping platforms that offer members-only pricing or discounts.	4.10	0.97	Important
5. I will pay attention to whether online shopping platforms offer discount seasons or special offers on a regular basis.	3.85	1.14	Important
6. I would choose an online shopping platform that offers a price guarantee (e.g. lowest price guarantee).	3.78	1.06	Important
7. I often use price tracking tools to wait for the ideal price to come along.	3.10	1.28	Medium
Total	**3.94**	**0.71**	**Important**

Price strategy has the least impact on university students, showing that they are less sensitive to price and that price is not a major factor in their purchase decision. However, discounts and promotions can still attract some price-sensitive consumers.

Table 6 Mean and Standard Deviation of University Students' Online Shopping Behavior

University Students' Online Shopping Behavior	n = 374		Level of agreement
	$\bar{x}$	s.d.	
Shopping Problem Identification	4.32	0.61	Strongly agree
Recognizing alternatives	4.33	0.58	Strongly agree
Comparing Options	4.32	0.65	Strongly agree
Purchase Decision	4.32	0.61	Strongly agree
Consumer Online Shopping Behavior ckeck word?	4.29	0.66	Strongly agree
Total	**4.32**	**0.53**	**Strongly agree**

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According to the data, students strongly agree on all aspects of online shopping behavior, with the highest levels of agreement in recognizing alternatives ($\bar{X}$= 4.33, s.d.=0.58) the second, Shopping Problem Identification ($\bar{X}$= 4.32, s.d.=0.61), comparing options ($\bar{X}$= 4.32, s.d.=0.65) and Purchase Decision ($\bar{X}$= 4.32, s.d.=0.61). These factors highlight the importance of students' active evaluation of options before making a purchase decision, indicating that their online shopping behavior is highly influenced by the availability of choices and the process of comparison.

Table 7 Mean and Standard Deviation of Shopping Problem Identifiers

Shopping Problem Identification	**n =374**		**Level of agreement**
	$\bar{x}$	s.d.	
1. I search for the relevant information on the Internet first.	4.40	0.78	Strongly agree
2. I am be curious and go online to look for more information about the product.	4.38	0.76	Strongly agree
3. I actively look for product reviews and user feedback on the Internet.	4.16	0.96	Agree
4. I prioritize my search on online platforms that specialize in this type of product.	4.27	0.83	Strongly agree
5. I actively search for more information to see if it is worth buying.	4.25	0.85	Strongly agree
6. When I have questions about a product, I seek out online reviews to help me make a decision.	4.44	0.74	Strongly agree
Total	**4.32**	**0.61**	**Strongly agree**

The data reveals that students place the greatest emphasis on seeking online reviews ($\bar{X}$= 4.44, s.d.=0.74) and researching product details online ($\bar{X}$= 4.40, s.d.=0.78). This indicates that students are proactive in gathering information and tend to prioritize platforms that offer specialized and reliable product information to guide their purchasing decisions.

Table 8 Mean and Standard Deviation of Recognizing Alternatives

Recognizing Alternatives	n = 374		Level of agreement
	$\bar{x}$	s.d.	
1. I usually compare similar products on different online shopping platforms.	3.99	1.04	Agree
2. I check the reviews of other consumers to help me make a decision before making a purchase.	4.49	0.76	Strongly agree
3. I compare product reviews and prices to choose the best purchase option.	4.51	0.71	Strongly agree
4. I consider the warranty and after-sales service of the product before making a purchase.	4.03	0.95	Agree
5. I shop around for the best alternative.	4.38	0.82	Strongly agree
6. I prioritize the platform where I have had a good shopping experience.	4.60	0.64	Strongly agree
Total	**4.33**	**0.58**	**Strongly agree**

The highest levels of agreement are seen in prioritizing platforms with positive past shopping experiences ($\bar{X}$= 4.60, s.d.=0.64) and comparing product reviews and prices ($\bar{X}$= 4.51, s.d.=0.71). These findings suggest that students place significant emphasis on evaluating various options and customer feedback to choose the best purchase option.

Table 9 Mean and Standard Deviation of Comparison Options

Comparing Options	n = 374		Level of agreement
	$\bar{x}$	s.d.	
1. I compare promotions and coupons on different platforms to choose the most cost-effective purchase option.	4.17	0.97	Agree
2. I consider price, quality, speed of delivery and other factors when choosing a platform for my purchase.	4.44	0.76	Strongly agree
3. I compare shipping rates and delivery times between multiple online shopping platforms.	3.94	1.10	Agree
4. I compare multiple products and choose the one that best meets my needs.	4.40	0.77	Strongly agree
5. I choose the one with a clearer product presentation.	4.45	0.76	Strongly agree
6. I decide whether or not to purchase from the platform based on its reviews and reputation.	4.51	0.69	Strongly agree
Total	**4.32**	**0.65**	**Strongly agree**

The results indicate that students highly value comparing different factors before making a purchase decision. The highest levels of agreement were observed in evaluating the platform's reviews and reputation ($\bar{x}$= 4.51, s.d.=0.69) and the clarity of product presentation ($\bar{x}$= 4.45, s.d.=0.76). This implies that students prioritize platforms with strong reputations, clear product displays, and favorable delivery conditions when shopping online.

Table 10 Means and Standard Deviations of Purchasing Decisions

Purchase Decision	N = 374		Level of agreement
	$\bar{x}$	s.d.	
1. I usually make a quick purchase decision to avoid losing out on the offer.	3.91	1.11	Agree
2. I tend to shop on online shopping platforms that are highly rated by consumers.	4.43	0.73	Strongly agree
3. If a product meets my needs and has good reviews, I will buy it immediately.	4.26	0.90	Strongly agree
4. If I need an item urgently, I will choose a platform that guarantees same-day or next-day delivery.	4.39	0.91	Strongly agree
5. I am more likely to shop on an online shopping platform if the checkout process is simple, fast and convenient.	4.43	0.78	Strongly agree
6. I decide whether to buy from the same platform again based on my shopping experience.	4.50	0.72	Strongly agree
Total	**4.32**	**0.61**	**Strongly agree**

Based on the data, students place high importance on factors such as platform reputation, convenience, and delivery speed when making purchase decisions. The most significant influences are the platform's reputation ($\bar{x}$ = 4.50, s.d.=0.72). These results indicate that students are more likely to make purchases on platforms they trust and find easy to use, while also considering fast delivery options when necessary.

Table 11 Means and Standard Deviations of Consumer Online Shopping Behavior Factors

Consumer Online Shopping Behavior	n = 374		Level of agreement
	$\bar{x}$	s.d.	
1. I tend to shop on familiar shopping platforms to ensure a smooth shopping experience.	4.52	0.71	Strongly agree
2. I have a high level of loyalty to the online shopping platforms I use.	4.41	0.79	Strongly agree
3. I would recommend a good shopping platform to a friend or family member.	3.97	1.09	Agree
4. I decide whether or not to use a shopping platform on a long-term basis based on its interface design and ease of use.	4.35	0.80	Strongly agree
5. I increase my loyalty to an online shopping platform when its interface is updated or its functions are improved.	4.20	0.87	Agree
Total	**4.29**	**0.66**	**Strongly agree**

The data shows that students exhibit strong loyalty to familiar and user-friendly online shopping platforms. The highest levels of agreement are seen with statements regarding platform familiarity ($\bar{x}$= 4.52, s.d.=0.71) and loyalty ($\bar{x}$= 4.41, s.d.=0.79), indicating that students tend to stick to platforms they trust and find easy to navigate. Additionally, platform interface design and improvements also play a significant role in fostering long-term loyalty, with a mean of 4.35 for interface design being a key factor in their decision to continue using a platform.

Table 12 Correlation between Marketing Strategies and University Students' Online Shopping Behavior

		Marketing Strategy	University Students' Online Shopping Behavior
Marketing Strategy	Pearson Correlation	--	
University Students' Online Shopping Behavior	Pearson Correlation	.841**	--
	Sig. (2-tailed)	<.001	
	N	374	374

**. Correlation is significant at the 0.01 level (2-tailed).

According to Pearson's correlation analysis, there is a highly positive correlation between marketing strategy and university students' online shopping behavior ($r=0.841$, $p<0.001$), indicating that the stronger the marketing strategy, the more significant the response of university students' online shopping behavior.

Table 13 Variables Entered and Removed in the Regression Model

Model	Variables Entered	Variables Removed	Method
1	Product, Price, Place, Promotion	.	Enter

a. Dependent Variable: University Students' Online Shopping Behavior

b. All requested variables entered.

This table presents the variables included in the regression model. The predictors are Product, Price, Place, and Promotion, all of which were entered into the model using the Enter method. No variables were removed during the analysis, ensuring a comprehensive evaluation of all marketing strategies.

The dependent variable, University Students' Online Shopping Behavior, reflects the purchasing tendencies influenced by these marketing strategies. This process allows for a detailed assessment of each predictor's contribution to explaining the variations in the dependent variable.

Table 14 Summary of Multivariate Regression Analysis Model of Marketing Strategies Influencing Online Shopping Behavior of Students at Asia Eastern University of Science and Technology

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**				
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**
1	.854[a]	0.729	0.726	0.27777	0.729	248.048	4	369	<.001

a. Predictors: (Constant), Product, Price, Place, Promotion

b. Dependent Variable: University Students' Online Shopping Behavior

In addition, the results of the regression analysis shows that from the model summary, the R value was 0.854, which indicated a high positive correlation between the marketing strategies and the online shopping behavior of the university students.The value of R Square was 0.729, which indicated that these four marketing strategies could explain 72.9% of the variations in online shopping behavior of the university students. This shows that these marketing strategies are effective in explaining most of the variations in shopping behavior.

Table 15 Regression Analysis of Marketing Strategies on University Students' Online Shopping Behavior

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.681	0.125		5.438	<.001
Product	0.327	0.034	0.335	9.564	<.001
Price	0.119	0.029	0.158	4.079	<.001
Place	0.234	0.031	0.298	7.583	<.001
Promotion	0.175	0.025	0.262	6.896	<.001

a. Dependent Variable: University Students' Online Shopping Behavior

Based on the results of the regression analysis, Product Strategy (Beta = 0.335) and Place Strategy (Beta = 0.298) have the greatest impact on university students' online shopping behavior. These findings suggest that product-related factors (such as variety and details) and place-related factors (such as shipping and delivery services) are the most influential in shaping students' purchasing decisions.

Promotion Strategy (Beta = 0.262) and Price Strategy (Beta = 0.158) have a smaller effect on shopping behavior, indicating that these strategies may be more effective in targeting specific consumer groups rather than having a broad influence across all students.

Discussions

The results of this study are consistent with the existing literature showing the effects of different marketing strategies on the online shopping behavior of university students. According to Fishbein and Ajzen's (1975) Theory of Planned Behavior, consumers' purchasing behavior is driven by attitudes, subjective norms, and perceptual-behavioral control. This theory explains the multiple considerations of college students in their online shopping decisions, especially the combined effects of product, Place, Promotion, and price.

Product strategy proved to be the most important influence. The authenticity of product details and pictures helps to build consumer trust (Gefen & Straub, 1997). Since online shopping does not allow for in-person viewing of products, college students rely on this information to assess product quality. Research has also shown that brand diversity enhances consumers' sense of control and satisfaction with their purchases (Kim, Williams, & Lee, 2003), which reflects students' preferences when choosing a platform.

Place strategy is less influential than product strategy, but still important. Free shipping service and multiple payment methods are key factors, which is consistent with other research that suggests that the quality

of logistics services influences consumers' purchasing decisions (Haque et al., 2011). In addition, university students pay particular attention to return and exchange policies when purchasing high-priced products (Hasan, 2010), and cross-border shopping options are more appealing to students with a demand for international brands (Lim et al., 2016).

Promotion strategies also had a significant impact. Exclusive coupons and social media promotions have a clear appeal to consumers, especially when limited-time offers create a sense of urgency to buy (Hernández et al., 2011; Shih, 2004). Young consumers are more likely to obtain product information through social media (Ranganathan & Grandon, 2002).

Price strategy, although less influential, is still one of the considerations when choosing a shopping platform. University students compare prices across platforms to find the best deals and are particularly sensitive to discounts and offers (Liao & Cheung, 2001; Sorce et al., 2005).

Benefits

By analyzing how marketing strategies affect the online shopping behavior of university students, it is an important reference for e-commerce platforms to formulate more accurate and effective marketing plans, especially when targeting university students as a specific group. Research can help e-commerce platforms better understand the needs and preferences of their target consumers, especially university students, so that they can formulate targeted marketing strategies and improve the accuracy of their marketing strategies.

In addition, through in-depth research on marketing strategies, enterprises can design more attractive shopping websites and applications to enhance market competitiveness, and update the functions and services of shopping applications based on the research results to enhance users' shopping experience and satisfaction, thereby increasing user loyalty.

The study will also help to understand the impact of marketing practices on the online shopping behavior of university students, encourage more innovative enterprises to enter the market, support young entrepreneurs to develop new shopping applications that meet the market demand, and promote the innovation and development of the market.

The impact of these marketing approaches will also help young entrepreneurs position and promote their products more effectively during the entrepreneurial process, contributing to their growth and success.

Conclusions and Recommendations

Conclusions

This study examines the influence of marketing strategies (product, price, Place, and Promotion) on the online shopping behavior of Asia East University of Science and Technology (AEUST) students and reveals the key role of these strategies in influencing consumers' purchasing decisions. The results show that product strategy is the most influential factor, especially in terms of product detailing and brand diversity. The high value placed on product quality and brand reputation suggests that university students are more likely to look for products with detailed information and a wide range of choices when choosing a shopping platform.

Place strategy also shows its importance, especially free delivery service and a variety of payment methods, indicating that university students highly value the convenience of logistics services when shopping. This finding not only reflects young consumers' expectations of the shopping experience, but also highlights the need for e-commerce platforms to provide services.

Although the impact of pricing strategies is relatively small, they are still able to attract price-sensitive consumers to a certain extent, showing that price is not completely unimportant in the minds of university students. Promotion strategies, such as platform coupons, are helpful in increasing purchase intention, especially in specific contexts.

Taken together, this study emphasizes that e-commerce platforms should prioritize product and Place-related factors in formulating marketing strategies to increase students' satisfaction and loyalty. By gaining a deeper understanding of university students' shopping behavior and the motivations behind it, platforms can more effectively adjust their marketing strategies to meet the needs of young consumers and stand out in a competitive market.

Recommendations for the current research

Adding Data Collection Methods

This study mainly relied on quantitative methods for data collection. In the future, we may consider adding qualitative research methods, such as in-depth interviews or focus group discussions, in order to gain a deeper understanding of the motivation and thinking process behind university students' shopping behavior, especially in terms of the influence of marketing strategies such as product descriptions or price concessions on the decision-making process, so as to provide a richer insight.

Gender and Grade Level Analysis

It is recommended that in-depth analyses be conducted on students of different genders and grade levels in order to develop more accurate marketing strategies to meet the needs and behavioral characteristics of

different groups.

Breakdown of Independent and Response Variables

The study may consider an in-depth breakdown of specific elements of the marketing strategy to explore the specific impact of product attributes (e.g. design, functionality) and forms of price promotion (e.g. time-limited discounts, membership privileges) on the shopping behavior of university students. In addition, the convenience of delivery methods, the variety of payment options and the quality of customer service can also be analyzed in depth to understand their impact on consumer satisfaction and shopping experience.

Recommendations for Future Research

Expanding Sample Size

In the future, the sample can be expanded to include consumers from different schools, districts and age groups to explore the different responses of these groups to the marketing strategies. This will help provide more representative and generalizable results and a more comprehensive understanding of the impact of marketing strategies on different consumer groups.

Comparing the effectiveness of marketing strategies across different shopping platforms

With the diversification of shopping platforms, the future study can compare the effectiveness of marketing strategies of different platforms (e.g. Shopee, PChome, Momo, etc.), analyze the strategic differences in product display, Promotion and logistics services, and compare their performance in attracting consumers.

Long-term Impact of Digital Marketing

Future research could explore the long-term impact of digital marketing (e.g., social media marketing, email marketing) on consumer behavior, especially how brands influence consumer loyalty and purchase behavior through continuous digital interactions.

Psychological Factors and Purchase Behavior

In addition to marketing strategies, consumers' psychological factors such as risk perception, shopping satisfaction and brand attachment also have a significant impact on shopping behavior. Future research could explore the role of these factors in the online shopping environment from a psychological perspective to further enrich the academic discussion.

The Impact of New Technologies on Consumer Behavior

With the development of new technologies such as Virtual Reality (VR) shopping and Artificial Intelligence (AI) recommendation systems, future research could analyze how these technologies have changed consumers' shopping decisions, and examine whether these innovations can enhance the shopping experience, which in turn can promote consumers' long-term purchasing behavior.

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Research on Marketing Strategies of Decoration Design Company's Supply Chain

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Abstract

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With the rapid development of China's real estate industry and improved living standards among urban and rural residents, the demand for decoration design services has surged, driving the continuous growth of decoration design enterprises. However, fluctuations in the real estate market have intensified competition, presenting challenges to sustaining business development. Marketing management plays a crucial role in addressing these challenges, with a focus on formulating scientific marketing strategies to guide enterprise growth and ensure stability. This paper examines MS Decoration Design Company, leveraging literature review and field research to analyze its marketing strategy dilemmas. Key issues include ambiguous target customer groups, misalignment between product offerings and price positioning, insufficient brand awareness, limited marketing channels, and a lack of personalized services. These challenges highlight significant deficiencies in the company's marketing strategy framework. To address these issues, this study applies SWOT analysis to propose targeted countermeasures. These include diversifying core business offerings, expanding market reach, optimizing the industrial ecological environment, and refining the company's strategic focus. Recommendations emphasize clearly defining target customer groups, aligning product and price positioning, strengthening brand planning, enhancing channel development, and prioritizing personalized service delivery. By implementing these strategies, MS Decoration Design Company can improve its marketing approach, achieve sustainable development, and contribute to the broader growth of the decoration design industry.

Keywords: Marketing Strategy, Decorative Design, Marketing Management, Brand Planning, Channel Building

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Introduction

Research background

With the rapid development of China's economy, residents' living standards have improved significantly, leading to higher demands for material well-being. Housing has become a primary focus of consumption, stimulating a booming real estate market and driving related industries, including the decoration design sector. In this context, the demand for interior decoration has evolved, with consumers prioritizing green, environmentally friendly, and high-quality designs. While this creates significant opportunities, it also presents substantial challenges for decoration design enterprises.

The rapid expansion of China's decoration design industry has led to increased competition. By the end of 2018, the number of decoration design enterprises in China had reached approximately 150,000, creating a saturated market with intense competition (Li et al.,2024). Most companies in this sector remain small, with limited resources and capabilities. For instance, enterprises with assets exceeding 1.5 billion yuan accounted for only 9% of the industry's total output value, reflecting low industry concentration and widespread disorderly competition(Zhao et al.,2012). Consequently, many companies have struggled to survive amidst fierce competition.

MS Decoration Design Company, a small and medium-sized enterprise with over 20 years of experience, has demonstrated resilience through market challenges. During the past decade, the company thrived alongside a booming real estate sector. However, as the real estate market stabilizes and demand declines, MS Decoration Company faces increasing survival pressures. Despite maintaining stable annual sales of approximately 130 million yuan, the company's profit margin has declined from 16.75 million yuan to 13.55 million yuan over the past five years, highlighting growing financial challenges.

Furthermore, MS faces competitive disadvantages compared to large industry players like Gold Mantis, whose economies of scale enhance their market dominance. The inability to adapt to shifting consumer demands in terms of products, pricing, and distribution channels underscores weaknesses in MS's marketing strategy. To overcome these challenges, MS must refine its market positioning and adopt a robust, adaptive marketing strategy to ensure sustainable development in a competitive landscape.

Research Significance

The analysis of enterprise marketing strategies by domestic and international scholars has predominantly focused on real estate enterprises, leaving a gap in the study of related industries such as the decoration design sector. Additionally, existing studies largely emphasize large decoration design companies, with limited exploration of small and medium-sized enterprises (SMEs) like MS Decoration Company. This paper addresses these gaps by analyzing the marketing strategies of SMEs in the decoration design industry, thereby contributing to the theoretical understanding of this underserved area(Porter, 1998).

In recent years, China's real estate market has stabilized, leading to a decline in overall market demand, which has adversely impacted related industries, including decoration design. However, past research

has largely examined marketing management in the context of a booming real estate market, with insufficient focus on the challenges faced by decoration design enterprises during economic downturns. This study leverages analytical frameworks such as STP marketing strategy theory and the SWOT model to examine the marketing strategy dilemmas faced by MS Decoration Company. By combining theory with practical insights, this paper identifies transformation strategies that are significant for both theoretical research and practical applications (Kotler et al., 2016).

From the perspective of MS Decoration Company, the business faces intense market competition and increasing survival pressures. To sustain and grow, the company must promptly adapt its marketing strategies. This study identifies specific challenges within MS's marketing management and offers actionable recommendations. Such insights enable enterprise managers to recognize and address their shortcomings, align strategies with market trends, and develop marketing plans tailored to their unique needs. These findings are not only beneficial for MS Decoration Company but also serve as valuable references for other SMEs in the industry (Hänle et al.,2022).

Finally, the decoration design industry's dependence on the real estate market underscores its vulnerability to macroeconomic policies. Recent national capacity reduction policies and slower real estate growth have heightened these threats. This paper's analysis of MS Decoration Company's marketing strategy provides a broader understanding of industry dynamics and offers practical guidance for ensuring sustainable and stable development in the sector.

Literature Review

Theoretical Basis

STP Marketing Strategy Theory

STP marketing strategy theory, initially proposed by American economist Del Smith and later refined by Philip Kotler, is a foundational framework in marketing strategy. The theory comprises three key components: market segmentation, target market selection, and market positioning.

1) Market Segmentation: This involves dividing the market into distinct customer groups based on varying consumer needs. It outlines the structure of market segments, enabling enterprises to categorize and prioritize customer groups (Kotler et al., 2016).

2) Target Market Selection: Once the market is segmented, businesses identify one or more segments as their target markets, aligning the selection with the company's capabilities and strategic objectives.

3) Market Positioning: The final step involves crafting a specific corporate image in the minds of the target audience through effective marketing techniques. This positioning helps establish the company's presence in the market.

The purpose of the STP theory is to analyze the business conditions of an enterprise and evaluate market dynamics to identify suitable customer groups and allocate resources efficiently. Given the complexity of modern consumer preferences and product diversification, businesses must prioritize specific markets to maximize economic benefits. By focusing their efforts on well-defined market segments, enterprises can achieve higher returns with limited resources (Smith, 1956).

STP theory is highly relevant in the current competitive environment. Companies like MS Decoration Design Company can leverage this framework to identify niche markets, optimize resource allocation, and develop tailored marketing strategies to enhance their competitive advantage. This structured approach ensures that businesses concentrate on high-priority segments, enabling them to implement reliable and focused marketing activities.

SWOT Model Theory

The SWOT analysis method is a prominent tool for evaluating an enterprise's internal environment and strategic positioning. Developed in the 1980s and influenced by Michael Porter's theories on competition, SWOT combines insights from the resource-based school of thought and external market dynamics (Porter, 2008).

SWOT analysis examines four key dimensions:

1) Strengths: Internal capabilities that provide a competitive edge.

2) Weaknesses: Internal limitations that hinder growth.

3) Opportunities: External factors that the company can capitalize on.

4) Threats: External challenges that may impact the company's success.

This method employs a structured matrix to map internal and external factors systematically. By identifying these dimensions, enterprises can develop strategies that align internal strengths with external opportunities while mitigating weaknesses and threats (Gurl, 2017).

For MS Decoration Design Company, SWOT analysis offers a robust framework for understanding its strategic position. By evaluating its internal strengths and weaknesses alongside external opportunities and threats, the company can formulate and refine its marketing strategies. Using systematic analysis and matrix representation, MS Decoration Design Company can identify optimal strategic combinations to address market challenges effectively.

Application to MS Decoration Design Company

MS Decoration Design Company is a small and medium-sized enterprise specializing in decoration design. Over the years, it has developed a distinct business system and secured a modest share in the market. By employing STP theory, the company can refine its focus on specific customer groups, ensuring that its marketing efforts are precise and resource efficient. Similarly, leveraging SWOT analysis enables the company to align its internal capabilities with market opportunities and address external threats systematically.

Research Methods

This study employs a combination of the literature research method, case study method, and field research method to analyze and propose marketing strategies for MS Decoration Design Company.

1) Literature Research Method

The study systematically reviews a range of domestic and international academic literature, internet resources, newspapers, and government documents to establish a solid research foundation. This comprehensive review provides a rich source of data, offering a deeper understanding of "decoration design companies" and "marketing strategies" (Bryman, 2016). During the literature review process, emphasis is

placed on careful examination and systematic synthesis of related academic studies. This approach ensures a broad and in-depth understanding of the research topic and clarifies the problem awareness and research framework. By organizing existing knowledge, the study develops insights into the marketing strategies of MS Decoration Design Company.

2) Case Study Methodology

The marketing strategy of MS Decoration Design Company is a complex practical issue, making the case study method an appropriate choice. The study employs a typical case analysis approach, which allows for an in-depth understanding of specific problems through detailed exploration (Yin, 2018). This method summarizes the company's marketing strategy development and evaluates its current challenges and environmental factors. By observing and analyzing typical cases, the study provides valuable insights and recommendations for constructing an improved marketing strategy tailored to the company's needs. (Eisenhardt, 1989)

3) Field Research Method

Accessing primary information is crucial for the case study approach, and field research serves as the primary means of gathering this data. The field research process involves two key steps:

1. Initial Field Investigation: This includes conducting interviews with ordinary employees of the marketing department to gain a comprehensive understanding of the company's current marketing strategies and their implementation.

2. In-Depth Interviews: Following the initial investigation, detailed discussions are held with the head of the marketing department. These exchanges delve into the company’s marketing strategies, exploring the challenges and specific actions undertaken by the department. The collected information is then analyzed to extract the dilemmas faced by MS Decoration Design Company and propose actionable solutions.

By integrating these methods, the study aims to provide a thorough analysis and well-supported recommendations for enhancing the company's marketing strategies.

An analysis of the marketing strategy of MS Decoration Design Company reveals that the current approach fails to align with the dynamic needs of enterprise development. The fluctuations in the real estate market and the evolving preferences of consumer groups necessitate timely adjustments to marketing strategies, enabling the company to adapt to market trends and sustain its growth.

Macro Environment Analysis of MS Decoration Design Company

Political and Legal Environment

Political and legal factors profoundly influence enterprise development, particularly through government policies. In recent years, the national real estate market regulation policies in China have significantly affected the interior decoration industry. As a dependent industry, the trajectory of the decoration sector closely aligns with the real estate market.

1) Gradual Withdrawal of Purchase Restriction Policies According to the "2018 National Real Estate Market Report" released by the Shell Research Institute, while the rapid growth in housing prices has stabilized, certain cities have relaxed purchase restrictions. This shift back to market-oriented adjustments signals opportunities for decoration companies like MS Decoration Design Company to expand during market recovery phases (Shell Research Institute, 2018).

2) Supportive Policies by the Ministry of Housing and Urban-Rural Development Policies such as encouraging the housing rental market and standardizing engineering specifications have mitigated risks and created opportunities for the decoration industry. Notably, policies targeting inventory reduction in third- and fourth-tier cities open untapped markets for MS Decoration Design Company to explore (Chen et al., 2020)

Economic Environment

Economic conditions significantly influence the real estate and decoration design industries. The current trends in China reveal key insights:

1) Stable Economic Growth China's GDP growth rate has hovered around 6.5% since 2015, signaling a stable macroeconomic environment. While the real estate market may appear saturated, maintaining a stable economic policy ensures steady demand in the decoration design market. Companies must innovate to capture market share within a constrained yet consistent environment.

2) Central Bank Policy Adjustments Interest rate reductions by the central bank since 2014 have positively influenced the real estate market by reducing borrowing costs. Lower housing loan interest rates have particularly benefited first-time buyers, indirectly aiding the decoration design industry.

3) Regional Economic Growth Key markets like Beijing, Shanghai, and Guangzhou, where MS Decoration Design Company operates, demonstrate stable economic and real estate conditions. However, saturation in these first-tier cities necessitates exploring new markets and strategies to sustain growth.

Social Environment

Social factors, including cultural influences and evolving consumer preferences, are pivotal for the decoration industry.

Segmented Consumer Groups Consumer groups in the real estate market include single individuals, newlyweds, and families upgrading their homes. Newlyweds and growing families prioritize aesthetics and eco-friendly materials, emphasizing the need for tailored marketing strategies (Chen et al., 2020).

Rise of Environmental Awareness Increasing environmental consciousness drives demand for green materials and technologies in home design. Decoration companies must integrate sustainability into their products to meet customer expectations.

Low Brand Awareness Despite growing brand recognition in other industries, the decoration design sector remains fragmented. Most consumers rely on recommendations rather than established brands, indicating a need for companies like MS Decoration Design Company to enhance brand visibility through marketing.

Technological Environment Technological advancements shape the future of the decoration industry, and adapting to these trends is critical.

1) Internet of Things (IoT) Integration IoT technology enables smart home solutions, allowing consumers to control their environments through connected devices. Developing IoT-compatible decoration services will enhance the company’s competitive edge.

2) Popularization of Heating and Environmental Technologies Innovations like floor heating and air purification systems are gaining traction, especially in southern China. Companies offering these technologies at competitive prices will strengthen their market position (Gann, 2000; Kovacevic & Ivanova, 2014)

SWOT Analysis of the Marketing Strategy of MS Decoration Design Company

Strengths

1. Strong Design Capabilities MS Decoration Design Company has a well-established reputation within the decoration design industry, having grown alongside the real estate market over the past two decades. A significant strength lies in its highly skilled and youthful workforce. Designers make up approximately 50% of the company's total employees, with an average age of 35.3 years, reflecting a trend toward younger, dynamic talent. Notably, 15% of the workforce holds master's degrees or higher, showcasing a strong pool of expertise and development potential.

2. High Market Visibility As a mid-sized company, MS Decoration Design has garnered a robust reputation through its numerous accolades and awards. This recognition has bolstered its visibility in key markets, such as Beijing, Shanghai, and Guangzhou, where consumer trust in the brand is notably strong. Market share data further highlights MS Decoration Design's competitive advantage, reflecting its ability to capture and retain a loyal customer base in these regions.

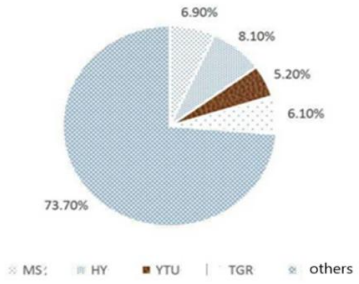

Figure 1 Market Share of MS Decoration Design Company and Its Competitors

Data Source: Annual Financial Report Statistics

3. Superior Performance MS Decoration Design Company has consistently prioritized quality in its decoration design projects, creating several iconic landmarks such as the Shanghai Haili Building, Beijing China Workers' Home, and the Dongguan Exhibition Center. These projects serve as vital showcases of the company's expertise, significantly enhancing its reputation. The company's recent project performance, presented in Table 1, highlights its consistent growth despite challenges such as a cooling market. By maintaining high-quality performance standards, MS Decoration Design has effectively attracted clients and secured its market position, even during industry downturns.

Table 1 Project Volume Undertaken by MS Decoration Design Company

Year	Tooling Engineering (pcs)	Other Projects (pcs)
2015	8	19
2016	11	22
2017	9	21
2018	12	18

Source: MS Decoration Design Inc. internal data

4. Advanced Business Philosophy

MS Decoration Design Company has adhered to the philosophy of “integrity-based, innovation and development” throughout its two-decade-long journey. This approach enables the company to adapt to dynamic market conditions by continually innovating its services and offerings. Under this strategic framework, MS has successfully entered first-tier cities such as Beijing and Shanghai, securing major contracts and earning widespread client praise.

5. Comprehensive Internal Management

Efficient management systems are critical to the success of any enterprise. MS Decoration Design Company boasts a robust internal management framework, with clear job responsibilities, detailed position descriptions, and streamlined organizational operations. These attributes contribute to the company’s operational efficiency and competitive edge.

6. Strong Corporate Culture

Corporate culture plays a pivotal role in fostering employee loyalty and motivation. MS Decoration Design Company emphasizes both internal engagement - enhancing employees' sense of mission and belonging - and external branding, which builds customer trust and satisfaction. These efforts underpin the company’s sustainable growth.

Summary of Advantages

MS Decoration Design Company demonstrates a customer-centric approach rooted in a forward-looking vision. Its strategic focus on past successes, current performance, and future opportunities solidifies its competitive position in the market. These strengths collectively contribute to its robust development trajectory.

Disadvantage Analysis

Despite the numerous advantages of MS Decoration Design Company, several disadvantages have hindered its development. These issues stem primarily from its business strategies and the evolving market environment.

1. Limited Industrial Chain Expansion

The economic benefits of decoration design enterprises often rely on material cost differences achieved through large-scale procurement. MS Decoration Design Company, however, continues to source materials exclusively from upstream suppliers, resulting in weak bargaining power. This dependence significantly impacts profitability, as raw material costs and total expenses have been steadily increasing (see Figure 2). Currently, the company has not ventured into raw material supply, leaving its industrial chain underdeveloped and profit margins compressed.

A significant limitation is the company's underdeveloped industrial chain. In the decoration design industry, profit margins often depend on the ability to control material costs through economies of scale. However, MS Decoration Design relies entirely on upstream suppliers for raw materials, as illustrated in Figure 2, which shows the rising costs of raw materials and total expenses. The company’s lack of bargaining power with suppliers has constrained its profitability. Without deeper vertical integration into raw material supply, MS faces compressed profit margins, limiting its ability to optimize operational costs. By addressing these weaknesses, MS Decoration Design Company can enhance its market competitiveness and secure long-term growth.

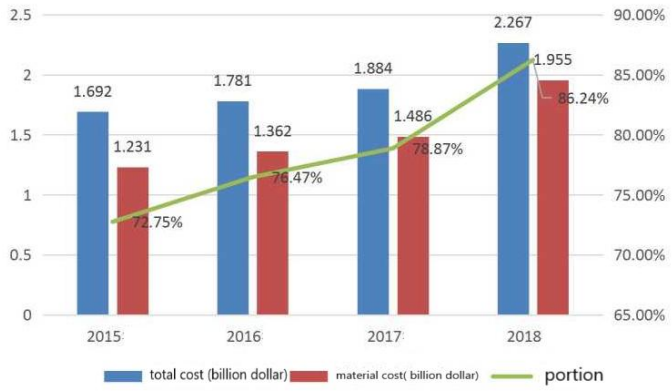

Figure 2 Rising Raw Material and Total Costs for MS Decoration Design

Data source: annual financial report data statistics

2. Shortage of Human Resources

As a decoration design enterprise, MS faces a pressing demand for skilled designers, especially senior design professionals. The company currently employs only around 100 senior designers. In large markets such as Beijing, Shanghai, and Guangzhou, each branch office operates with fewer than 30 designers, which is insufficient to meet growing market demands. To optimize resource utilization amidst this talent shortage, MS must refine its market positioning.

3. Challenges in Project Performance

Delivering quality, timely, and safe project outcomes is essential. However, MS struggles to meet these standards consistently, partly due to resource limitations. This inability to fulfill contracts according to client expectations - especially when catering to new and returning customers—has negatively impacted the company's reputation and creditworthiness.

4. Insufficient Horizontal Cooperation

In some cases, competitors can become strategic collaborators, particularly in large projects involving multiple tenders. Horizontal cooperation allows companies to share resources and expertise, effectively overcoming manpower shortages. MS Decoration Design Company, however, has partnered with fewer than 10 other enterprises, leaving it unable to secure timely partnerships when needed. This lack of horizontal collaboration limits the company’s flexibility in project delivery.

Opportunity Analysis The rapid economic growth and urbanization in China have created numerous opportunities for MS Decoration Design Company to thrive in the decoration design industry.

High-End Event Hall Decoration

With China's growing international presence and its successful hosting of large-scale events (e.g., the Olympics, Asian Games, and World Expo), there is an increasing demand for high-quality decoration projects. MS has successfully undertaken notable projects, such as the Beijing Olympic Sports Center and the Shanghai World Expo venue. Future opportunities in this area are expected to grow as China continues to host high-profile events.

Batch Decoration of Large Building Complexes

The Chinese government's push for affordable rental housing and the transition of commercial housing to unified developer-led decoration projects provide a lucrative market for mid-sized companies like MS. The company's existing partnerships with developers such as Vanke and China Resources position it well to capitalize on this growing market segment.

Periodic Renovation for Hotels and Restaurants

The cyclical nature of the decoration design industry, particularly for businesses like hotels and restaurants that renovate every 5–8 years, offers a steady revenue stream. MS has built a substantial customer base in this sector, ensuring a stable demand for periodic renovation projects in the future.

Threat Analysis

While opportunities abound, MS Decoration Design Company faces several external threats that could impede its growth.

Intensified Industry Competition

With 150,000 decoration design enterprises in China and an annual growth rate of 8%, competition has become increasingly fierce, particularly in first-tier cities like Beijing, Shanghai, and Guangzhou. As a mid-sized company, MS struggles to expand its market share and establish horizontal alliances with competitors, placing it at a competitive disadvantage.

Industrial Chain Expansion by Material Suppliers

Many material suppliers are extending their business scope to include decoration and construction. Given their significant advantage in raw material access and the low entry barriers in the decoration design industry, these suppliers pose a growing threat to companies like MS.

Integration by General Contractors

Traditionally, property owners subcontracted decoration services separately, providing early growth opportunities for MS. However, as general contractors now integrate decoration into their service offerings—encouraged by policies promoting pre-furnished housing—companies like MS face shrinking market opportunities. The rise of EPC (Engineering, Procurement, and Construction) firms further heightens this challenge by enabling tighter control over the market.

SWOT Matrix Analysis

To adjust its marketing strategy, MS Decoration Design Company must leverage its strengths (S), address its weaknesses (W), capitalize on opportunities (O), and mitigate threats (T). The following matrix highlights strategic directions:

Table 2 MS Decoration Design Company SWOT Matrix

Strengths/Opportunities (SO)	**Strengths/Threats (ST)**
1. Leverage its high-quality projects to expand into high-end event hall decoration.	1. Utilize its strong brand reputation to differentiate itself from competitors in first-tier cities.
2. Deepen partnerships with developers to secure batch decoration contracts.	2. Enhance service offerings to counteract competition from integrated general contractors.
Weaknesses/Opportunities (WO)	**Weaknesses/Threats (WT)**
1. Invest in talent acquisition to address human resource shortages for expanding opportunities.	1. Improve cost efficiency through backward integration into raw material supply.
2. Develop horizontal alliances to enhance project execution capabilities.	2. Expand service portfolio to remain competitive against new entrants.

Through the analysis above, MS Decoration Design Company can refine its strategy to ensure sustainable growth and competitiveness in the evolving market. Based on the SWOT analysis and using the SWOT strategic selection matrix, the development strategy for MS Decoration Design Company is outlined as follows:

SO Strategy (Strengths-Opportunities Strategy):

Seize External Development Opportunities: Capitalize on the ongoing urbanization and the increasing demand for high-quality residential decoration, especially in third- and fourth-tier cities. MS Decoration Design Company should leverage its strengths by enhancing its brand image and strengthening alliances with real estate developers.

Focus on Core and Expanding Markets: Strengthen relationships with existing clients, such as catering hotels, and focus on maintaining a strong presence in first-tier markets. At the same time, expand aggressively into third- and fourth-tier markets to maximize the reach and growth of the company.

ST Strategy (Strengths-Threats Strategy):

Mitigate External Threats with Strengths: Use the company's existing competitive advantages to shield itself from growing competition. Strengthen partnerships with large decorative design companies and suppliers to create a more robust supply chain.

Enhance Strategic Alliances: Strengthen cooperation with general construction contractors to leverage outsourcing business advantages, ensuring cost efficiency and gaining recognition from key contractors.

WO Strategy (Weaknesses-Opportunities Strategy):

Diversify the Industrial Chain: Based on the current industrial chain, MS Decoration Design Company should accelerate its extension and diversification. Expanding into new areas such as general contracting projects would broaden its scope and revenue base.

Talent and Price Management: Establish a more comprehensive talent management system, improve the price management system, and enhance horizontal cooperation to increase market influence and attract top-tier projects.

WT Strategy (Weaknesses-Threats Strategy):

Enhance Market Positioning: MS Decoration Design Company must refine its market positioning and customer management practices to strengthen its competitive edge. The company should focus on differentiation strategies, such as product, brand, and service differentiation, to attract customer attention in a crowded market.

Accelerate Organizational Streamlining: Improve organizational efficiency to better respond to external challenges and streamline processes for faster market adaptation.

Conclusion:

To ensure the sustainable growth and competitiveness of MS Decoration Design Company, continuous refinement of its strategies is essential, especially in light of challenges and opportunities in the evolving market landscape.

Optimization of MS Decoration Design Company's Marketing Strategy

The growth of an enterprise is intricately tied to effective management, and the formulation of a robust marketing strategy provides a clearer direction for future development. MS Decoration Design Company must focus on "creating a grand residential scene with benevolence and down-to-earth morality" while working towards its vision of becoming a respected decoration company in China. To optimize its marketing strategy, MS Decoration Design Company should focus on the following key areas:

1) Diversification Strategy for Core Business

The future marketing strategy of MS Decoration Design Company will require a diversification of its core business. This strategy should be approached from three key directions:

Expansion of Raw Material Business: MS Decoration Design Company should further strengthen its expansion into the raw material business. By gradually managing the supply of raw materials within its capabilities, the company can build a more comprehensive industrial chain, leading to cost efficiencies and more sustainable growth.

Cultural and Educational Business: With its years of expertise in the decoration design industry, MS Decoration Design Company is well-positioned to expand into the cultural and educational sectors. The company can offer training and management services in decoration design, creating an additional revenue stream and expanding its market reach.

Expansion of Service Offerings: MS Decoration Design Company can extend its core business by offering a wider range of services, including maintenance services for new customers. This will help diversify the company’s strategic operations and strengthen customer loyalty.

2) Market Space Expansion Strategy

To continue its development and improve its scale, MS Decoration Design Company should adopt a market space expansion strategy. This can be achieved through the following initiatives:

Reorganization of Marketing Departments: MS Decoration Design Company should restructure its marketing departments into two major divisions: one focusing on first- and second-tier cities and another on third- and fourth-tier cities. This will help streamline the marketing operations and optimize resource allocation.

Zoning Management of Marketing: To address the insufficient development in third- and fourth-tier cities, MS Decoration Design Company should establish regional marketing offices in key cities to coordinate efforts and enhance market penetration.

Bidding Management Adjustments: To improve project bidding outcomes, MS Decoration Design Company should adjust its management of bidding processes across regions, ensuring that each marketing department can efficiently handle the bidding and approval process.

3. Industrial Ecological Environment Optimization Strategy

MS Decoration Design Company needs to optimize the industrial environment to support its growth. Key aspects include:

Supplier System Enhancement: The company should create a more robust supplier system, ensuring stable and long-term relationships with suppliers, particularly for raw materials. This will help safeguard the quality and timely delivery of materials.

Strengthening Business Relationships: MS Decoration Design Company should enhance its cooperation with key business sources, providing follow-up maintenance services alongside decoration design, thereby improving customer retention.

Horizontal Cooperation with Competitors: Collaborating with other decoration design enterprises can help alleviate competition and improve overall market efficiency, fostering a more cooperative industry environment.

4. Clarification of Target Customer Groups

As the company's marketing strategy shifts towards targeting both first-tier cities and third- and fourth-tier cities, MS Decoration Design Company needs to focus on managing customer relationships more effectively:

Develop Strong Relationships with Large Enterprises: The company should strengthen its relationships with large enterprises, institutions, and catering hotels, ensuring ongoing communication and follow-up management.

Expand in Mid- to High-End Markets: MS Decoration Design Company should gradually shift focus from low-end markets to mid- and high-end segments, particularly by targeting large-scale developers in third- and fourth-tier cities.

5. Product and Pricing Optimization

To meet the evolving needs of customers, MS Decoration Design Company should:

Launch Personalized Products: MS Decoration Design Company must innovate by introducing green and intelligent decoration design options to meet the growing demand for personalized, sustainable designs.

Optimize Pricing Strategy: The company should implement a tiered pricing system to cater to different market segments. For high-end markets, a higher price point is recommended, with specific pricing levels for varying customer needs, such as 2000, 2400, 2700, and 3000 yuan per square meter.

6. Strengthening Brand Planning

Brand development is critical for the long-term success of MS Decoration Design Company. To enhance brand recognition:

Design a Strong Brand Culture: The company should incorporate environmental protection as part of its brand culture, reflecting its commitment to sustainability. This will not only resonate with customers but also differentiate the company in a competitive market.

Green Store Concept: The company should design its stores to reflect its green brand culture, ensuring customers experience the company's commitment to sustainability as soon as they engage with the brand.

In conclusion, by optimizing its marketing strategy in these critical areas—business diversification, market expansion, industrial environment optimization, target customer group management, product and pricing optimization, and brand development—MS Decoration Design Company can achieve sustainable growth and remain competitive in an evolving market.

MS Decoration Design Company Marketing Strategy Analysis

Redesigning the Company Logo As depicted in Figure 3, the MS Decoration Design Company logo has been redesigned to better reflect its industry characteristics and cultural content. The new logo integrates the essence of the company's business and philosophy. The use of a house form in the design symbolizes the company's focus on home and decoration services, while the green window represents its commitment to eco-friendly decoration concepts. This logo also communicates the company’s future direction in the decoration design process, emphasizing sustainability and innovation.

Brand Promotion Strategies

Brand publicity plays a pivotal role in increasing the MS Decoration Design Company's visibility and customer base. Effective brand promotion not only enhances recognition but also drives consumer choice. The company can adopt several strategies to strengthen its brand presence:

1) Bundled Publicity: MS Decoration Design Company can leverage its completed projects to promote the brand. By showcasing these projects with the company’s name prominently displayed, the brand's influence can grow. Signing agreements with clients to feature the company's branding in visible locations post-project completion is essential.

2) Television and Online Advertising: Advertising through traditional media, such as TV, can help reach a broad audience. Online channels, including search engine advertising, should be expanded to further enhance brand recognition. This multi-channel approach will ensure that the company remains top of mind for consumers when they are in need of decoration services.

3) Event Marketing: MS Decoration Design Company can utilize event marketing to increase brand awareness. For example, during the COVID-19 pandemic, the company could have made donations of medical supplies and offered its design services for public welfare projects, leveraging media coverage to boost its image.

Channel Construction and Sales Expansion

Consolidating Original Sales Channels: MS Decoration Design Company should focus on strengthening its existing sales channels. Word-of-mouth marketing is a valuable, low-cost channel that should

not be underestimated. By nurturing relationships with existing customers, the company can foster positive reviews and repeat business. Additionally, improving store management and service quality will attract more customers and maintain healthy sales channels.

Expanding Online Sales Channels: With the increasing importance of e-commerce, MS Decoration Design Company should expand its online presence. This includes optimizing its official website and exploring platforms like Tmall or Jingdong, particularly during major sales events like Double 11, to attract new customers. These online platforms also provide opportunities to tap into high-end individual users.

Personalized Service Provision

Customer Service Demand Surveys: Understanding and responding to customer needs is crucial for business survival. MS Decoration Design Company should implement a robust system to collect, track, and respond to customer feedback. The company should invest in information systems to capture customer needs and ensure that business departments promptly address them, improving overall service efficiency.

Personalized Design Services: Offering tailored design services is a cornerstone of MS Decoration Design Company's strategy. The company should provide customers with the opportunity to design their own spaces using 3D design software like "3D Home 3D Cloud Design." This allows customers to visualize their design choices, enhancing communication and personalization. In addition, MS Decoration Design Company should strive to make a positive first impression, especially when working with developers or high-end clients, through model houses that showcase the company’s unique offerings.

Customer Return Visits: Regular follow-ups with customers are vital for maintaining satisfaction and ensuring continuous business. MS Decoration Design Company should implement a system for customer return visits, allowing the company to address any issues and maintain strong client relationships.

Conclusions and Outlook

As urbanization continues to accelerate in China, the decoration design industry is poised for rapid growth. While government regulation has affected the real estate market, particularly in smaller cities, it also presents a significant opportunity for MS Decoration Design Company. The company must adapt its marketing strategies to address the evolving market conditions and meet the increasing demand for home decoration services. From the analysis, it is clear that MS Decoration Design Company’s current marketing strategy requires significant improvement. Issues such as unclear target customer groups, misalignment between product and price positioning, insufficient brand focus, limited marketing channels, and lack of personalized services need to be addressed. Moving forward, the company should diversify its offerings, refine its market positioning, and continuously adjust its marketing strategies to meet the demands of an ever-changing market. Ensuring the company’s long-term success depends on the effective implementation of these strategies.

In conclusion, MS Decoration Design Company, as a small to medium-sized enterprise, must make timely adjustments to its marketing strategies to stay competitive. The future of the company hinges on its ability to adapt to the market, focus on customer needs, and enhance its brand presence. Future research should continue to focus on monitoring the company’s performance and refining marketing strategies based on real-world results.

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Application of MATLAB-assisted Ridge Regression in Weight Reduction and Environmental Protection of Glass Bead Concrete

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Abstract

This study utilizes MATLAB to develop a Ridge regression prediction model, aimed at assessing the impact of incorporating vitrified microbead insulation sand into concrete on both weight reduction and environmental performance. Empirical findings indicate that substituting 20% of the manufactured sand with vitrified microbead insulation sand in C25 concrete reduces the concrete's weight from 24.98 kg to 24.68 kg, achieving a 0.12% reduction. Concurrently, the compressive strength is significantly enhanced, increasing from 38.5 MPa to 40.3 MPa, indicating a notable improvement in material performance. The weight of the model-predicted concrete is 24.8873 kg, closely aligning with the actual experimental data, thereby affirming the accuracy and reliability of the Ridge regression model. The findings of this study provide robust scientific evidence supporting the lightweight design and sustainable application of concrete materials, highlighting the extensive potential of vitrified microbeads in construction engineering.

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Introduction

Glass beads, an inorganic glassy mineral material made from slag such as silicon and aluminum that is melted at high temperatures and rapidly cooled, have stable physicochemical properties and excel in thermal insulation, fire protection, sound absorption, and lightweight. As a result, they are widely used in various fields such as construction, chemical engineering, and aerospace (Li, 2018; Wu et al., 2023). In the construction industry, glass beads are used as lightweight aggregate to enhance the flowability and self-compressive strength of the sand, reduce the shrinkage of the material, improve the comprehensive performance of the product, and at the same time, effectively reduce production costs (Azevedo, 2024; Hou et al., 2023; Li et al., 2020).

Wu Yuan's research indicated that mixing 20%-40% glass beads into concrete can significantly enhance its mechanical properties and effectively reduce its thermal conductivity, showing substantial energy-saving advantages (Wu, 2021). Through orthogonal experiments, Wang Xuan optimized the proportions of fly ash, silica fume, and glass beads in concrete to obtain the best combination of cubic compressive strength, splitting tensile strength, and flexural strength, which further demonstrated the significant advantages of glass bead concrete in energy saving (Wang, 2022). Additionally, other studies, such as the seismic performance analysis by Zhu Baohua and the shear wall tests by Gao Yuxuan, verified the potential of glass bead concrete in energy-saving and seismic applications, showing its promise as a sustainable building material (Gao et al., 2018; Zhu & Han, 2018).

However, relatively few studies have been conducted on the use of glass beads insulating sand for replacing mechanism sand to reduce the deadweight of concrete. Exploring this area could further enhance the market application value of glass beads. In order to summarize and deepen these studies, this paper investigated the effectiveness of glass bead insulating sand in replacing concrete with machine-made sand through experimental analysis, ultimately producing glass bead concrete with optimized properties. Using Matlab to construct a Ridge regression prediction model (Zeng & Lü, 2001), this study verified the impact of manufactured sand weight, the volume of glass bead insulation sand substitution, and the amount of water-reducing agent on the concrete weight. The aim of this research is to provide theoretical support and practical guidance for the application of glass bead concrete in future construction projects by optimizing concrete design, which will help its promotion and application in the construction industry.

Literature Review

With the acceleration of urbanization and the increasing energy consumption in buildings, developing energy-efficient and environmentally friendly building materials has become one of the core tasks in the construction industry. As a new type of lightweight material, glass beads have shown great potential in enhancing concrete performance due to their excellent insulation properties and lightweight characteristics (Li et al., 2017). Hou et al. (2023) found that using glassy fly ash microbeads as a concrete admixture can significantly improve its microstructure and enhance crack resistance and compactness. The addition of this material notably reduced the

heat of hydration released in concrete, thereby decreasing the risk of temperature-induced cracking and improving the stability and durability of the structure (Hou et al., 2023). This was further verified by Wu et al. (2023). The highly doped slag fly ash glass bead insulating sand walls had low thermal conductivity and excellent thermal insulation performance, achieving an energy-saving rate of over 50%, which strongly indicated the significant potential of glass beads in building energy-saving (Wu et al., 2023). Through orthogonal experiments, Liu et al. (2023) analyzed the impact of straw powder, polypropylene fibers, and glass beads on the thermal conductivity of insulation concrete. The results showed that glass beads can effectively extend the heat transfer path and enhance thermal insulation effect. In addition, the concrete crack width calculation method developed by Liu was using Matlab showed higher accuracy and efficiency than the traditional method, providing an innovative technical approach to crack detection (Liu et al., 2022).

In conclusion, glass beads exhibit significant potential in enhancing the thermal performance of concrete, improving structural durability, and reducing weight. Future research should focus on exploring their performance under various environmental conditions and the possibility of combining them with other innovative materials. These studies not only highlight the broad prospects of glass beads as an innovative material in construction engineering but also provide new perspectives and methods for developing lightweight and efficient building materials.

Materials and Experiment

Materials and Parameters

Cement: P•O42.5, sulfur trioxide content 2.44%, 3-day compressive strength 27.3 MPa. Glass beads Insulation Sand: JFGN inorganic insulation sand, dry density 256 kg/m³, linear shrinkage rate 0.085%.

Fly Ash: Fineness 45 μm, moisture content 0.1%.

Water-Reducing Agent: Polyhydroxy acid-based high-performance water-reducing agent, water release rate 57%, oxygen content 2.4%.

Manufactured Sand: Fineness modulus 2.6, apparent density 2602 kg/m³.

Crushed Stone: Particle size 5–10 mm, apparent density 1594 kg/m³.

Water: Potable water.

Mix Design

Based on China's Specification for Mix Proportion Design of Ordinary Concrete (JGJ55-2011), this experiment was designed for the performance of C25 grade normal concrete (NC) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2011). The same design mix was also referred for the preparation of Glazed Hollow Bead Concrete (GHBC). During the experiment, glass bead insulation sand was used to replace the volume of manufactured sand aggregate in normal concrete, with replacement ratios set at 0%, 15%, 20%, and 25%. The experimental mix proportions are shown in Table 1.

Table 1 Experimental Mix ratios for C25 Normal Concrete and Glazed Hollow Bead Concrete

Concrete	Water-Cement Ratio (W/C)	Cement /kg (y)	Crushed Stone/kg	Manufactured Sand/kg (x_1)	Fly Ash /kg	Glass bead Insulation Sand Replacement Ratio in NC /% (x_2)	Water-Reducing Agent /kg (x_3)	Water /kg
NC	0.50	7.735	33.705	33.75	3.325	0	0.21000	5.530
GHBC15	0.50	7.735	33.705	29.25	3.335	15	0.21545	5.530
GHBC20	0.50	7.735	33.705	27.56	3.335	20	0.21686	5.530
GHBC25	0.50	7.735	33.705	25.92	3.335	25	0.21328	5.530

Note: In the experimental mix proportion table, the independent variables include the weight of manufactured sand (x_1), the replacement ratio of glass bead sand(x_2), and the weight of the water-reducing agent (x_3), while the dependent variable is the weight of the cement (y)

Testing Methods

This study employed the cement-coated sand method (Hu, 2021) to prepare Glazed Hollow Bead Concrete (GHBC). Based on the design mix ratios, precise measurements of cement, glass bead insulation sand, manufactured sand, coarse aggregate, and fly ash were taken. The amounts of water-reducing agent and water were adjusted according to the cement ratio and the desired slump. Firstly, the weighed manufactured sand, coarse aggregate, fly ash, and glass bead insulation sand were mixed with some water. Secondly, cement and the remaining water were added and mixed until evenly distributed. Thirdly, the water-reducing agent was combined with part of the water to form a solution, which was slowly added to the mixer, gradually incorporating the remaining water to achieve a uniform concrete texture. Then, a portion of the mixed concrete was taken for a slump test, and adjustments to the water or water-reducing agent were made as needed to achieve the desired slump. Standard 150mm cubic test molds were selected (Hou et al., 2023), and a vibrating plate was used to remove air bubbles and compact the concrete. After the final setting, the specimens were placed in a standard curing room for standard curing. At 7 and 28 days of curing, the weight, load, and strength of the specimens were tested to evaluate whether they met the design requirements. The GHBC experiments are illustrated in Figure 1.

Figure 1 Concrete Mixing, Specimen Weight and Concrete Performance Testing

Results and Discussion

Experimental Results

In the experiment, glass bead insulation sand was mixed into C25 normal concrete and Glazed Hollow Bead Concrete (GHBC) at different ratios. The results showed improvements in slump, spread, specimen weight, failure load, and compressive strength, with performance parameters detailed in Table 2. Specifically, the specimen weight changed as the volume of manufactured sand replaced by glass bead insulation sand increased: with a 15% replacement ratio, the weight decreased by 0.04%; with a 20% replacement ratio, the weight decreased by 0.12%; however, with a 25% replacement ratio, the weight increased by 0.72%. This indicates that mixing an appropriate amount of glass bead sand can effectively reduce the weight of the concrete. To analyze the impact of different replacement ratios on concrete weight more scientifically, this study utilizes Matlab to develop a Ridge regression prediction model, verifying the feasibility and effectiveness of reducing concrete weight by substituting manufactured sand with glass bead insulation sand.

Table 2 Performance Parameters of C25 Normal Concrete and Glazed Hollow Bead Concrete

Concrete	Slump /mm	Spread /mm	Concrete Weight f_{mg}/kg	Failure Load f_{Pf}/KN 28d	Compressive Strength $f_{cu,o}$/Mpa 28d
NC	145	315	24.98	865.167	38.5
GHBC15	200	269	24.99	999.967	44.4
GHBC20	195	283	24.68	908.167	40.3
GHBC25	205	248	25.17	913.167	40.6

Note: In the experimental results table, the dependent variables include the concrete weight, 28-day compressive strength, and others.

MATLAB Ridge Regression Analysis

To study the impact of the volume of glass bead sand replacing manufactured sand in concrete, as well as the weight of manufactured sand and water-reducing agent on the weight of concrete, a Ridge regression prediction model was designed in this study using Matlab. Ridge regression achieves parameter shrinkage through regularization, specifically by adding a penalty term to the loss function (least squares method), as shown in Equation (1):

$$L(\beta) = \sum_{i=1}^{n}(y_i - \sum_{j=1}^{p} x_{ij}\beta_j)^2 + \lambda \sum_{j=1}^{p} \beta_j^2$$

$$L(\beta) = \sum_{i=1}^{n}(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_{ij})^2 + \lambda \sum_{j=1}^{p} \beta_j^2 \quad \text{.....(1)}$$

In this equation, λ is the regularization parameter, where a larger λ value imposes a stronger constraint on the model parameters, bringing them closer to zero, thereby reducing the likelihood of overfitting. p represents the number of features or independent variables. As λ increases, the penalty term becomes more significant, leading to greater compression of the model coefficients.

After incorporating the regularization term, the linear regression equation for Ridge regression effectively reduces the complexity of the model, particularly in the presence of multicollinearity issues, thereby enhancing the generalization capability of the model. Before applying Ridge regression, the input variables have to be standardized to eliminate the influence of different dimensions. The standardization formula is shown in Equation (2):

$$z = \frac{x-\mu}{\sigma} \quad \text{.....(2)}$$

Where:

- X is the independent variable, represents the standardized values of the independent variables, including *WmsA*, *VrepB*, and *WadC*.;
- μ is its mean;
- σ is its standard deviation.

By introducing the regularization term into the regression equation, Ridge regression can effectively address potential overfitting issues that may arise in ordinary least squares (OLS) regression, so as to improve the predictive accuracy for new data. The regression prediction model is expressed as follows:

$$\hat{Y} = b_o + b_1 Z_{W_{msA}} + b_2 Z_{W_{repB}} + b_3 Z_{W_{adC}} \quad \text{.....(3)}$$

Where:

Z_{WmsA} : Standardized weight of manufactured sand;

Z_{VrepB} : Standardized replacement ratio of vitrified microbead sand;

Z_{WadC} : Standardized additional parameter.

Y : represents the actual measured weight of the concrete.

$\hat{y}$: represents the concrete weight predicted by the Ridge Regression model.

By introducing the λ term, Ridge regression effectively mitigates the potential overfitting problem associated with ordinary least squares (OLS) regression and enhances the prediction of unknown data. Using this model and its computational principles, it is possible to accurately predict the weight of concrete based on the new decision variables and to gain a deeper understanding of the statistical reasoning behind the model

Based on the data related to the replacement of manufactured sand with glass bead sand from Table 1 and 2, Matlab was used to perform Ridge regression prediction. The regression coefficients obtained from the model were: an intercept of 24.9550, a manufactured sand weight coefficient of -0.0421, a glass bead replacement ratio coefficient of 0.0438, and a water-reducing agent weight coefficient of -0.1271. The predicted values were 25.0023, 24.8873, 24.8687, and 25.0617 respectively. These results demonstrate the linear impact of the Ridge regression coefficients on the target variable and indicate that the model effectively captures trends. Overall, the model's predictions are close to the actual values, as shown in Figures 1. The residuals are generally small, indicating a good fitting effect, as illustrated in Figure 1. Meanwhile, the two-dimensional field plot analysis reveals that the interaction effect between the weight of manufactured sand and the replacement ratio of glass bead sand is relatively complex, as shown in figure 1, which highlights the need for careful selection of appropriate proportions in concrete mix design to achieve optimal performance.

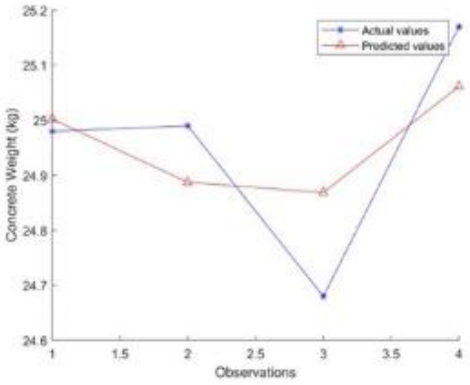

Figure 2 Comparison of Actual and Predicted Values

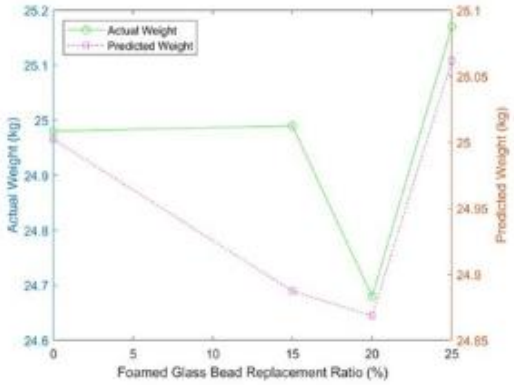

Figure 3 Actual vs. Predicted Weight with Multi-Y Axis

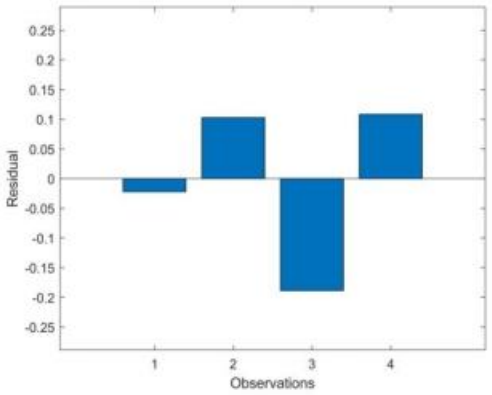

Figure 4 Residuals Plot

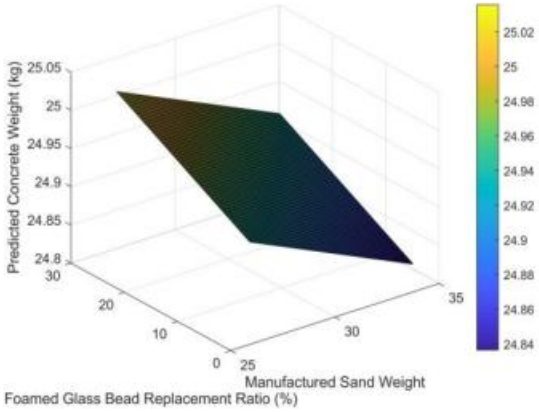

Figure 5 Two-Dimensional Field Plot

In summary, the experiment demonstrates that when glass bead insulation sand is mixed into C25 normal concrete and Glazed Hollow Bead Concrete (GHBC) at different ratios, the performance parameters, such as slump, spread, specimen weight, failure load, and compressive strength, show improvement. Notably, with a 20% replacement ratio, the concrete weight decreased by 0.12%, from 24.98 kg to 24.68 kg, while the compressive strength increased to 40.3 MPa, a significant improvement compared to the 38.5 MPa of normal concrete. Ridge regression model analysis using Matlab yielded the following regression coefficients: an intercept of 24.9550, a manufactured sand weight coefficient of -0.0421, a glass bead insulation sand replacement ratio coefficient of 0.0438, and a water-reducing agent weight coefficient of -0.1271. The predicted concrete weight was 24.8873, which closely matched the actual data, indicating that the model had a good fit. The study shows that a 20% replacement ratio not only effectively reduces the weight of C25 normal concrete but also improves its mechanical properties, highlighting the significant advantages of using glass bead sand in concrete.

Conclusions and Future Directions

The experimental study indicates that with 20% glass bead insulation sand replacement, the performance of C25 concrete is significantly improved. Specifically, the concrete weight decreased from 24.98 kg to 24.68 kg, a reduction of 0.12%, demonstrating the significant effect of glass bead insulation sand in weight reduction. Meanwhile, the compressive strength increased from 38.5 MPa to 40.3 MPa, indicating that it not only reduces weight but also enhances strength.

The analysis of Matlab's Ridge regression model confirmed the effectiveness of substituting glass bead sand for manufactured sand in reducing weight and increasing strength. Model predictions are highly consistent with the actual data, with small residuals and excellent fitting results.

Furthermore, the reduced concrete weight cuts down construction and transportation energy consumption and carbon emissions. By replacing natural sand and gravel with glass bead insulation sand, natural resources can be conserved, environmental damage will be reduced, and the excellent thermal insulation properties can also

improve building energy efficiency and reduce operational costs.

In conclusion, glass bead thermal insulation sand shows a broad prospect in construction projects, not only to optimize the performance of concrete, but also to bring significant social and economic benefits, with great value of promotion and application.

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Global Green Logistics: Challenges and Opportunities in Vietnam's Sustainable Development

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Abstract

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The continuous intensification of global climate change makes it imperative for governments and companies to take effective measures to achieve carbon neutrality goals and reduce carbon emissions. As one of the main sources of carbon emissions in the global supply chain, the logistics industry is facing an urgent need for transformation. As a global manufacturing and exporting powerhouse, Vietnam's logistics industry is facing the challenge of high carbon emissions and technological lag while promoting economic growth. This study aims to explore the problems faced by Vietnam's logistics industry in terms of infrastructure, technology application, policy framework and finance, and propose short-term, medium-term and long-term development strategies based on international experience to promote the green transformation of Vietnam's logistics industry. The results of this study show that Vietnam should strengthen infrastructure construction, promote policy and regulatory reforms, raise environmental awareness of enterprises and society, and actively introduce smart logistics technologies and green financial tools to achieve carbon neutrality. Finally, this study provides concrete policy recommendations aimed at assisting the Vietnam government and enterprises to accelerate the sustainable development of the logistics industry.

Keywords: Green Logistics, Carbon Neutrality, Vietnam Logistics Industry, Green Technology, Sustainable Development

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Introduction

Green Logistics - Challenges and Opportunities in Vietnam

The urgency of global climate change and the goal of net-zero emissions

1. Global impacts of climate change According to the United Nations Framework Convention on Climate Change (UNFCCC), the average global temperature has risen by about 1.2 degrees Celsius since the Industrial Revolution. This change has led to frequent extreme weather events such as droughts, floods, and heat waves, which have far-reaching impacts on the global economy and the environment (UNFCCC, 2021). Scientists warn that if the global average temperature rises by more than 2 degrees Celsius, it will trigger an irreversible ecological catastrophe (Ogunbode, 2020). As a result, countries around the world must take more stringent measures to reduce emissions to ensure that temperature rise is kept under control.

2 The development of carbon neutrality policies and the trend of green logistics in various countries Countries have put in place several policies to achieve carbon neutrality to reduce carbon emissions and promote the development of green logistics:

- European Union: The European Union has proposed a "European Green Deal" to achieve carbon neutrality by 2050 and a series of policies for the transport sector to phase out fossil fuel vehicles and support the development of electric and hydrogen vehicle technologies (Gengnagel & Zimmermann, 2022).
- China: China's 14th Five-Year Plan clearly states that it will peak carbon emissions by 2030 and achieve carbon neutrality by 2060. China's logistics industry is actively adopting electric vehicles and intelligent logistics management systems to promote green warehousing technologies to reduce carbon emissions (Wei et al., 2020).
- United States: The United States passed the Clean Energy Act, which commits to net zero emissions by 2050 and increases investment in green infrastructure, especially in electric vehicle infrastructure, to encourage logistics companies to transition to electrification (Zhou & Noonan, 2019).

3. Support from international organizations for the development of green logistics International organizations have played an important role in promoting green logistics:

- United Nations: The United Nations promotes green logistics in global supply chains through the Sustainable Development Goals (SDGs). The United Nations Climate Change Conference (COP) is held annually to promote cooperation between countries in carbon emission reduction, carbon trading and technology transfer (Clark & Wu, 2016).
- World Bank and International Monetary Fund (IMF): The World Bank and IMF support developing countries to build green logistics infrastructure through green financial instruments and funds, and provide technical assistance and financial support to countries such as Vietnam to promote sustainable development (Khan, 2019; Gabor et al.,2019)

Current situation and challenges of Vietnam's logistics industry

1. Vietnam's important position in the global supply chain

Vietnam is a key manufacturing and exporter in the global supply chain, especially in the fields of electronics, textiles and agricultural products. According to Vietnam's government data, the country's annual exports have exceeded $240 billion, with about 70% of its goods relying on the global logistics system to operate. However, as Vietnam continues to integrate into the global market, logistics demand continues to rise, which also brings serious problems of high carbon emissions. Currently, the logistics sector accounts for nearly 20% of Vietnam's total carbon emissions, becoming one of the important challenges for Vietnam to achieve carbon neutrality (Vu, 2019; Le, 2022).

2. The rapid growth and challenges of Vietnam's logistics industry

Vietnam's logistics industry is growing at an annual rate of more than 12%, especially driven by the booming cross-border e-commerce, which has become one of the core drivers of the country's economic growth. However, poor infrastructure and inefficient operating models, especially traffic congestion, make it difficult for Vietnam to cope with the growing demand for green logistics. According to the World Bank, Vietnam's port operations are significantly less efficient than the global average, and cargo clearance takes an average of 2 to 3 days longer than the rest of Southeast Asia, which negatively impacts the operational efficiency of international supply chains. In addition, the dependence of ports and logistics facilities on fossil fuels further exacerbates the problem of carbon emissions (Nguyen et al., 2018; Hansen, 2023).

Research Objectives

This study aims to achieve the following specific objectives:

1. Analyze the role of Vietnam's logistics industry in the global green transition
   - Deeply explore the current situation and development potential of Vietnam's logistics industry in the process of green transformation and analyze the challenges facing the country in terms of infrastructure, technological innovation, policy promotion and financial support.
2. Formulate short-, medium- and long-term green logistics development strategies
   - Propose a specific development path:

Short-term (1-2 years): Rapid improvement of infrastructure efficiency and promotion of the initial application of green logistics technologies.

Medium-term (3-5 years): Strengthen the popularization of green technologies and improve the implementation of relevant policies and regulations.

Long-term (5-10 years): Achieve a nationwide low-carbon logistics network and enhance Vietnam's competitiveness in the global green supply chain.

3. Draw on international successful cases and put forward policy recommendations Analyze successful international green logistics cases, learn lessons from other countries and regions, and provide feasible policy

recommendations for the Vietnam government and enterprises to promote the sustainable development of the logistics industry.

Literature review

As an important strategy to cope with global climate change, green logistics has become a widely discussed topic in academia and industry. According to the report of the United Nations Framework Convention on Climate Change (UNFCCC), the average global temperature has risen by 1.2 degrees Celsius, and extreme weather events are frequent (UNFCCC, 2020). Therefore, countries have promoted carbon neutrality policies, and the logistics industry, as an important part of the global economy, is also facing transformation pressure. The European Green Deal proposed by the European Union emphasizes achieving carbon neutrality by 2050 (European Commission, 2019), while major economies such as China and United States have also introduced policies to promote the development of low-carbon logistics (State Council of China, 2021; U.S. Congress, 2022)

In the practice of green logistics, the upgrading of technology and infrastructure is the key driving force. The literature states that the adoption of intelligent logistics systems and green energy technologies can help reduce carbon emissions (Zhu & Sarkis, 2004). However, many developing countries face challenges in promoting green logistics, such as insufficient funding, technological backwardness, and difficulties in policy implementation (Verma, 2024). As an important manufacturing country in the global supply chain, Vietnam's logistics industry is growing rapidly, but its inefficient infrastructure and dependence on traditional fuels pose challenges to carbon neutrality goals (Nguyen & Le 2020).

At the same time, international organizations such as the World Bank and the International Monetary Fund (IMF) are also actively promoting green finance and technology transfer to support developing countries such as Vietnam in achieving the Sustainable Development Goals (World Bank, 2021). These international assistance is crucial for Vietnam's green logistics transition, with the scholars emphasizing government-business cooperation in formulating policies and drawing on international success stories, such as the experiences of Europe, Japan and other countries, to provide direction for the sustainable development of Vietnam's logistics industry (Pham et al., 2023).

In conclusion, the existing literature shows that countries around the world are facing different degrees of challenges and opportunities in the process of promoting green logistics. Although Vietnam plays an important role in the global supply chain, it still needs international cooperation, technological progress and strong government policies to achieve a low-carbon transition.

Research Methodology

This study uses a combination of literature review and current situation investigation to analyze the green transformation of Vietnam's logistics industry. First, through extensive collection of secondary data related to green

logistics, carbon neutrality policies and global supply chains, the development trends and successful cases of international green logistics were sorted out, and Vietnam's position and challenges in the global supply chain were analyzed. Secondly, in view of the current situation of Vietnam's logistics industry, through policy documents, reports and official data, we understand the current situation of the country in terms of infrastructure, technology application, policy support and capital needs. In addition, this study draws on the green logistics practices of other developing countries, summarizes their successful experiences, and proposes specific short-, medium- and long-term development strategies for the Vietnam government and enterprises to reference.

Results & Discussion

Analysis of survey results: Problems and challenges of green logistics in Vietnam

1. Inadequate infrastructure Challenges of road, port and rail infrastructure:

O There is still room for improvement in Vietnam's road network. Despite the government's heavy investment in infrastructure, traffic congestion and poor road quality persist, resulting in slow logistics and transportation, especially around large cities and ports.

O Case in point: According to the World Bank report, Vietnam's ports are less efficient in handling cargo, with an average loading and unloading time of more than 2 days per 20-foot container, compared to 1.5 days per 20-foot container in other Asian countries (Dappe & Suárez-Alemán, 2016). This not only delays the international movement of goods, but also increases energy consumption and further exacerbates carbon emissions.

The lack of charging infrastructure is limiting the adoption of electric vehicles:

O Although electric vans are seen as one of the main technologies to solve the carbon emission problem of the logistics industry, Vietnam's EV charging infrastructure is severely insufficient, which greatly limits the adoption of electric logistics vehicles. The existing charging stations are mainly concentrated in a few large cities, and the logistics hubs and major transport corridors lack the corresponding infrastructure support.

O Data: According to the Ministry of Industry and Trade of Vietnam, as of 2022, there were only about 500 charging stations in Vietnam, compared to hundreds of thousands of EV charging stations in China and the EU (Le et al., 2022). This means that Vietnam still has a long way to go in terms of infrastructure construction to catch up with global trends.

2. The application of green technologies is lagging behind Difficulties in the application of electric vehicles and clean energy fleets:

O Despite the rapid adoption of electric vehicles worldwide, the use of electric vehicles and clean energy vehicles in Vietnam's logistics industry is still very limited. High purchase costs, insufficient battery life, and a lack of charging infrastructure have led to a low willingness to adopt such technologies.

O Example: According to the statistics of the Ministry of Transport of Vietnam, as of 2023, Vietnam's electric trucks account for less than 1% of the total logistics fleet, compared to more than 20% in EU countries such as Germany (Nguyen et al., 2024).

The penetration rate of smart logistics technology is low:

O Smart logistics technologies, such as the Internet of Things, artificial intelligence and big data, can greatly improve the efficiency of logistics and transportation and reduce energy consumption. However, the awareness and application of these technologies in Vietnam's logistics industry is still low, and many enterprises still rely on traditional manual operations and management methods.

O Data: According to a survey by the Vietnam Chamber of Commerce, less than 15% of logistics companies use smart logistics management systems, compared to more than 50% in the EU and United States (Van Ha, & Giang, 2023).

3. Inadequate policies and regulations Lack of specific carbon reduction policies and incentives:

O Although the Vietnam government has committed to reducing carbon emissions in a number of international agreements, the specific policy framework is still not perfect. Existing environmental regulations are mainly aimed at the manufacturing and energy sectors, while guidance on emissions reductions in the logistics sector is still missing.

O International comparisons: The European Union has introduced the European Green Deal, and the United States has encouraged the development of low-carbon technologies through the Clean Energy Act, which provides clear guidance for companies to reduce emissions (Fetting, 2020).

4. Funding and technical bottlenecks Funding shortfall for SMEs:

O Vietnam's large logistics companies have a certain amount of capital reserves to invest in green technologies, but SMEs often face the problem of insufficient funds. The high cost of technology transition makes it impossible for many SMEs to afford an initial investment in green technology.

O Data: According to a survey by the Vietnam Association for the Promotion of Small and Medium Enterprises, more than 80% of small and medium-sized logistics enterprises said that they were unable to adopt advanced green logistics technologies due to a lack of funds, which led to their disadvantage in the market competition (Chowdhury et al., 2022).

Lack of technology transfer and cooperation platforms:

O Vietnam logistics enterprises lack an effective technology transfer and cooperation platform, and it is difficult to obtain international advanced technology. Many business owners said that although they are aware of the importance of smart logistics and green technology, they are unable to carry out technology upgrades smoothly due to the lack of relevant technical support and cooperation opportunities.

O International experience: China and EU countries have effectively applied advanced electric vehicles and intelligent transportation technologies to the logistics industry through technology transfer cooperation platforms, and have achieved significant emission reduction results (Chen, & Kenney, 2016).

5. Weak social awareness Lack of environmental awareness among the public and businesses:

O In Vietnam, society's awareness of green logistics and sustainable development is still limited. Many logistics companies are still focused on reducing short-term operating costs, with less consideration for long-term environmental benefits.

O Data: According to a survey by the Vietnam Environmental Protection Organization, about 60% of logistics company management lack understanding of carbon neutrality goals, which directly affects the enthusiasm of enterprises in adopting green technologies (Ngo, 2022).

Table 1 Overview of the main issues and challenges of green logistics in Vietnam

Problems and challenges	description	Data/Case
Inadequate infrastructure	Road and traffic congestion affects the speed of logistics.	Port loading and unloading time is more than 2 days.
	Charging facilities are lacking.	Only about 500 charging stations.
Technology adoption lags	Low use of electric vehicles.	Less than 1% are electric vans.
	Smart technology is used sparingly.	Only 15% use smart systems.
The policy is not perfect	There is a lack of policy guidance on emissions reduction.	The EU already has a policy in place.
Funding and technical bottlenecks	Small and medium-sized enterprises are underfunded.	80% of small and medium-sized enterprises cannot transform.
	Lack of technology transfer platforms.	Effective use of technology in China and the EU.
Weak social awareness	Lack of environmental awareness.	60% of management does not understand carbon neutrality.

Short-term strategy (1-2 years): infrastructure and policy framework

1. Promote the establishment of policies and regulations Establish carbon reduction policies and targets:

O Target setting: The Vietnam government should set specific carbon reduction targets based on global trends and domestic demand, such as reducing carbon emissions from the logistics industry by 30% by 2030. This can be achieved through the introduction of a carbon tax and carbon cap system, as well as the development of relevant guidelines.

O International comparisons: The EU's Climate Act provides for a reduction in carbon emissions by at least 55% by 2030 (Bäckstrand, 2022).

Launch of the Low Carbon Transport Act:

O The government should introduce the Low Carbon Transport Law as soon as possible, which will set out mandatory low-carbon measures for the logistics industry, requiring all logistics companies to phase out fuel vehicles and replace them with electric vehicles or other clean energy vehicles in the next 5 to 10 years.

2. Infrastructure construction Investing in green logistics infrastructure:

O Construction of EV charging stations: Vietnam should prioritize the construction of EV charging stations and new energy supply stations in large cities and major logistics hubs to promote the application of electric trucks.

O International comparisons: China has made significant progress in the construction of charging facilities, with the number of charging piles in the country exceeding 1 million by 2023 (Hu et al., 2024).

Promote the energy transformation of logistics warehouses:

O The Vietnam government should encourage logistics companies to retrofit their warehouses and gradually adopt renewable energy sources such as solar and wind power to supply the energy needs of storage facilities.

O Case in point: In Europe, Amazon's green warehouse in Germany uses solar and wind power to provide electricity demand and improve energy efficiency through intelligent management systems (Araujo et al., 2022).

Table 2 Short-term (1-2 years) strategies and infrastructure construction to promote green logistics in Vietnam

Short-term strategy	content
Drive policies and regulations	
Carbon reduction policies and targets	Set a target of reducing carbon emissions by 30% by 2030 and introduce a carbon tax and cap system.
Low-carbon transport law	Mandatory low-carbon measures have been introduced, requiring the phasing out of fuel vehicles and switching to electric or clean energy vehicles.
Infrastructure development	
Green logistics infrastructure	Construction of EV charging stations in major cities and logistics hubs.
Warehouse energy retrofit	Encourage logistics companies to use renewable energy to supply storage facilities.

Medium-term strategy (3-5 years): technology application and regional cooperation

1. Expansion of the application of technology

Full promotion of electric vehicle fleets:

O Among the medium-term goals, Vietnam should fully promote electric trucks and other clean energy vehicles on major logistics routes. The government should develop specific subsidy policies and purchase incentives to incentivize logistics companies to gradually replace old fuel vehicles. This will effectively reduce the carbon emissions of the logistics industry and enhance its international competitiveness.

O Case in point: Companies such as UPS and FedEx in the United States have replaced some of their fleets with electric and hydrogen vehicles and achieved significant emissions reductions. While reducing carbon emissions, these companies have also reduced long-term operating costs through technological innovation.

Digital management of the whole logistics process:

O Logistics companies in Vietnam should fully promote digital management of the entire logistics process, using the Internet of Things, big data and artificial intelligence technologies for transportation monitoring, route optimization and inventory management. This not only improves transport efficiency, reduces empty trucks and energy waste, but also makes the entire logistics chain more transparent and traceable.

O Case Study: In China, JD Logistics has realized the digital management of the entire logistics process, greatly improved distribution efficiency and reducing carbon emissions by more than 30% through intelligent distribution and automated warehousing technology.

2. Construction of regional green logistics hubs Construction and expansion of green logistics hubs:

O The Vietnam government should turn major cities such as Hanoi and Ho Chi Minh City into green logistics hubs, focusing on green warehousing, low-carbon transportation, and renewable energy infrastructure. These green logistics hubs will provide efficient and low-carbon logistics solutions for domestic and foreign logistics companies, enhancing Vietnam's competitiveness in the global supply chain.

O International example: The Port of Rotterdam in the Netherlands has become the world's leading green logistics hub, with logistics facilities operating entirely on renewable energy and the world's most advanced electric van and hydrogen logistics infrastructure, serving as a model for other countries to follow.

Strengthen regulations and supervision

1. Establish a carbon emission supervision mechanism:

O Vietnam should establish a national carbon emission monitoring system to monitor the carbon emissions of logistics companies through data management. The government can use the Internet of Things and big data technology to track each company's carbon emissions data in real time and regularly publish the achievement of emission reduction targets.

O International comparisons: The European Union has established a complete carbon emission regulatory system, allowing companies in various countries to conduct carbon trading according to carbon emission allowances. This not only effectively monitors carbon emissions, but also incentivizes companies to reduce emissions through market mechanisms.

2 Introduction of carbon trading market:

O In Vietnam, the government should gradually introduce a carbon trading system to allow companies to trade carbon allowances, reduce emission reduction costs through market-based means, and achieve a low-

carbon transformation of the logistics industry. This will provide new investment opportunities for Vietnam's logistics industry and accelerate the adoption of green technologies.

Table 3 Medium-term (3-5 years) strategy for the low-carbon transition of Vietnam's logistics industry: technology application and regional cooperation

Policy category	Specifics	Cases/Comparisons
Technology application	Electric vehicle fleet promotion	Promote electric trucks in key logistics routes, and develop subsidies and preferential policies to reduce carbon emissions and improve competitiveness. Case in point: UPS, FedEx have replaced some of their fleets with electric and hydrogen vehicles.
	Digital management	Promote digital logistics management, use the Internet of Things, big data, and artificial intelligence to monitor transportation and optimize routes, and improve efficiency. Case: JD Logistics realizes digital management, improves distribution efficiency, and reduces carbon emissions by 30%.
Regional cooperation	A green logistics hub	Build green logistics hubs such as Hanoi and Ho Chi Minh City, develop green warehousing and renewable energy infrastructure, and enhance competitiveness. Case in point: The Port of Rotterdam becomes a global green logistics hub that relies on renewable energy.
Regulatory Strengthening	Carbon emission regulation	Establish a national carbon emission supervision system, and use data management to monitor carbon emissions. Comparison: The EU has established a carbon emission regulatory system to support carbon trading.
	Carbon trading market	Gradually introduce a carbon trading system to reduce the cost of emission reduction, promote low-carbon transformation, and provide investment opportunities.

Long-term strategy (5-10 years): zero-carbon logistics and global competitiveness

Fully realize zero-carbon logistics

1. Fully zero-carbon logistics system:

O Vietnam should achieve a fully carbon-free logistics system in its long-term goal, with all logistics hubs, warehouses and means of transport achieving zero carbon emissions. The government should enact

mandatory regulations requiring all logistics companies to use electric or hydrogen vehicles, and convert logistics and warehousing facilities to 100% renewable energy.

O Case in point: Amazon has pledged to achieve a company-wide carbon neutrality goal by 2040, and its logistics system has begun to fully adopt electric vehicles and green energy warehousing, and is gradually achieving zero carbon emissions from its logistics operations.

2. Promoting hydrogen energy and advanced logistics technologies:

O Vietnam should actively promote the application of hydrogen energy technology, especially in heavy-duty trucks and long-distance transportation. The government should increase investment in hydrogen infrastructure and work with international partners to develop advanced hydrogen logistics technologies to achieve full decarbonization of the logistics industry.

O International example: The Japan government has vigorously promoted hydrogen logistics technology and cooperated with Germany and Korea on the research and development of hydrogen trucks. Through technical cooperation and investment, these countries have gradually realized the commercial application of hydrogen logistics vehicles.

Enhance Vietnam's competitiveness in the global green logistics market

1. International promotion of green logistics products:

O Vietnam should promote its green logistics products to the global market through international cooperation and market promotion. The government should establish green trade agreements with international trading partners such as the EU, North America and ASEAN, promote the export of low-carbon goods and services, and attract multinational companies to set up their supply chains in Vietnam.

O Case in point: Vietnam can learn from the EU's Green Supply Chain Initiative, which provides incentives for multinational companies to sell green products in the European market, to enhance the international competitiveness of green logistics products through trade agreements and policy support.

Promote international cooperation and technological innovation

1. Deepening international cooperation:

O Vietnam should strengthen cooperation with other countries and regions around the world, participate in the formulation of global logistics standards, and actively promote global green logistics innovation projects. Vietnam can obtain technical support and jointly carry out research and development of green logistics technologies by cooperating with the European Union, United States and Asian countries.

O Examples: For example, the "Green Logistics Technology Alliance" jointly launched by the European Union and Japan focuses on the research of electric vehicles, hydrogen logistics technologies and intelligent logistics systems. Vietnam can participate in such international cooperation and upgrade its logistics technology through technology transfer.

Table 4 Long-term (5-10 years) development strategy of Vietnam's logistics industry: achieving zero-carbon goals and enhancing global competitiveness

tactics	Specific measures
Zero-carbon logistics	- Zero-carbon logistics system: electric and hydrogen vehicles are used, and storage facilities are 100% renewable energy. - Case in point: Amazon plans to be carbon neutral by 2040. - Promoting hydrogen technology: hydrogen applications for heavy-duty trucks and long-distance transportation. - Case study: Japan cooperates with Germany and Korea to promote hydrogen energy technology.
International competitiveness	- International promotion of green logistics products: Establish green trade agreements with trading partners such as the European Union to promote the export of low-carbon products. - Case Study: The European Union's Green Supply Chain Initiative promotes the sale of green products.
International cooperation	- Deepen international cooperation: Participate in the formulation of global logistics standards and promote green logistics innovation projects. - Case study: Collaborative research between the EU and Japan's "Green Logistics Technology Alliance".

Conclusions and Recommendations: The Future of Green Logistics in Vietnam

Looking forward to the opportunities and challenges of the future

As the global demand for reducing carbon emissions becomes more stringent, the green transformation of Vietnam's logistics industry has become an inevitable trend. In the next 10 years, Vietnam will face competitive pressure from domestic and foreign markets, but also huge development opportunities. With infrastructure upgrades, technological innovations, and policy improvements, Vietnam will be able to become an important player in the global green logistics market.

The positive impact of green logistics on Vietnam's economy, society and environment

By promoting green logistics, Vietnam can not only reduce carbon emissions in the logistics industry, but also improve supply chain efficiency, reduce operating costs, and further attract foreign investment and international cooperation. The promotion of green logistics will also create a large number of jobs and improve the living standards of the people, so as to achieve the dual goals of economic growth and environmental protection.

Long-term strategy for sustainable development in the future, Vietnam should continue to maintain a global vision, take green logistics as the core strategy for sustainable development, and gradually realize the comprehensive green transformation of the logistics industry through technological innovation, policy support and international cooperation. This will lay a solid foundation for Vietnam in the global green economy and ensure that Vietnam will maintain a competitive advantage in the international market in the future.

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Envisioning the Future of Supply Chain Transportation Management- Exploring Crowd Density Image Recognition with Deep Learning

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Abstract

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Over the past few decades, artificial intelligence (AI) technology has made significant progress, especially in image recognition and natural language processing. Deep learning, as a multi-level artificial neural network architecture, can automatically identify and learn data features through large amounts of data to achieve high-precision prediction and identification. This research aims to explore the practical application of deep learning in the field of image recognition, and designs an automated image recognition system, taking the identification of crowd density in a train carriage as an example. The system can accurately detect the number of passengers in each carriage, thereby optimizing urban rail transit strategies, ensuring even distribution of passengers and providing the best commuting experience. This technology also has important implications for supply chain management. Accurate people flow identification technology can improve resource utilization efficiency, optimize logistics resource allocation, and reduce transportation time and costs through real-time monitoring and prediction of people flow density. It can also improve demand forecasting and analyze historical data through deep learning algorithms to help companies predict demand more accurately and avoid excessive transportation and shared traffic. This technology enhances supply chain transparency and promotes sustainable development by monitoring the entire transportation process in real time. These applications can improve the operational efficiency of the transportation system and significantly improve the quality and efficiency of supply chain management, demonstrating the huge potential of deep learning technology in modern supply chain management.

Keywords: Artificial Intelligence, Deep Learning, Image Recognition, Machine Vision, Supply Chain

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Introduction

Preamble

The fusion of data and technology has marked a new revolutionary turning point. Among these, artificial intelligence (AI) has showcased its revolutionary potential across various domains. From healthcare and finance to every aspect of daily life, AI technology is profoundly impacting the way we work and live.

In recent years, especially deep learning technology, it has exhibited unparalleled capabilities in handling complex image and language data. These advancements are not just theoretical breakthroughs but have changed the way we approach problems in real-world applications. For instance, utilizing deep learning to optimize metropolitan rail transport strategies can fundamentally enhance the commuting experience for passengers.

However, the genuine integration of these technologies into practical applications and the realization of their potential value remains a significant challenge for many researchers and engineers. In light of this, this research delves deep into the practical applications of deep learning in the field of image recognition, taking the identification of human density within train carriages as a case study. The aim is to offer fresh perspectives and solutions for the optimization of metropolitan rail transport strategies.

Research Background

With the accelerated development of global informatization and digitization, data has become the core asset of modern society. Among these, image data, due to its vast informational content and intricate structure, poses massive challenges for automatic recognition and analysis. In the past, traditional image processing techniques could extract basic features and recognize images, but their performance was often limited in highly complex and dynamically changing environments.

In recent years, deep learning has spearheaded a new wave of artificial intelligence, especially in the domain of image recognition, demonstrating capabilities that surpass traditional methods. Yet, translating these advanced techniques into practical applications still requires overcoming various technical and engineering obstacles.

Rail transportation, being a crucial pillar of urban development, faces burgeoning passenger flows with accelerating urbanization. Ensuring a balanced distribution of passengers within carriages to provide a comfortable commuting experience has become an urgent demand in the transport industry. Exploring the practical applications of deep learning in this domain holds profound academic significance and offers novel solutions for the real-world operations of urban rail transport.

Research Motivation

With global rapid development, rail transportation has increasingly become the central transportation infrastructure of cities, where its efficiency directly affects the quality of life for urban residents and the economic vitality of the city. However, during peak transportation hours, drastic variations in human density within carriages lead to diminished passenger experiences and unbalanced utilization of transport resources. This not only inconveniences passengers but also poses challenges to the operational efficiency and safety of metropolitan rail systems.

Traditional methods of crowd monitoring and analysis often rely on manual counts or rudimentary sensor technologies, such as CCTV, infrared sensors, or manual tallying. These methods struggle to achieve real-time, high-precision analysis when faced with large-scale, high-frequency, and dynamically changing crowd data. Hence, there's a need for a method that can automatically and accurately identify and analyze human density within train carriages.

In recent years, deep learning has achieved astonishing feats in the realms of image recognition and analysis. Its potent feature extraction and pattern recognition capabilities make it an ideal choice for optimizing metropolitan rail transport strategies. This research, grounded in deep learning, explores its potential in recognizing human density within train carriages, aspiring to offer a more efficient and intelligent solution for existing transport strategies. The ultimate goal is to enhance the commuting experience for passengers and boost the operational efficiency of rail transportation.

The benefits of supply chain management and the application of deep learning

In contemporary business operations, an effective supply chain management system is an indispensable cornerstone to support daily business. It is directly related to whether a company can stay ahead in market competition. The lack of effective supply chain management puts businesses at risk of operational disruption, underscoring the importance of supply chain management. The challenge for companies is whether to continue maintaining outdated systems or respond to rapid technological and social changes and build a supply chain that can grow, modernize, and digitally optimize with the changing times.

Optimizing supply chain management can bring the following main benefits:

Improve productivity: Through enterprise asset equipment management systems and predictive maintenance, we can improve the operating efficiency of machines and systems, solve production bottlenecks, and improve work processes, thereby significantly improving productivity. Leveraging deep learning technology to automate processes and data analysis can speed up product shipping and delivery times.

Reduce supply chain costs: Deep learning technology can perform accurate predictive analysis, effectively eliminate "uncertainty" and reduce the risk of inventory waste or shortages. The Internet of Things (IoT) combined with deep learning provides flexible asset management and optimized workflows.

Improve product quality: Combining customer feedback with deep learning analysis, the R&D team can more accurately grasp market demand and effectively improve product design to meet consumer expectations and trends.

Improve customer service: Modern supply chain management should be customer-centric. Deep learning technology makes the supply chain more flexible and adaptable, providing personalized customer experience and improving customer satisfaction.

Improve transparency and sustainability: Deep learning technology can provide transparency at every stage from product design to logistics, helping companies work with suppliers to improve their environmental footprint and achieve sustainable development goals.

In this study, deep learning technology is particularly applied to image recognition of crowd density. This technology can not only improve the passenger flow distribution of the rail transit system, but also provide real-time data support for logistics distribution in supply chain management, further optimizing the entire supply

chain. efficiency and response speed.

Literature Review

Artificial Intelligence (Development and Current Status of AI)

Since its introduction in the 1950s, Artificial Intelligence (AI) has experienced several ups and downs. In its early stages, researchers explored rule-based systems, such as expert systems, to mimic human thought processes. Due to hardware limitations and the complexity of knowledge representation, initial AI research progressed slowly. As computational power improved, data-driven AI research became dominant. In the early 21st century, with the rise of big data technologies and a significant boost in hardware computational capacity, the field of AI experienced rapid growth. In today's AI domain, its applications have permeated all aspects of life, from voice assistants and facial recognition to self-driving cars. Particularly in image recognition and natural language processing, AI has not only achieved performances surpassing human levels but also attained commercial value in various real-world scenarios (Russell & Norvig, 2020 & LeCun et al., 2015).

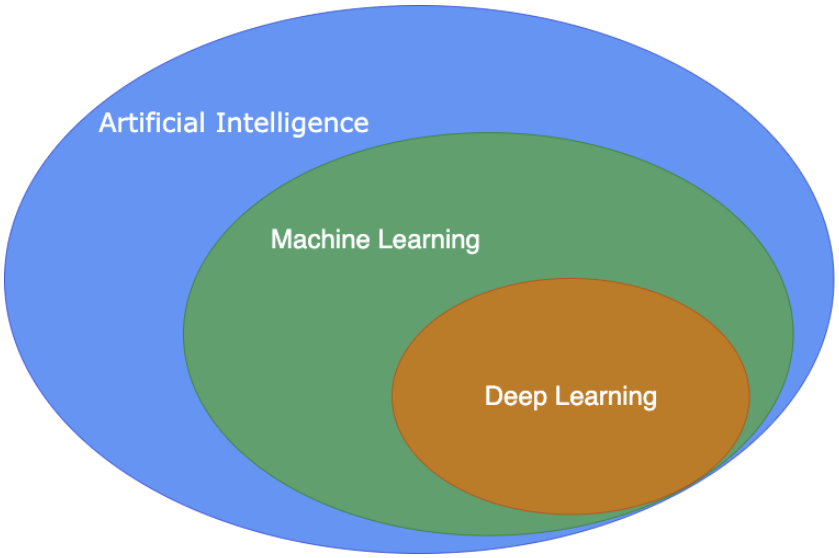

Figure1 Machine Learning Relationship Diagram

Machine learning

Machine Learning is a subfield of AI, centered on enabling computers to perform specific tasks using data and algorithms without explicit instructions. Over the past few decades, machine learning has become the driving force behind many technological and commercial applications. It involves building models that learn from data to make predictions or decisions (Goodfellow et al., 2016).

Supervised Learning is the most common learning strategy in machine learning. In this approach, we provide the model with input data and corresponding output results, enabling it to learn predictions for unknown outputs from these paired data. In other words, supervised learning requires a labeled dataset where each data sample has a predefined label or result. The goal is to discover the relationship between inputs and outputs to predict new, unseen data. Common supervised learning tasks include classification (e.g., categorizing emails

as "spam" or "non-spam") and regression (e.g., predicting house prices based on their features).

Unsupervised Learning differs from supervised learning as it doesn't rely on predefined output labels. Instead, it focuses on the underlying structure or patterns in the data. It seeks to automatically extract and learn useful information or features from input data without explicit output labels. This makes unsupervised learning particularly suitable for exploratory data analysis as it can reveal hidden structures in data. Typical unsupervised learning tasks are clustering (e.g., segmenting customers into different market segments) and dimensionality reduction (e.g., projecting high-dimensional data into a two-dimensional space for visualization (Murphy, 2012).

The primary distinction between supervised and unsupervised learning lies in whether explicit output labels guide the learning process. Supervised learning focuses on predicting precise output results, whereas unsupervised learning emphasizes discovering hidden data structures or patterns.

Deep Learning

Originating from artificial neural networks, Deep Learning has surged in popularity in recent years due to enhanced computational capabilities and the availability of vast datasets. This learning strategy mimics the functioning of neurons in the human brain, using multi-layered neural structures to model and abstract data.

In practical applications, deep learning has been successfully applied to voice recognition, image processing, and natural language processing. Its success lies in its ability to capture intricate patterns in vast datasets. As the depth of the model increases, it can capture more abstract and complex features (Hinton et al., 2006).

However, deep learning also presents challenges. These models require vast amounts of data for training, limiting their potential in data-scarce scenarios. Moreover, deep learning models often demand substantial computational resources, which can restrict their application in some situations (Schmidhuber, 2015).

Convolutional Neural Networks

Convolutional Neural Networks (CNNs) are designed specifically for handling image and video data within deep learning. Unlike traditional fully connected neural networks, CNNs use convolutional operations to process data, allowing them to capture spatial structures in images (Krizhevsky et al., 2012).

Basic components of CNNs include convolutional layers, pooling layers, and fully connected layers. Convolutional layers extract features from input images, pooling layers reduce the spatial dimensions of features, and fully connected layers are used for classification and regression tasks.

CNNs have achieved remarkable results in various fields, especially in image recognition, face recognition, and object detection. Their efficiency largely stems from their ability to capture relevancy within local regions and identify features at different levels.

At the same time, CNNs face challenges. Deep CNN models can contain millions or even billions of parameters, making the training process both time-consuming and resource-intensive. Moreover, like all deep learning models, the interpretability of CNN models remains an ongoing issue.

YOLO

Object detection has always been a core research topic in the field of computer vision. Earlier methods, such as the R-CNN series, required multiple analyses of images or their segments. YOLO (You Only Look

Once) offers a faster and more efficient detection method. It assesses the entire image in just one pass, treating the detection task as a form of regression (Redmon et al., 2016)

What's unique about YOLO is that it doesn't rely on traditional sliding windows or region proposals. Instead, it directly evaluates the whole image. This means that during training and testing, it can fully understand all the contents of an image, enabling it to better recognize global classes and features. Compared to systems that only capture local information, like Fast R-CNN, YOLO is more precise in differentiating between backgrounds and objects, with relatively fewer false positives.

Moreover, YOLO has demonstrated strong generalization capabilities. When trained on real-world images, its performance often surpasses that of models like DPM and R-CNN when evaluating images from specialized domains like artwork. This suggests that YOLO can maintain good recognition performance even when faced with images it hasn't been trained on (Liu et al., 2016).

Despite these advantages, YOLO still lags behind some advanced detection systems in terms of accuracy. While it can locate objects quickly, it sometimes struggles with the precise positioning of smaller objects.

In conclusion, YOLO is an efficient object detection model that excels in real-time processing and generalization. However, in certain situations, it might compromise on accuracy.

While YOLO may not be as accurate as variants of R-CNN, it significantly reduces the chances of background misidentification. By sacrificing a bit of accuracy in favor of reducing false positives and increasing speed, it becomes a very practical choice in many real-world considerations.

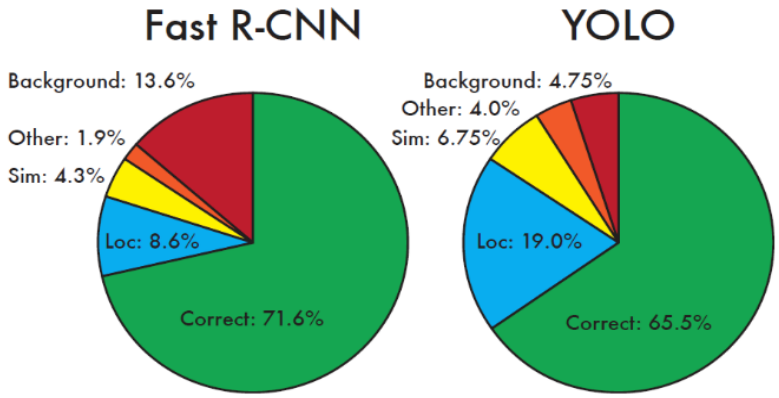

Figure 2 Comparison between CNN and YOLO

Train Passenger Flow Analysis System

In recent years, with the rapid development of smart technologies, various fields have begun to harness the power of these technologies to enhance operational efficiency. Among them, the "Train Passenger Flow Analysis System" has emerged as an excellent application. This technology, through advanced data analysis and real-time recording, can accurately count and effectively manage passenger flow. In train stations and on trains, the application of the passenger flow analysis system has become a crucial aspect of optimizing the transportation experience. Below are four major advantages of applying the passenger flow analysis system to

trains (Yang et al., 2021; Lu et al., 2018 & Behrooz et al., 2022).

Advantage 1: Enhanced Safety

The Train Passenger Flow Analysis System can monitor the flow of people inside and outside the station in real-time, especially during peak hours, helping to prevent overcrowding situations. The system can quickly detect areas with excessive passenger flow and alert station management through a warning system, thus avoiding potential safety risks.

Advantage 2: Reduced Wait Times for Passengers

With the Train Passenger Flow Analysis System, transportation management can accurately predict the passenger flow at stations and allocate an appropriate number of trains according to different times, reducing the waiting time for passengers on platforms. This not only enhances passenger satisfaction but also makes more efficient use of train resources.

Advantage 3: Efficient Management of Onboard Facilities

The Train Passenger Flow Analysis System can also monitor passenger flow within the train. Based on the flow in different carriages, the system can adjust facilities such as air conditioning and seat arrangements, offering a more comfortable travel experience. Moreover, the system can detect overcrowded areas within the train and guide passengers to less crowded carriages, ensuring a balanced distribution of people within the train.

Advantage 4: Flexible Train Operations

With the Train Passenger Flow Analysis System in place, transportation management can adjust train operations more flexibly. Based on special events, holidays, and other scenarios, the system can predict peak flows, allowing for reasonable allocation of transportation resources and ensuring the smooth operation of stations and trains.

The application of the Train Passenger Flow Analysis System not only elevates the management efficiency of train transportation but also provides passengers with a safer and more convenient travel experience. The introduction of this technology will effectively revolutionize the operational model of train transportation, making the entire system more intelligent and user-friendly.

The relationship between supply chain and deep learning people flow management

With the accelerated development of global informatization and digitization, data has become the core asset of modern society. Among these data, due to their rich information content and complex structure, automatic recognition and analysis of image data are extremely challenging for traditional technologies. In the past, traditional image processing technology could extract basic features and perform image recognition, but its performance was often limited in highly complex and dynamically changing environments.

In recent years, deep learning has set off a new trend in the field of artificial intelligence, especially in the field of image recognition, showing its ability to surpass traditional methods. However, translating these advanced technologies into practical applications still requires overcoming various technical and engineering obstacles.

As an important part of modern enterprise operations, supply chain management is facing growing demands and challenges. The effective operation of the supply chain is crucial to an enterprise's production

efficiency, cost control and market competitiveness. With the acceleration of urbanization, transportation, as a key link in supply chain management, is also facing an increasing passenger flow. How to use advanced technological means to optimize passenger distribution and improve transportation efficiency has become an urgent problem to be solved.

In this context, accurate crowd flow prediction and identification have become particularly important. Using deep learning technology, accurate prediction and real-time monitoring of the flow of people in the carriage can be achieved, thereby reducing the imbalance of population transportation and improving transportation efficiency.

Supply chain management challenges include:

Demand forecast accuracy:

Supply chains need to accurately predict population transportation needs to avoid overloads or shortages. Deep learning technology can provide more accurate demand forecasts by analyzing historical data. The same technology can also be used to predict the number of passengers in the carriage at different times and optimize passenger distribution.

Efficiency of logistics and distribution:

In the supply chain, logistics and distribution are key links. Deep learning can optimize logistics routes, reduce transportation time and costs, and improve overall distribution efficiency. People flow recognition technology can help optimize the distribution of people flow in the carriage, reduce crowding, and improve passenger travel efficiency and comfort.

Optimal allocation of resources:

Effective supply chain management requires flexible allocation of resources to respond to rapid changes in the market. Deep learning technology can provide real-time data analysis to help managers make more informed decisions. Through real-time people flow data analysis, transportation resources can be flexibly adjusted to avoid resource waste.

Supply chain transparency and sustainability:

Modern supply chains require transparency from production to logistics and consideration of environmental impact. Deep learning technology can provide comprehensive monitoring and analysis to promote the sustainable development of the supply chain. Through real-time monitoring and analysis of people flow, the transparency of the transportation process can be improved, further promoting environmental protection and energy saving.

Research Framework and Methodology

Research Framework

This study aims to utilize deep learning techniques for image recognition of pedestrian density. The framework employed is based on the YOLOv5 object detection model, trained and tested using the COCO dataset. The primary research structure consists of five steps: dataset preparation, model construction, model training, model testing, and result analysis, as illustrated in the figure.

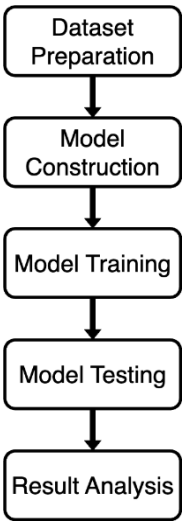

Figure 3 Research Architecture Diagram

Data Collection

For training, this study uses Microsoft's COCO dataset. This dataset provides comprehensive training data for machine learning and utilizing an existing dataset saves significant time.

COCO Dataset

The COCO dataset is one of the most commonly used datasets for machine learning, especially in areas like object detection, instance segmentation, and human key point detection.

Research Software and Tools

Development Environment

MacOS (Sonoma14.0 Beta version)

The advantages of using macOS as a development system include:

Stability: macOS is known for its exceptional stability, which is crucial for machine learning models that need to run for extended periods.

Unix Foundation: As macOS is based on Unix, it offers developers powerful terminal tools and environments. These tools simplify tasks like data processing, script execution, and many others.

Deep Learning Framework

Since real-time object detection is our goal, YOLO is the most widely used object detection method. We use YOLOv5, the latest version in the YOLO series, which strikes a good balance between speed and accuracy.

YOLOv5 utilizes the PyTorch deep learning framework, an open-source machine learning library developed by Facebook's AI Research lab (FAIR).

Model Optimization Method

The original COCO dataset is vast, with many images unrelated to humans, leading to excessive training time and resource consumption. Thus, we leveraged the labels provided in the dataset to extract images containing humans, optimizing the training efficiency of the model.

Model Selection

Among the many models in the YOLOv5 family, YOLOv5s is the most lightweight. As the model size increases, there are more convolution layers, implying higher computational costs, such as increased processing time. Hence, YOLOv5s is better suited for this study.

Training and Validation Strategy

At the start of training, we meticulously pre-processed the COCO dataset, specifically selecting images containing humans. We divided the data into 80% training, 10% validation, and 10% testing sets. Regarding training parameters, we chose a batch size of 16, ensuring computational efficiency and stable learning. We also set the total training epochs to 100, based on a preliminary assessment to ensure comprehensive model training and avoid overfitting. 3.7 Model Testing and Result Analysis

We evaluated the model using the previously reserved test set to ascertain its performance on unseen data. With the image detection program, each identified person is clearly marked, and the total number of detected individuals is displayed in the top-left corner of the image. Preliminary results indicate the model has commendable recognition abilities, but further in-depth evaluation is necessary for specific scenarios.

Training Implementation and Analysis

Dataset Preparation

The dataset used for training and testing is the COCO dataset provided by Microsoft. The ultimate purpose of the experiment is to identify the number of people, so we only used data labeled as "person" from the dataset.

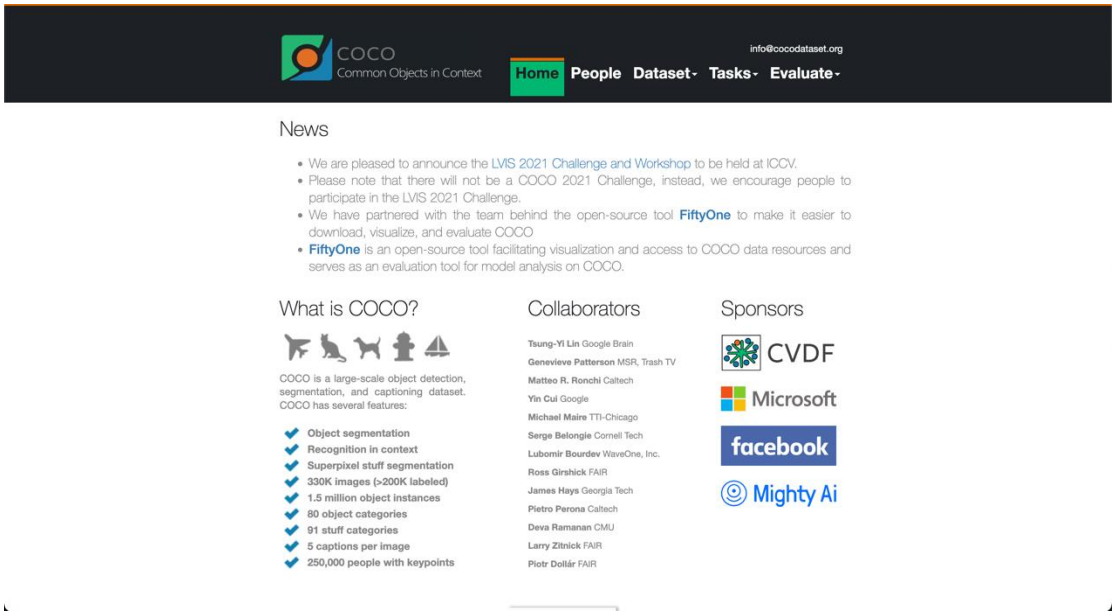

Figure 4 COCO Dataset Website

Dataset Processing

The original COCO dataset contains as many as 160,000 images. However, a large portion of these photos is irrelevant to people. Since our model only needs to recognize people, we extracted photos with labels related to people from the original dataset for training.

```python
import json
import shutil
import os

# 設置路徑
coco_annotations_path = '/Users/chenguanhong/Documents/yolov5_training/annotations/instances_train2017.json'
images_dir = '/Users/chenguanhong/Documents/yolov5_training/train2017/'
output_dir = 'coco_people/'

# 讀取標註文件
with open(coco_annotations_path, 'r') as f:
    data = json.load(f)

# 創建輸出目錄
if not os.path.e
    os.makedirs(output_dir)

# 提取只有人的圖片
for image_info in data['images']:
    image_id = image_info['id']
    image_annotations = [ann for ann in data['annotations'] if ann['image_id'] == image_id]

    if all(ann['category_id'] == 1 for ann in image_annotations) and len(image_annotations) > 0:
        image_filename = image_info['file_name']
        input_image_path = os.path.join(images_dir, image_filename)
        output_image_path = os.path.join(output_dir, image_filename)
        shutil.copy(input_image_path, output_image_path)
```

(variable) output_dir: Literal['coco_people/']

Figure 5 A program for extracting photos labeled as 'person

The benefit of this approach is a reduction in the dataset from the initial 160,000 photos to 6,000 photos, substantially reducing the model's training time.

For model training, in addition to providing photos, we need to provide .txt files indicating the positions of people in each photo. This is to train the model to recognize the position of people in the training photos. The content format of the record file is: person's category in the COCO dataset, x-coordinate of the person in the photo, y-coordinate of the person in the photo, width of the person, and height of the person.

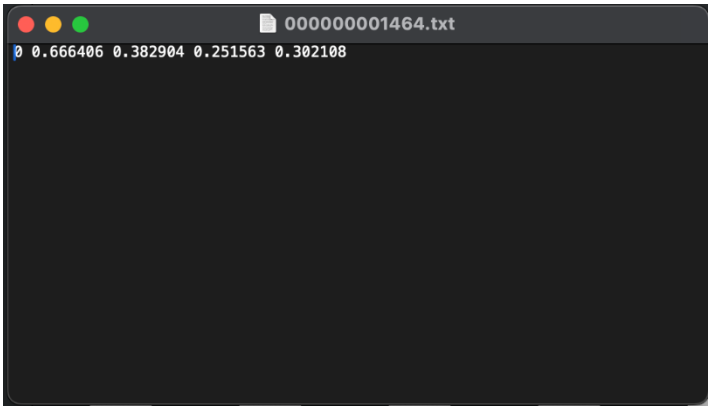

Figure 6 The content of the log file

Model Creation

YOLOv5 officially provides four different model versions, namely YOLOv5s, YOLOv5m, YOLOv5l, and YOLOv5x. YOLOv5x has the highest accuracy but the slowest processing speed. Considering the need for fast processing speed in real-time video recognition, YOLOv5s was chosen for training and subsequent recognition.

Model Training

Firstly, the YOLOv5 official model should be downloaded from GitHub.

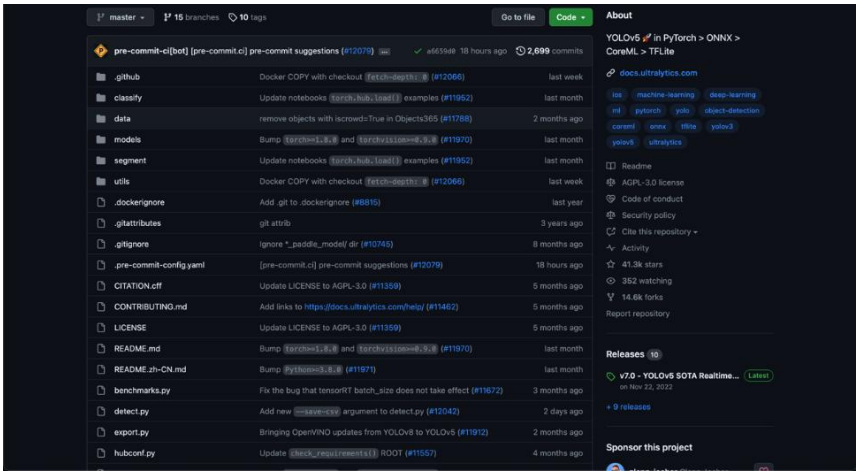

Figure 7 Official YOLOv5 GitHub

Next, download the required dataset from the COCO dataset official website. For this purpose, we selected the 2017 Train Image as the primary dataset because, compared to earlier versions, the 2017 training set contains more photos.

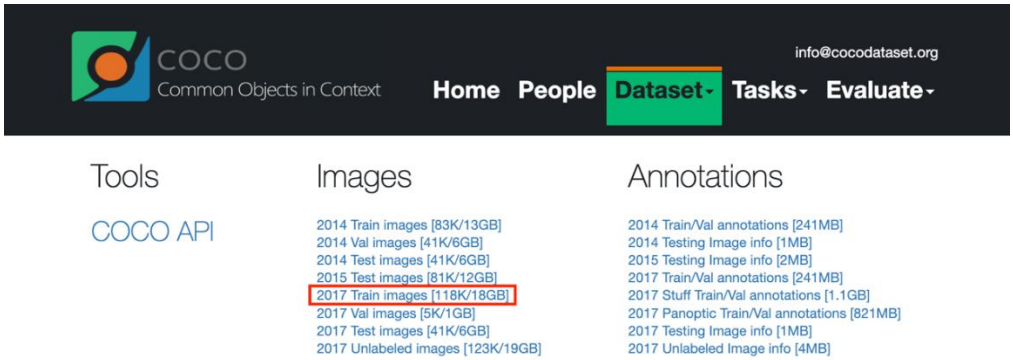

Figure 8 2017 Dataset

The downloaded training set folder should be placed together with the model files. The 'images' folder contains the training photo set, and the 'labels' folder contains the labels for people.

The command to execute the training program is:

python3 train.py -- img 640 --batch 16 --epochs 100 --data

/Users/chenguanhong/Documents/yolov5_training/dataset.yaml --cfg yolov5s.yaml --weights yolov5s.pt

This includes specifying the training image size as 640x640, the batch size as 16, and the number of iterations as 100. Further training command parameters are illustrated in the figure below.

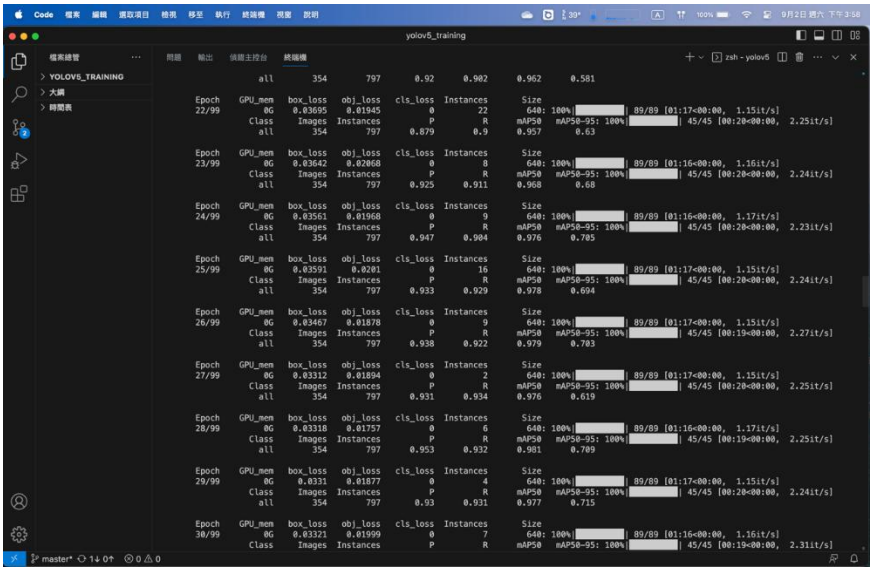

Figure 9 Training Model Process 1

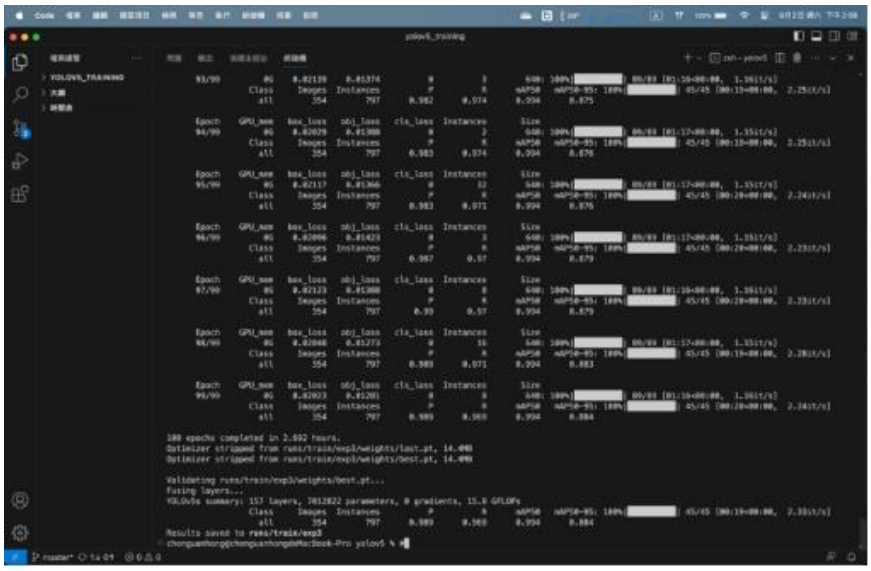

Figure 10 Training Model Process 2

Upon completion, a folder will be generated containing the weight file from this training for subsequent testing. It also contains data charts visualizing the training process.

The 'box_loss' represents the mean GIoU loss function value, where a smaller value indicates higher accuracy in bounding box predictions.

The 'obj_loss' indicates the mean objective detection loss value; the smaller the value, the more accurate the object detection.

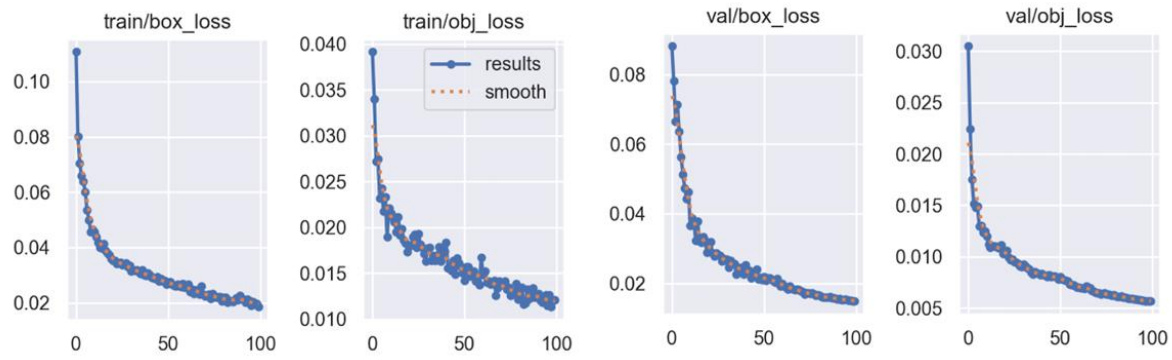

Figure 11 Training Results

Model Testing

The official detect.py is used for detection. Since we need to display the total detected people count, we made some additions to detect.py. The following command is then entered:

python3 detect.py --weights runs/train/exp2/weights/best.pt —source/Users/chenguanhong/Desktop/1.jpg

The --weights parameter indicates the weight file generated from model training, while the --source parameter indicates the path of the image to be tested. Setting the --source parameter to 0 allows real-time recognition.

```
        if int(cls) == 0 and conf > 0.01:
            num_people_in_image += 1

    total_people += num_people_in_image

    font = cv2.FONT_HERSHEY_SIMPLEX
    font_scale = 3
    font_thickness = 3
    cv2.putText(im0, f"People in Image: {num_people_in_image}", (10, 70), font, font_scale, (0, 255, 0), font_thickness)
```

Figure 12 Added content to detect.py

```
chenguanhong@chenguanhongdeMacBook-Pro yolov5 % python3 detect.py --weights runs/train/exp5/weights/best.pt --source /Users/chenguanhong/Desktop/1.jpg
detect: weights=['runs/train/exp5/weights/best.pt'], source=/Users/chenguanhong/Desktop/1.jpg, data=data/coco128.yaml, imgsz=[640, 640], conf_thres=0.25, iou_thres=0
.45, max_det=1000, device=, view_img=False, save_txt=False, save_conf=False, save_crop=False, nosave=False, classes=None, agnostic_nms=False, augment=False, visualiz
e=False, update=False, project=runs/detect, name=exp, exist_ok=False, line_thickness=3, hide_labels=False, hide_conf=False, half=False, dnn=False, vid_stride=1
YOLOv5 🚀 v7.0-212-g9074d51 Python-3.11.3 torch-2.0.1 CPU

Fusing layers...
YOLOv5s summary: 157 layers, 7012822 parameters, 0 gradients, 15.8 GFLOPs
image 1/1 /Users/chenguanhong/Desktop/1.jpg: 480x640 6 persons, 64.8ms
Speed: 1.0ms pre-process, 64.8ms inference, 5.0ms NMS per image at shape (1, 3, 640, 640)
Results saved to runs/detect/exp
```

Figure 13 Detection Process

Figure 14 Detection Results1

Figure 15 Detection Results 2

Figure 16 Detection Results3

The detection results are accurate. Even in the evening, as long as there is sufficient lighting, the model can still effectively recognize groups of people.

Results Analysis

To evaluate the performance of the model, we employed common performance evaluation methods such as the confusion matrix and ROC curve.

Model Performance Evaluation Methods

Confusion Matrix

The confusion matrix is a tool used to assess the performance of classification models. This matrix displays the correct and incorrect classifications made by the model across various categories. It is primarily divided into four parts:

True Positive (TP): The actual value is positive, and the software prediction is also positive. This is correct.

False Positive (FP): The actual value is negative, but the software predicts a positive result. This is incorrect. This represents a false alarm or Type I error.

True Negative (TN): The actual value is negative, and the software prediction is also negative. This is correct.

False Negative (FN): The actual value is positive, but the software predicts a negative result. This is incorrect. This represents a miss or Type II error.

Using these four values, we can calculate other essential evaluation metrics, such as precision and recall.

Precision: Also known as accuracy, it refers to how many of the data predicted to be Positive are genuinely Positive.

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

Recall: Also known as the hit rate, it means how much of the original Positive data was predicted correctly.

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

Taking the PR_AUC graph as an example, the larger the area under the PR curve, the better the performance of the model.

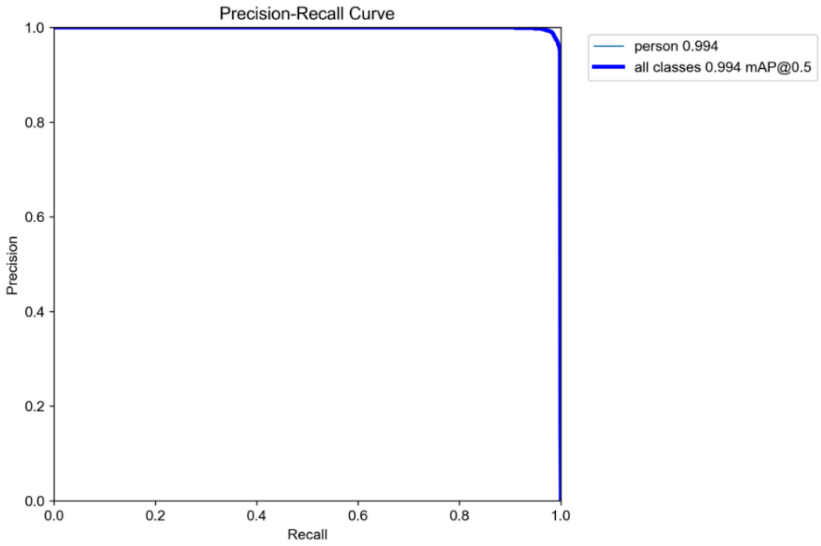

Figure 17 PR_AUC Curve

Conclusion

With advancements in technology, artificial intelligence is playing an increasingly crucial role in optimizing transportation strategies. This study introduces an efficient and accurate method for monitoring and assessing crowd density inside train compartments.

The research results demonstrate the superior performance of YOLOv5s in recognizing crowd density within train compartments. While it exhibits slightly lower precision compared to other versions, such as YOLOv5m, YOLOv5x, and YOLOv5l, its rapid detection speed makes it highly suitable for real-time applications. Future iterations of YOLO are anticipated to address limitations in low-light recognition capabilities, further enhancing its effectiveness.

Future research could focus on developing a congestion alert system that automatically issues warnings when crowd levels exceed specific thresholds. Additionally, exploring multi-angle real-time recognition techniques by deploying cameras strategically across compartments or platforms could capture multi-angular visual data. Advanced image fusion technologies could then generate comprehensive passenger distribution maps, improving recognition accuracy and reducing misjudgments caused by angle constraints.

From a societal and economic perspective, this technology offers substantial benefits. It can help transportation authorities better understand compartment usage, enabling optimized strategies that enhance passenger comfort and safety. This improvement in operational efficiency has the potential to lower costs and increase overall transportation effectiveness.

In the context of supply chain management, integrating deep learning technologies like YOLOv5s provides significant advantages. Real-time and accurate crowd density monitoring can facilitate more informed logistics decisions, optimizing the flow of goods and resources in high-density areas. This reduces shipping costs, minimizes delays, and improves overall supply chain efficiency.

Understanding crowd patterns and peak congestion times enables better asset utilization and resource allocation. For instance, recognizing peak travel times can help schedule more efficient routes for goods transportation, ensuring timely deliveries while reducing vehicle idling.

Moreover, the transparency offered by real-time crowd density monitoring aligns with the objectives of modern supply chain management, which emphasizes visibility and sustainability. Leveraging deep learning and multi-angle recognition technology can enhance demand forecasting accuracy, increase operational flexibility, and support sustainable practices by optimizing resource use and minimizing waste.

This study presents a promising framework for crowd density recognition, laying the groundwork for future research and applications. It underscores the potential of multi-angle recognition and deep learning technologies in improving the accuracy of crowd monitoring in train compartments while highlighting their broader implications for supply chain optimization.

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A Review of Research on System Dynamics in Supply Chain Management

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Abstract

Based on bibliometric methods, this paper employs text mining techniques to generate a keyword cloud map and keyword co-occurrence networks. This approach aims to thoroughly explore and systematically identify the core application topics of system dynamics in supply chain management, along with its methodological framework. The findings indicate that system dynamics holds significant application value across some critical areas, including inventory management, risk management, supply chain finance, green supply chain management, supply chain coordination management, supply chain performance, and supply chain quality management. For the first four core application themes, this paper further extracts relevant keywords and constructs a co-occurrence network. This reveals specific research directions, methodologies employed, and their interrelationships within each sub-theme in detail. Additionally, to enhance the empirical foundation of the discussion, this paper references several representative studies that analyze simulations and numerical analyses conducted within the context of system dynamics. Key parameters from these studies are summarized for clarity. Finally, based on a comprehensive review and analysis of prior research efforts, this paper anticipates future research trends that will serve as valuable references for subsequent investigations.

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Keywords: Supply Chain Management, System Dynamics, Bullwhip Effect, Risk Simulation Green Supply Chain

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Introduction

Supply Chain Management And System Dynamics

The supply chain is a complex network centered around a core enterprise, encompassing the entire process from raw material procurement and product manufacturing to final delivery to consumers through a sales network. Within this network, suppliers, manufacturers, distributors, and end users are intricately linked together to form a robust chain structure (Cooper et al., 1997). The essence of supply chain management lies in the effective integration of its various components, ensuring that products are delivered accurately - considering location, condition, quantity, quality, and timing. Simultaneously, it aims to optimize total ownership costs through meticulous planning, coordination, operation, control, and optimization.

System dynamics is an interdisciplinary field that investigates information feedback systems and has demonstrated its significant applications across various domains since its inception by Professor Forrester in the 1950s (Forrester, 2007). This discipline integrates structural, functional, and historical approaches while combining qualitative and quantitative reasoning; it employs computer simulation techniques for an in-depth analysis of the dynamic behavior exhibited by complex systems. System dynamics emphasizes a holistic perspective on systems as well as considerations of connectivity, development processes, and movement patterns. It effectively captures causal relationships among different variables along with associated risk factors and their corresponding behaviors. This, in turn, facilitates both the visualization and quantitative analysis of complex dynamic systems.

In the field of logistics and supply chain management, system dynamics plays a pivotal role (Sterman & John, 1989). In the 1960s, Professor Forrester's research on the “bullwhip effect” revealed the phenomenon of demand information amplification within the supply chain. System dynamics offers profound insights and strategic solutions to address this issue. Furthermore, MIT Sloan School of Management’s ‘Beer Game’ effectively illustrates the practical value of system dynamics by simulating production and distribution processes in the supply chain. This simulation visualizes the dynamic characteristics of information flow and logistics, thereby enhancing our understanding of the complexities inherent in supply chain operations.

In conclusion, applying system dynamics in supply chain management not only enriches researchers' comprehension of dynamic behaviors but also provides a scientific foundation for strategy formulation through simulation and analysis. This further underscores its unique value and irreplaceability as a cross-disciplinary research tool in tackling modern supply chain challenges (Sterman, 2000). In our next article, we will delve into a detailed discussion on the application of system dynamics in supply chain management along with an examination of achieved outcomes.

The technical roadmap of this paper is depicted in Figure 1

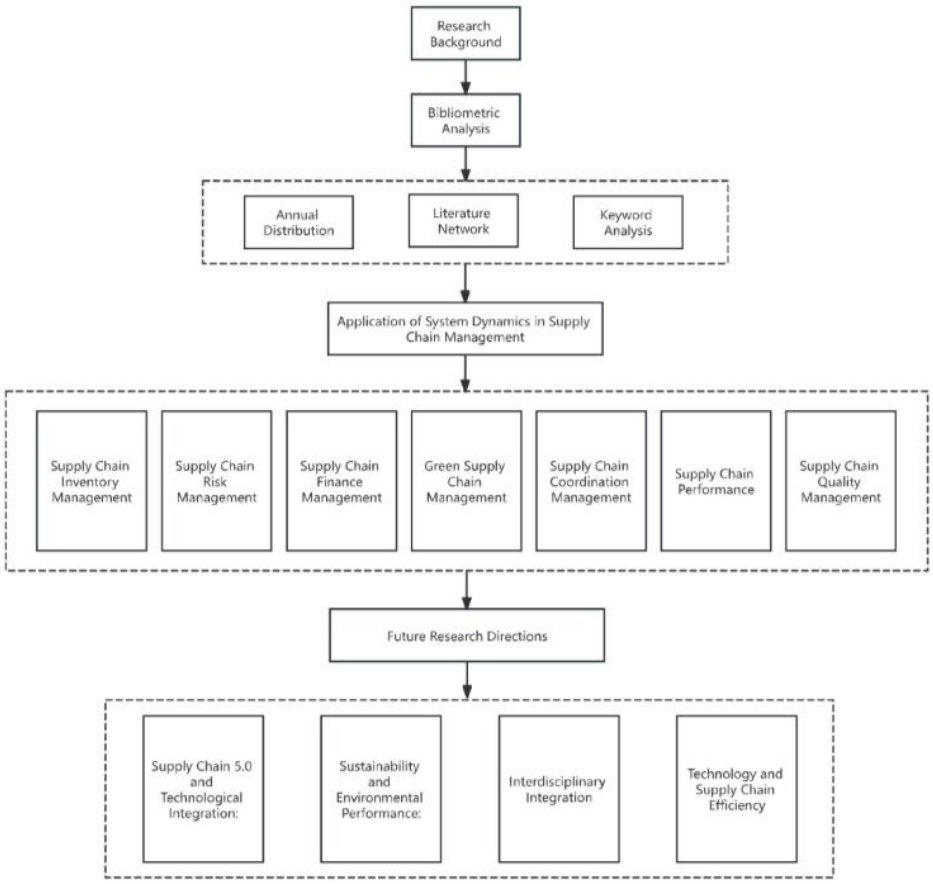

Figure 1 Technical Roadmap

Bibliometric Analysis

Based on the text analysis strategy employed by Chen et al. (2022), we conducted a bibliometric analysis using the Connected Papers tool, the Word Cloud package in Python and VOS viewer software. As an interactive visual graphic interface tool, Connected Papers offers an intuitive way to understand research progress and interrelationships within a specific field. By entering a key paper, Connected Papers can construct a visual graph that includes similar papers in the field, enabling us to quickly identify key papers and their interconnections. This is crucial for building a comprehensive research lineage and discovering new research trends. Simultaneously, the Word Cloud package generates visual representations, or cloud maps, of single-word keywords that vary in size according to their frequency, thereby providing an effective means of identifying research hotspots. Furthermore, VOS viewer serves as a powerful bibliometric tool that has been extensively used in numerous prior studies. It not only facilitates the visualization of academic network features such as co-authorship and co-citation networks but also excels at constructing co-occurrence networks for keywords. In our analysis, VOS viewers were employed to dig deeper into the intrinsic connections among these keywords, allowing us to categorize them into distinct

groups. This process enabled us to identify the research directions represented by each keyword group, offering robust support for further exploration of the research lineage within this field.

We conducted a comprehensive search for English-language journal articles on "Supply Chain and System Dynamics" within the Web of Science core collection, specifically focusing on the SCI-EXPANDED and SSCI databases. Through a meticulous screening process that excluded conference papers, review articles, and retracted publications, we identified a total of 676 eligible articles.

Figure 2 illustrates the annual distribution of articles on supply chain and system dynamics, revealing a steady increase followed by a notable surge. From 1991 to 2005, the field was in its early stages with limited research interest, resulting in a modest number of publications that peaked at only six articles in the most productive year. However, beginning in 2006, there was an observable rise in attention towards this field, with particularly marked growth commencing in 2010. Despite minor fluctuations in subsequent years, the overall trajectory demonstrated consistent upward growth. A more pronounced escalation in article publication occurred from 2016 onward, with significant intensification noted post-2019. Notably, after 2021, the rate of article publication experienced substantial acceleration reflecting rapid expansion. By 2023, the number of published articles reached an unprecedented high exceeding eighty. Collectively, the integration of system dynamics within supply chain management represents an emerging and dynamic domain; its modeling and simulation capabilities exhibit considerable potential within today's digital landscape characterized by Internet connectivity and e-commerce advancements. Furthermore, disruptions to supply chains caused by the COVID-19 pandemic have further expanded opportunities for applying system dynamics methodologies.

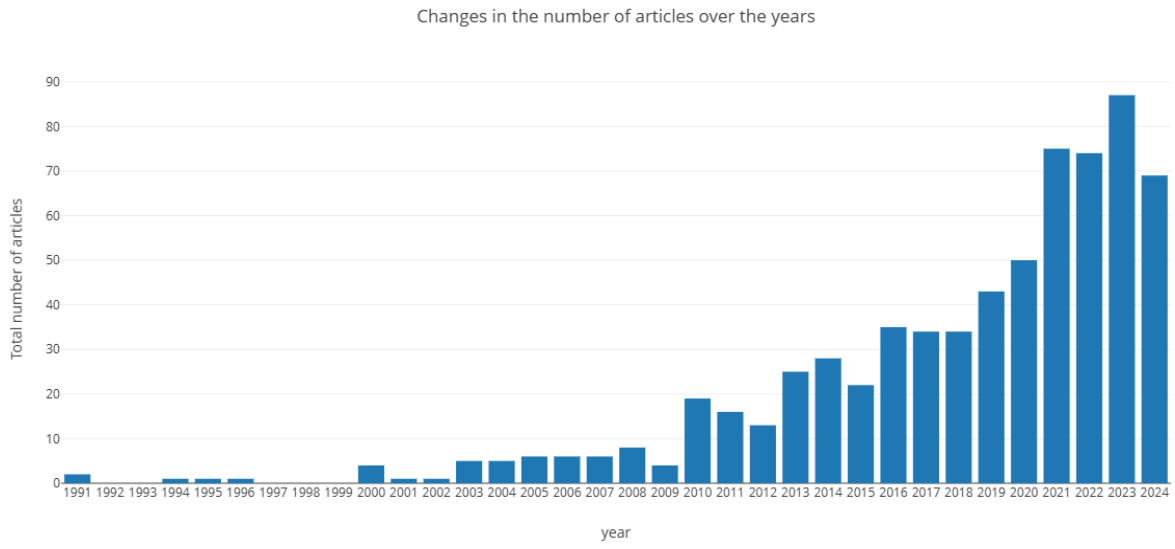

Figure 2 Changes in the number of articles on supply chain and system dynamics over the years

The current issue and full text archive of this journal is available on Supply Chain and Sustainability Research at:
https://so08.tci-thaijo.org/index.php/SCSR/index

Furthermore, On the Connected Papers platform, by inputting the document "Evolution of system dynamics in supply chain management," we constructed a literature network map (see Figure 3) that encompasses the fields of system dynamics and supply chain management. This map effectively reveals the research dynamics and associated papers within the domain. The key paper "Bernhard, 2000" prominently occupies a central position in the network map due to its larger node size, reflecting its significant impact and academic contribution to the field. By analyzing the timeline, we are able to trace the research outcomes from "Akkermans" in 1999 to "Raad" in 2019, showcasing the continuity and evolution of research in this area, thus providing a comprehensive understanding of its history and current state. Also, the connections of "Bernhard, 2000" with multiple nodes highlight the current hotspots and trends in research, revealing the extensive applications and pivotal role of system dynamics in supply chain management. Meanwhile, the nodes with fewer connections in the network map suggest potential gaps for future research, offering new directions and spaces for exploration in the academic community. Through this analysis, we can gain a deeper understanding of the application value and research prospects of system dynamics in the field of supply chain management.

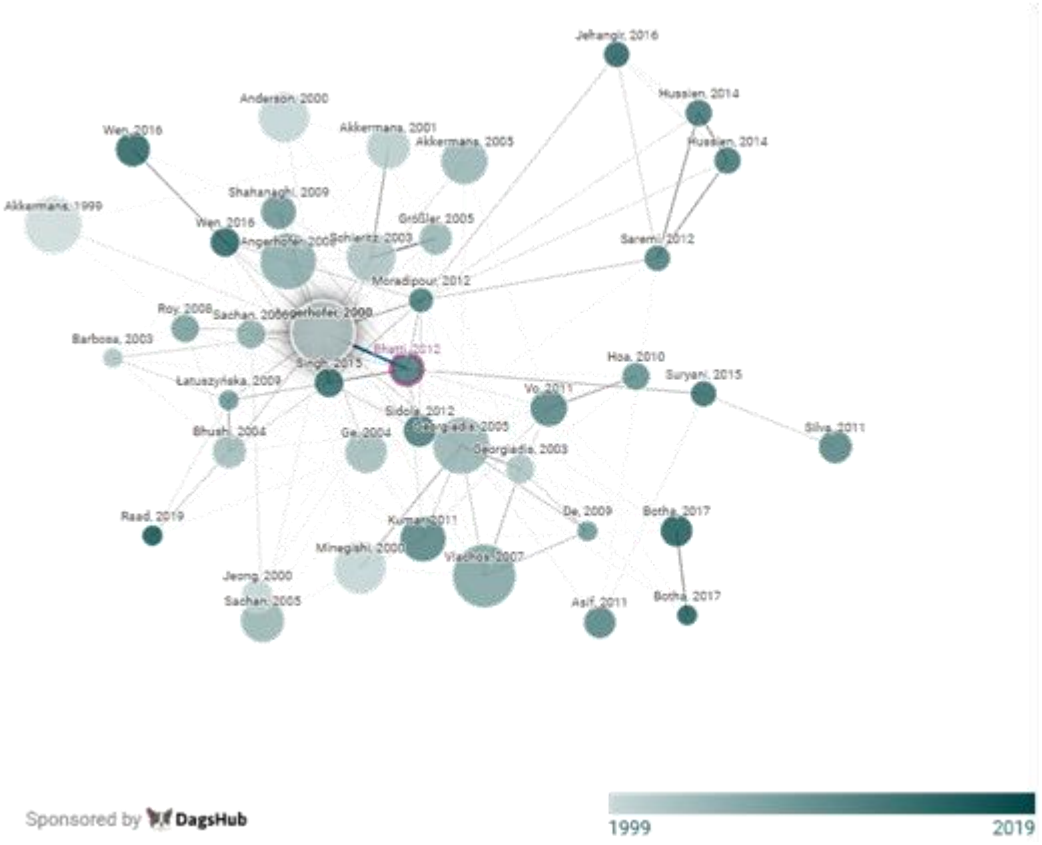

Figure 2 Literature network map for system dynamics in supply chain management

Subsequently, we further extracted key words from the relevant literature to elucidate the research direction concerning the specific application of system dynamics in supply chain management. Figure 4 presents a keyword cloud, while Figure 5 and Figure 6 illustrate the keyword co-occurrence network, which were generated using VOS viewer.

Figure 3 Word cloud of keywords for system dynamics in supply chain management

Figure 5 Keywords co-occurrence for system dynamics in supply chain management

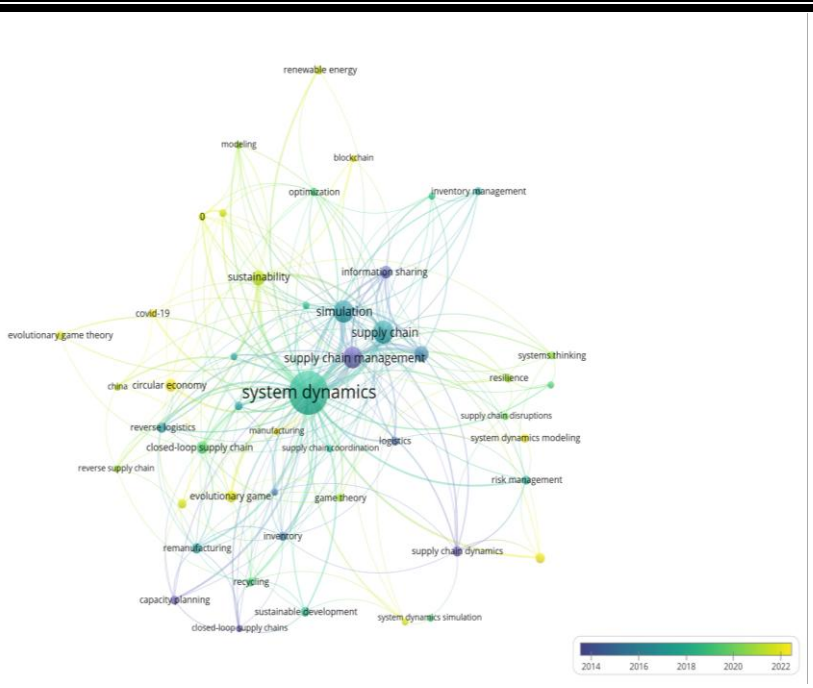

Figure 6 Keyword Heat Trend for for system dynamics in supply chain management

Through a thorough analysis, we highlight the significant use of system dynamics in supply chain management and the main research methodologies involved. The application areas include inventory management, risk management, financial aspects, green supply chains, coordination efforts, and performance evaluation. Common research methods are simulation techniques and game theory. In the following sections, we will concentrate on these core domains and methodologies to provide a comprehensive overview of the application of system dynamics

Application of System Dynamics in Supply Chain Management

Supply Chain Inventory Management

System dynamics is crucial in inventory management, particularly for identifying and mitigating the bullwhip effect, which offers significant advantages. As a prevalent issue, the bullwhip effect can cause increased inventory volatility and cost escalation throughout the supply chain. To better understand research on system dynamics in supply chain inventory management, keywords from related literature were extracted and demonstrated by a co-occurrence network (see Figure 7), revealing five major research clusters detailed in Table 1.

1) Cluster 1 emphasizes inventory planning, control, and batch size determination by leveraging control engineering and control theory to optimize the management process.

2) Cluster 2 concentrates on improving the accuracy of inventory demand forecasting and risk management. It integrates time series analysis, machine learning, and statistical methods for forecasting while employing risk assessment and simulation techniques to effectively manage risks.

3) Cluster 3 explores environmental sustainability in inventory management. This cluster aims to develop environmentally friendly inventories and evaluate the sustainability of green supply chains and reverse logistics through life cycle assessments and other methodologies.

4) Cluster 4 focuses on applying simulation and optimization techniques within inventory management. It seeks to enhance inventory systems using discrete event simulation, and Monte Carlo simulation, among other approaches.

5) Cluster 5 addresses inventory management challenges in specific application areas such as e-commerce and disaster relief. It incorporates specialized techniques like response methodology to tackle these unique challenges effectively.

In conclusion, system dynamics in supply chain inventory management, along with control theory, data analysis, and optimization algorithms, offers effective solutions for key areas such as inventory control (Rizqi & Chou, 2024), demand forecasting (Zhang et al., 2024), and environmental sustainability (Becerra et al., 2024)

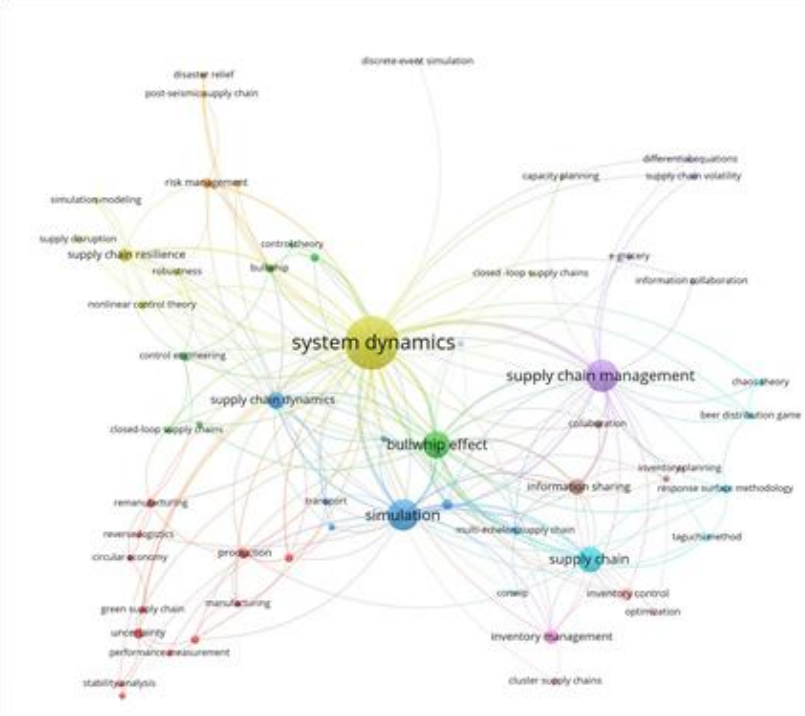

Figure 7 Inventory management keyword co-occurrence network

Table 1 Keyword clustering for supply chain inventory management

Cluster	Keywords
1	Inventory control, inventory management, inventory planning, batch sizing, control engineering, control theory
2	Forecasting, demand forecasting, risk management, robustness, uncertainty
3	Circular economy, green supply chain, remanufacturing, reverse logistics
4	Simulation, simulation modeling, optimization, nonlinear dynamics, nonlinear control theory, stability analysis
5	E-grocery, disaster relief, production, manufacturing, transportation, transport, response surface methodology, taguchi method, taguchi methods

In terms of empirical research, Yan et al. (2017) conducted an in-depth study on inventory management in cluster supply chains. They analyzed the system behavior patterns of the co-operation planning, forecasting and replenishment (CPFR), vendor-managed inventory (VMI), and jointly managed inventory (JMI) models of cluster supply chains. Then, using a system dynamics approach to establish a corresponding inventory management model for simulation. The results indicated that applying the CPFR model effectively mitigates the bullwhip effect, reduces inventory levels, and enhances overall supply chain efficiency. However, their focus was primarily on internal cluster dynamics without exploring external influences such as transport systems. Rathore et al. (2021) addressed this gap by employing a system dynamics approach to model dynamic feedback effects and complex interactions among risk factors impacting food transport systems. Their findings provided key recommendations for policymakers to enhance food supply chain efficiency. Building on this work, Zhou et al. (2022) further applied system dynamics to inventory management within the sulfur product supply chain. They analyzed distributor-retailer secondary inventory control strategies and found significant bullwhip effects influenced by changes in transport time and inventory adjustment periods at node firms. Based on these insights, they proposed optimization measures including establishing an information-sharing platform, implementing visual information management, and outsourcing logistics services to improve operational efficiency across the entire product supply chain.

Figure 8 presents the key parameters of the system dynamics simulations and numerical analyses applied in the three papers.

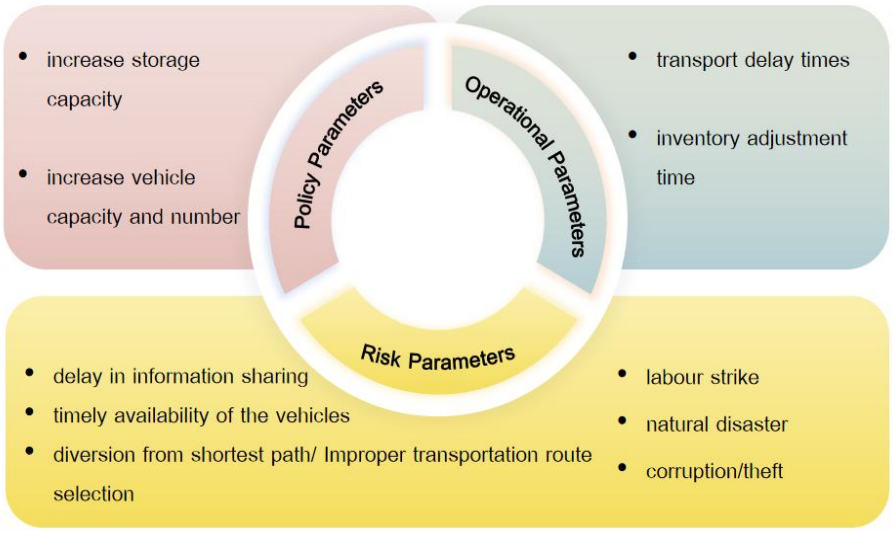

Figure 8 Map of the key parameters used
by Yan et al. (2017), Rathore et al. (2021), and Zhou et al. (2022)

Supply Chain Risk Management

System dynamics plays an important role in managing supply chain risk and enhancing supply chain resilience by dynamically modeling and analyzing the intricate behaviors of supply chains, as well as their performance under risk. Similar to the previous section, we extracted keywords from relevant literature and constructed the co-occurrence network shown in Figure 9.

Cluster information is detailed in Table 2.

1) Cluster 1 emphasizes risk identification, assessment, and diffusion while enhancing the resilience and responsiveness of supply chains. This cluster frequently incorporates risk assessment models along with simulation and optimization techniques.

2) Cluster 2 investigates the integration of information technology and data science in risk management. Key areas include data sharing, digital transformation, and simulation optimization. It often combines these elements with simulation techniques and data analytics to enhance risk management processes.

3) Cluster 3 explores how risk management adapts to environmental changes and policy requirements to promote supply chain sustainability. This is typically conducted alongside life cycle assessments, environmental impact evaluations, and policy analyses.

4) Cluster 4 analyzes cooperation and coordination mechanisms within supply chains as well as the roles of logistics and reverse logistics in effective risk management. This analysis often employs game theory, coordination models, and service supply chain frameworks.

5) Cluster 5 highlights systems thinking to bolster the robustness and overall performance of risk

management systems. It is commonly integrated with systems thinking frameworks alongside resilience analysis for designing and evaluating these systems effectively.

In summary, system dynamics offers supply chain managers comprehensive solutions for risk management by integrating risk assessment models, simulation, and optimization techniques. This approach effectively addresses disruption risk (Ke et al., 2024), resilience enhancement (Liu et al., 2023), risk identification and assessment (Jahani et al., 2023), and improved responsiveness (Saarinen et al., 2024).

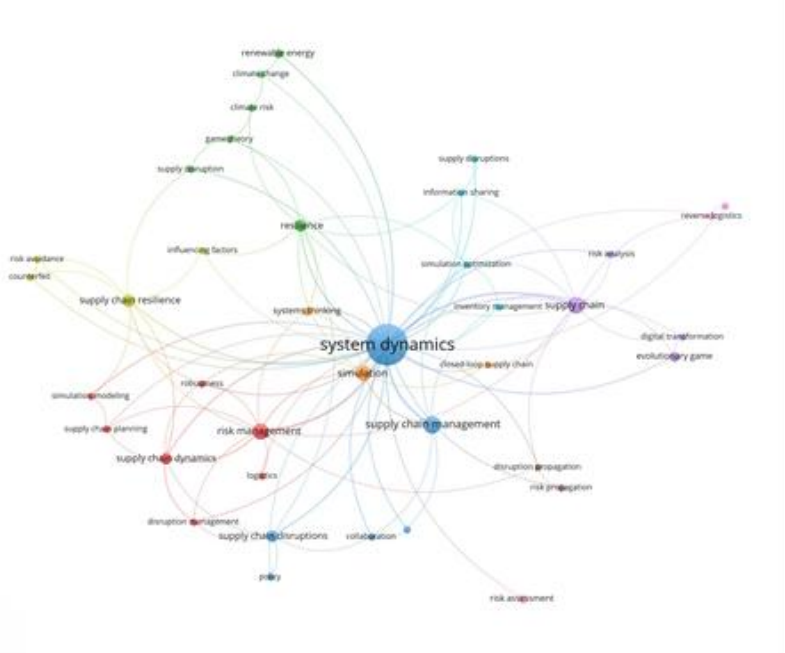

Figure 9 Supply chain risk management keyword co-occurrence network

Table 2 Keyword clustering for supply chain risk management

Cluster	Keywords
1	Risk management, supply chain resilience, risk assessment, supply chain dynamics, risk avoidance, supply chain disruptions, risk propagation, supply chain planning, risk analysis
2	Information sharing, digital transformation, simulation, simulation modeling, simulation optimization, system dynamics
3	Climate change, climate risk, renewable energy, sustainability, closed-loop supply chain, policy
4	Supply chain management, supply chain coordination, service supply chain, reverse logistics

5	Systems thinking, robustness, resilience

In empirical studies, Gu and Gao (2016) used a system dynamics model to simulate the effects of production disruptions on integrated remanufacturing/manufacturing (R/M) supply chains. They recommended that manufacturers establish multi-level inventories and develop contingency plans before disruptions occur. Building upon this foundation, Ghadge et al. (2022) expanded this research by designing four disruption scenarios to thoroughly investigate the propagation effects of supply chain disruptions. However, their study primarily concentrated on identifying and visualizing these impacts without offering specific solutions. To address this gap, Bussieweke et al. (2024) developed a model that integrates system dynamics with reinforcement learning, formulating a robust recovery policy that effectively mitigated chain reactions from supply chain disruptions while demonstrating significant resilience amid uncertainty and incomplete information.

Figure 4 Map of the key parameters used

by Gu and Gao (2016), Ghadge et al. (2022), and Bussieweke et al. (2024) presents the key parameters of the system dynamics simulations and numerical analyses applied in the three papers.

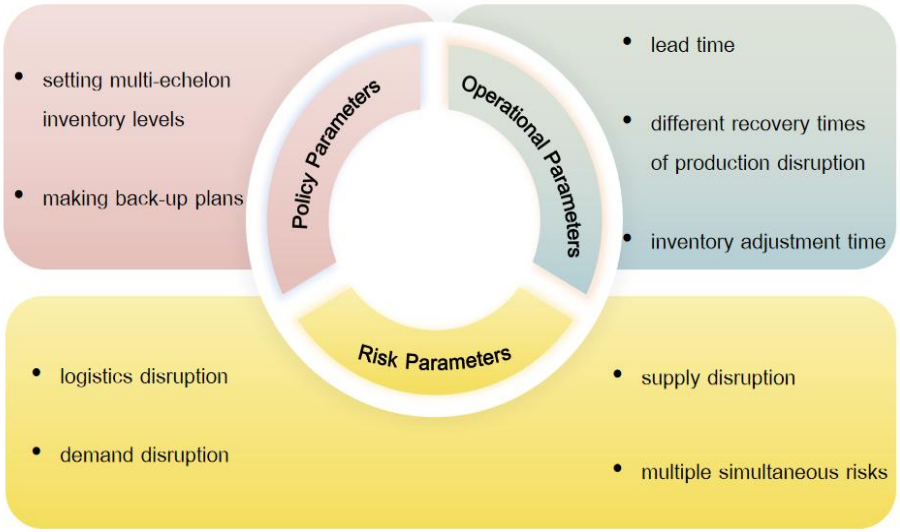

Figure 4 Map of the key parameters used

by Gu and Gao (2016), Ghadge et al. (2022), and Bussieweke et al. (2024)

Supply Chain Finance Management

In supply chain finance, system dynamics has demonstrated potential for enhancing robustness, especially in credit assessment, capital flow management, and decision optimization. Figure 11 Supply chain finance management keyword co-occurrence network presents the topics and methodologies in this field, with keywords organized into five clusters as shown in Table 3.

1) Cluster 1 focuses on supply chain finance and risk management, examining operational mechanisms,

financing methods, risk management strategies, and trade risk assessment. This often involves the utilization of financial and risk assessment tools to optimize the entire supply chain finance process.

2) Cluster 2 explores technology and innovation in supply chain finance, particularly blockchain and big data analytics, aiming to enhance transparency and efficiency through the integration of these technologies.

3) Cluster 3 investigates the link between supply chain finance and environmental sustainability, assessing how it can foster low-carbon supply chains and green financial products while incorporating environmental impact assessments and sustainability indicators to evaluate their ecological effects.

4) Cluster 4 examines the relationship between supply chain finance and government policies. It aims to understand how these policies can drive development through analysis and studies that predict their impacts on supply chain finance.

5) Cluster 5 assesses the impact of supply chain finance on firm performance metrics such as economic value added, profitability, and customer satisfaction using financial analysis tools.

In summary, supply chain finance management integrates system dynamics with financial modeling, data analysis, and financial analysis to optimize and develop supply chain finance.

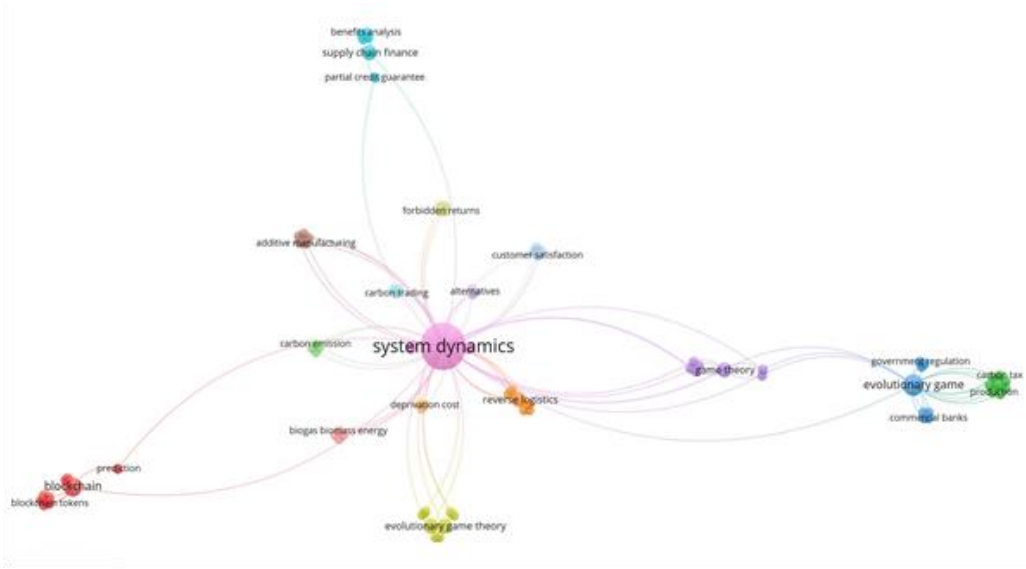

Figure 11 Supply chain finance management keyword co-occurrence network

Table 3 Keyword clustering for supply chain financial management

Cluster	Keywords
1	Commerce supply chain financing, supply chain finance, reverse factoring, risk management, trade risk
2	Blockchain, blockchain tokens, big data, digital marketing analytics, technological innovation
3	Green supply chain finance, low-carbon supply chain, sustainability, carbon emission, carbon tax
4	Government, government intervention, government regulation, policy factors, incentive policy
5	Economic value added, profitability, performance measurement, customer satisfaction

In empirical research, Ji et al. (2012) used system dynamics to examine how prepayment financing alleviates financial constraints for SMEs, finding it can optimize capital flow and enhance supply chain responsiveness and overall performance. However, their focus was primarily on prepayment finance rather than other forms of supply chain finance. Later, Dello Iacono et al. (2015) investigated reverse factoring arrangements and discovered that while these can provide economic benefits to all parties in the supply chain, such benefits are highly sensitive to market conditions and only feasible under specific circumstances. Supply chain finance still faces challenges, particularly in credit assessment. In this context, Zhang, H. Y. et al. (2023) proposed a dynamic credit assessment method using system dynamics, constructed a credit assessment index system for e-commerce micro and small enterprises, optimized weights through sensitivity analysis, and applied it within the TOPSIS-GRA model, which effectively enhancing both the accuracy of credit assessments and financing efficiency. Zhang, X. M. et al. (2023) further explored cash flow disruptions during the epidemic period with a focus on partial credit guarantees (PCG). They constructed models simulating various scenarios and found that PCG alleviates cash flow pressure while maintaining supply chain stability; additionally, price adjustments improve retailer performance and bolster supply chain robustness amid disruptions in manufacturers' production capacity.

Figure 12 presents the key parameters of the system dynamics simulations and numerical analyses applied in the three papers.

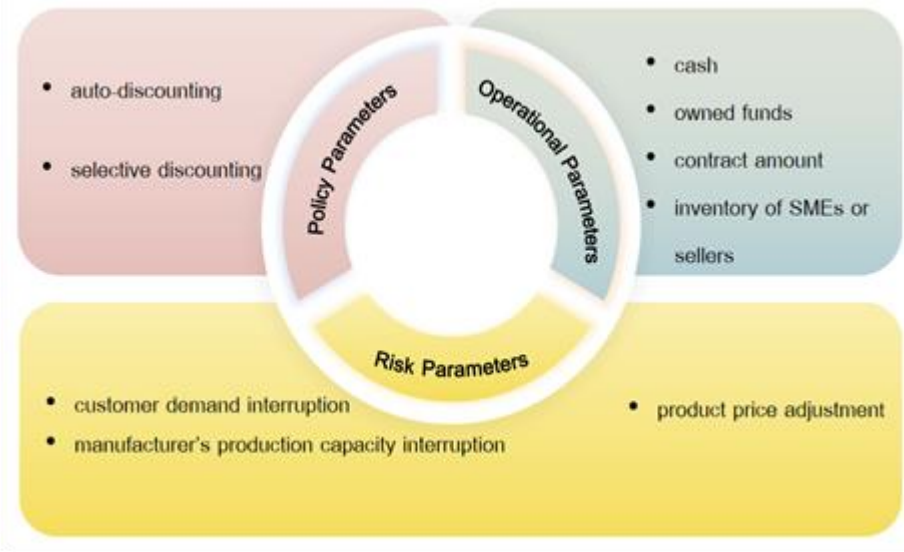

Figure 12 Map of the key parameters used
by Ji et al. (2012), Dello Iacono et al. (2015) and Zhang, X.M. et al. (2023)

Green Supply Chain Management

System dynamics serves as a fundamental analytical tool for green supply chain management, enabling researchers to gain profound insights into the dynamic behaviors of supply chain participants and providing a scientific foundation for sustainable decision-making. Figure 13 illustrates the keyword co-occurrence network in green supply chain management, highlighting the themes and methodologies explored within this domain. The keywords are categorized into five distinct clusters, as detailed in Table 4

1) Cluster 1 focuses on green supply chain management and policy, exploring green product development, government incentives, and their effects on the supply chain through policy analysis and management models.

2) Cluster 2 emphasizes environmental impact and sustainability assessment by evaluating the ecological effects of green supply chain activities, including carbon trading and life cycle assessments. This cluster frequently combines environmental impact assessments with life cycle evaluations and sustainability indicators.

3) Cluster 3 explores technology innovation and data management in green supply chains, emphasizing the use of artificial intelligence, blockchain, and data strategies to enhance efficiency and transparency.

4) Cluster 4 analyzes supply chain finance and performance, investigating how green finance influences business outcomes through financial analysis tools.

5) Cluster 5 examines system dynamics and complexity using evolutionary game theory to study the intricate behaviors of green supply chains, simulating and analyzing their dynamics and strategic interactions.

In summary, within the realm of green supply chain management, system dynamics is often integrated

with policy analysis, environmental impact assessment, financial analysis, and evolutionary game theory. This integration provides comprehensive analytical tools that facilitate the sustainable development of green supply chains.

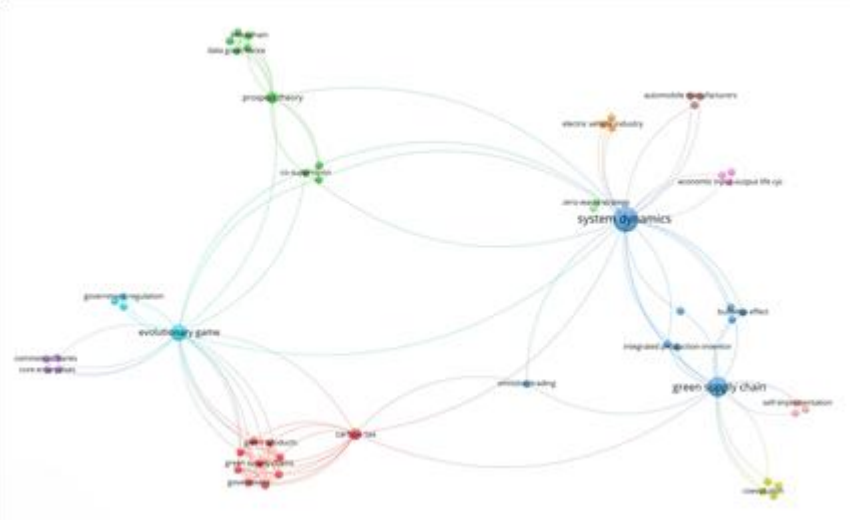

Figure 13 Green supply chain management keyword co-occurrence network

Table 4 Clustering of keywords for green supply chain management

Cluster	Keywords
1	Green supply chain, green supply chain management diffusion, green products, green sensitivity, green strategy, government intervention, government regulation, policy factors, incentive mechanism, incentive policy
2	Carbon tax, emission trading, product carbon footprint, sustainable development, economic input-output life cycle assessment, zero-waste strategy
3	Artificial intelligence, blockchain, data governance, electric ships, electric vehicle industry, electronic products, recycling, traceability
4	Green supply chain finance, commercial banks, firm performance, core enterprises
5	System dynamics simulation, systems theory, complex evolution game, evolutionary game, tripartite evolutionary game, uncertainty

In empirical studies, Tong et al. (2019) analyze the behavioral evolution of retailers and manufacturers under emissions trading policies using evolutionary games and system dynamics, emphasizing joint sustainable decision-making. However, their study primarily concentrates on the behavioral interactions between retailers and manufacturers, which remains insufficient for a comprehensive exploration of the overall design and management dimensions within green supply chains. To address this gap, Naderi et al. (2021) expand the research to include

green supply chain design in a global market context, particularly optimizing production, inventory, and logistics decisions. Their system dynamics modeling identifies minimizing transport costs, optimizing warehouse capacity, and improving productivity as key strategies. Meanwhile, van Keeken et al. (2024) examine the long-term effects of product life extension on environmental impacts within the European automotive supply chain for aluminum rolled products. Their system dynamics simulation shows that extending product life effectively reduces global warming potential and supports the goals of the European Green Deal.

Figure 14 presents the key parameters analyzed through system dynamics simulation and numerical analysis in the three papers

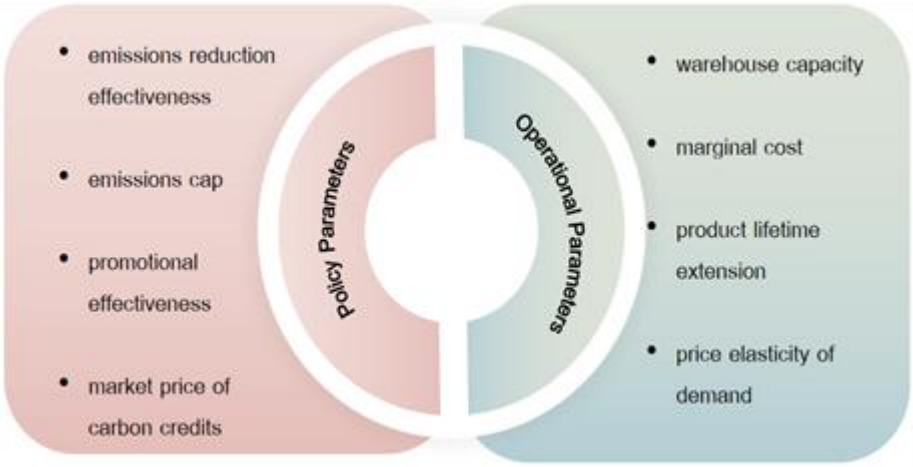

Figure 14 Map of the key parameters used
by Tong et al. (2019), Naderi et al. (2021) and van Keeken et al. (2024)

In addition, the application of system dynamics in supply chain management is extensive, encompassing key areas such as coordination, performance assessment, and quality management. To provide a comprehensive overview of its applications, Table 5 summarizes additional significant literature on system dynamics in this field.

Table 5 Additional Relevant Studies

Category	Authors	Research Objective	Key Findings
Supply Chain Inventory Management	Khan and Hebbar (2021)	Evaluate SCI strategies in chemical supply chains.	Increased transportation time does not affect sales, but raw material inventory rises.
	Hong (2022)	Study the impact of system dynamics on supply chain finance collaboration.	Higher bank input levels improve supply chain financial performance and support.
Supply Chain Risk Management	Olivares-Aguila and ElMaraghy (2021)	Develop a multi-echelon disruption plan.	Disruptions significantly impact service levels, costs, and profits; prioritize downstream policies.
	Zhu et al. (2021)	Assess SCI strategies on disruption recovery.	Operational integration is optimal; information integration often underperforms.
Supply Chain Finance Management	Chen (2024)	Design an agricultural supply chain financial system.	Identified key factors affecting coordination and provided strategies for improvement.
Green Supply Chain Management	Wang et al. (2024)	Analyze carbon quota allocation under EU-ETS.	Green technology effectively reduces emissions; profits may vary with price changes.
	Rajeev et al. (2024)	Simulate biofertilizer impacts on supply chains.	Insights for policymakers on subsidy levels for sustainable transitions.
	Tian et al. (2014)	Analyze green supply chain diffusion in China using system dynamics and evolutionary game theory.	Subsidies to manufacturers promote green supply chain management more effectively than those to consumers. Environmental awareness also influences diffusion.
Supply Chain Coordination Management	Zhang, M. L. et al. (2024)	Study decision coordination to mitigate the bullwhip effect.	Shorter lead times increase supplier profits, while retailer profits decrease.
	Izadi et al. (2023)	Explore blockchain in humanitarian supply chains.	Blockchain is effective in crises; labor increases are better when demand is low.
	Li et al. (2024)	Examine strategy impacts on maritime supply chain revenue using game theory and system dynamics.	Shipping company costs and benefits drive strategy selection. Information sharing and pricing improvements are essential for sustainable development.
Supply Chain Performance	Farjana and Ashraf (2023)	Identify key performance indicators for waste wood.	Established 12 key indicators for waste processing and management.
Supply Chain Quality Management	Duan et al. (2024)	Address quality management in closed-loop supply chains.	Contract coordination can resolve quality issues and enhance CLSC profits.

Summary

Following an in-depth analysis of the key areas where system dynamics is applied in supply chain management, we have found that system dynamics plays a crucial role not only in inventory management, risk management, finance, and sustainability, but also in supply chain coordination management, and its potential extends far beyond current applications. To meet readers' expectations for a deeper understanding and innovative insights, we propose a series of innovative research directions in the following text, aimed at advancing the development of theory and the application in practice.

1) Supply Chain 5.0 and Technological Integration: As an advanced phase in the evolution of supply chain coordination, Supply Chain 5.0 embodies a significant leap towards digitalization and intelligentization. Future research should delve into the specific context and inherent requirements of this phase, by Integrating system dynamics with advanced technologies such as Big Data, Artificial Intelligence (AI), and the Internet of Things (IoT) to streamline processes and enhance the supply chain's ability to adapt to the complexities of modern business.

2) Sustainability and Environmental Performance: Based on the analysis presented earlier, system dynamics has been widely applied in various fields such as low-carbon green policy analysis, environmental impact assessment, and green finance. Looking ahead, as the issue of sustainability continues to gain prominence, system dynamics is expected to play a pivotal role in optimizing the environmental performance of supply chains and leading the development of green supply chains.

3) Interdisciplinary Integration: In light of the pivotal applications of system dynamics in supply chain management, particularly its notable impact in inventory management, risk management, and green supply chain management, future research can delve into the integration of system dynamics with behavioral science, psychology, and sociology. This integration will provide an in-depth analysis of how decision-makers' behaviors, cognitive biases, social interactions, and cultural differences influence the dynamic operations of supply chains. For instance, by simulating supply chain decision-making processes across different cultural contexts, research could explore how to refine supply chain strategies to cater to the diverse global market environment.

4) Technology and Supply Chain Efficiency: Building on the analysis presented earlier, the application of system dynamics in supply chain finance and performance evaluation has demonstrated its potential to optimize supply chain processes and enhance transparency. Future research could focus on the integration of system dynamics with advanced technologies such as blockchain and machine learning to further improve the transparency, security, and overall efficiency of supply chains. For example, studies could explore how to leverage blockchain technology to enhance traceability and trust within supply chains, or how to optimize inventory management and demand forecasting through machine learning algorithms.

These studies will significantly advance toward both theoretical understanding and practical applications in supply chain management.

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- **Objectives**
- **Literature Review, Conceptual Framework (**Discussion of the research work of others in the field or topic area and how your work will enhance and contribute to the field. Citation of work by others should follow APA (7th edition) style e.g.

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

Wang and Pettit (2021).....;..... (Wang & Pettit, 2021)

Hisrich et al. (2020)……..;…… (Hisrich et al., 2020)

Novack et al. (2018)……;…… (Novack et al., 2018)

- **Research Methodology** This section indicates clear research objectives, conceptual framework(s) (if any), research question(s), hypotheses, population and sample, research instruments, and the data collection process. This section provides clear steps used in conducting your research. It means all procedures need to be described in sufficient detail to allow someone to replicate it.
- **Results and Discussion** This section covers the analysis of the data. It should include statistics in tables, charts, graphs, or pictures analyzed against hypotheses or in answering the research question(s) in quantitative research, or descriptive analyses of categories in qualitative research. **Results** is purely descriptive. **Discussion** describes and interprets the findings, placing them in a bigger context, relating them to other work(s) and issues outlined in the Introduction.
- **Research Benefits**
- **Conclusion and Recommendations** This section summarizes your study's key findings and implications. It should not be long and repetitive, but capture the essence of the study discussed in all previous sections. It should briefly cover the limitations of your research and suggested future direction for further research.

For academic articles, we recommend the structure below:

1. **Introduction**
2. **Discussion**
   2.1 subheading
   2.2 subheading
3. **Conclusion**

The author is advised to follow a logical, understandable point of argument. Break your main argument into sub-headings and present them in an outline at the end of the Introduction.

- **References List** all the sources you have cited in the body of your research. It states the author/s of the source, the material's year of publication, the name or title of the source material, as well as its electronic retrieval information, including the date it was accessed, if these were gathered from the Internet (Research articles, academic articles, reports, academic conferences, references, no later than the last 5 years and Books, unlimited years of reference)

Submission Guide

Authors are welcome to submit their manuscripts.

All submissions will be given an initial check by our editorial team, within **6-8 weeks after submission date** you will be notified of the initial check result on thaiJo system. Only the article which passes the initial check will proceed to the review process (6 -8 weeks). The author will be kept informed of the current status of their paper.

Articles being currently considered for publication by other journals will not be accepted by The Journal of Supply Chain and Sustainability Research (SCSR). If the author withdraws or sending a manuscript to other journals any time after the manuscript has been sent to peer review till the final decision, the Journal will charge the author a penalty fee for its time and resources spent. The authors must always pay the page charge even if the withdrawal is permitted.

Specific Instructions:

- **Format** The preferred format for the text and tables of a manuscript are MS Word DOC and PDF.
- **Paper size** Manuscripts must be typed double-spaced on A4 size paper, a single column format.
- **Margins** Use a 1-inch margin on all sides of each page-left, right, top, and bottom.
- **Spacing** Double space lines throughout the paper including appendices, footnotes. Exceptions: Triple or quadruple spacing can be done around equations. Single or one-and-a-half spacing can be done in tables or figures. Indent the first line of every paragraph a standard Tab key space (½ inch).
- **Font Size and Type**. Browallia New font (20 pts. bold for title; 14 pts. for author(s) and affiliation; 16 pts. bold for headings and 16 pts. bold subheadings; and 14 pts. for text)
- **Titles** should be no more than three typeset lines.
- **Headings** should be in bold type, in 16 point Browallia New font. First-level headings should be aligned to the left with initial caps. One line space should separate headings from the preceding text.
- ***Subheadings*** Italicize the subheadings in the bold type, single-spaced; in 16 point Browallia New font.

SUB-HEADING ONE Bold, Left, UPPERCASE HEADING

Sub-heading Two Bold, Left, Capitalize Each Word

Sub-heading Three Indented, bold, Capitalize Each Word

- Tables, Graphs, Charts, and Figures in 12-point Browallia New font, Bold
- **References** The Journal uses American Psychological Association (APA) style (7th edition).
  - Include only those sources you have cited in your paper.
  - Position the first line of each reference flush left, with subsequent lines wrapping with a ½-inch (hanging) indent.
  - Organize the list in alphabetical order according to the first letter beginning each entry. Usually, the author's last name is the first piece of information in each entry. Use initials for the author's first/middle names.
- Use the following format for your reference list:

Cokins, G., Pohlen, T., & Klammer, T. (2018). *Supply Chain Costing and Performance Management* (2nd ed). New Jersey : Wiley.

Hisrich, R. D., Peter, M. P., & Shepherd, D. A. (2020). *Entrepreneurship* (11th ed). New York : McGraw- Hill.

Heizer, J., Render, B., & Munson, C. (2020). *Operations Management Sustainability and Supply Chain Management* (13rd ed). U.K : Pearson.

Kumar, V., Leone, R. P., Aaker, D. A., & Day, G. S. (2018). *Marketing research* (13th ed). U.S.A.: John Wiley & Sons.

Maslow, A. H. (1970). Motivation and Personality (2nd ed). New York : Harper & Row.

Novack, R. A., Gibson, B. J., Suzuki, Y., & Coyle, J. J. (2018). *Transportation A Global Supply Chain Perspective* (9th ed). Singapore : Cengage.

Royal Thai Government Gazette. (2019). *National Education Act(no.4) , B.E. 2019*. Retrieved December 1, 2019, from http://www.ratchakitcha.soc.go.th/DATA/PDF /2562/A/057/T_0049.PDF

Thinwiangthong, S., & Inprasitha, M. (2018). The Model of Teaching Measurement in the School Level Mathematics Course. *Nakhon Phanom University Journal*. 8(3), 118-127.

Wang, Y., & Pettit, S. (2021). *E*- Logistics (2nd ed). U.S.A.: Kogan page.

- **Tables and Figures**
  - Line drawings should be of high resolution and high contrast. For color or grayscale photographs (halftones), use a minimum of 300 dpi (.JPG).
  - Provide captions to figures
  - Use the table function of Microsoft Word.
  - Figure and tables should be placed as close as possible to where they are mentioned in the text
- **Page Numbering**: Number all pages of the paper, beginning with the title page. The number is in the bottom right corner (1 inch from right and ½ inch from the bottom page edges).

Publication Charge

Publication Charge

The process of payment will be required to enable an effective and efficient screening process. Fee payment will be due at registration, will be **150 USD for both Thai and international authors. This fee is non-refundable.**

Remark: The fee shall be in effect from October 1, 2026 onward.

SUBMISSION PREPARATION CHECKLIST

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

1. The manuscript must not have been published or submitted elsewhere for consideration. (A brief explanation will be necessary to clarify this matter.)
2. The submitted file is in **Microsoft Word** and **PDF** document file with a single column format.
3. Where available, URLs for the references must be provided.
4. Research or academic papers must be 15-20 pages in length inclusive of references, tables, graphs, charts, and figures.
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).
9. The Journal of Supply Chain and Sustainability Research (SCSR) uses American Psychological Association **(APA) style** (7^{th} edition).
10. Please register as **Author** for paper submission online on Thaijo system.