

Green Innovation Among Transportation Enterprises in Guangdong, China Basis for Sustainable Development Model

Lan Shu

Adamson University, Manila, 1000, Philippines

Abstract: With escalating global climate change and environmental challenges, green innovation has emerged as a pivotal strategy for enterprises to achieve sustainable development. This study investigates the status of green innovation and its impact on sustainable development within transportation enterprises in Guangdong Province. Data were gathered through questionnaires from six representative enterprises and analyzed using descriptive statistics, correlation analysis, and multiple regression methods. The findings indicate that while substantial progress has been made in applying green innovation technology systems, significant gaps persist in implementing green management concepts. Moreover, green innovation markedly enhances sustainable development performance, including cost reduction, market share growth, enterprise expansion, and improved technology transfer. However, its implementation is constrained by insufficient policy support, limited resource allocation, and inadequate employee engagement. Based on these insights, the study recommends prioritizing green management, integrating green innovation into strategic planning, fostering stronger collaboration with policymakers, and optimizing resource allocation to advance sustainable development goals.

Keywords: Green Innovation, Sustainable Development, Transportation Enterprises.

1. Introduction

1.1. Background of the Study

The concept of green transformation and development has now gained widespread acceptance across the international community. It has become not only a major approach for addressing global challenges like climate change, environmental pollution, and ecological degradation but also presents a significant opportunity for future economic and societal progress. Currently, China's green transformation goals place equal emphasis on reducing pollution and cutting carbon emissions, focusing on establishing a new energy system while reducing reliance on traditional carbon-intensive industries.

Enterprises are the core subjects of green innovation. The report of the 20th National Congress of the Communist Party of China pointed out: "We must firmly establish and practice the concept that green water and green mountains are golden mountains and silver mountains, and plan and develop from the perspective of harmonious coexistence between man and nature."

Enterprises play a crucial role in advancing green innovation. The 20th National Congress of the Communist Party of China highlighted the importance of integrating the idea that "green mountains and clean waters are invaluable assets." The Congress emphasized planning and growth based on the harmonious coexistence of humanity and nature.

Chinese-style modernization embraces harmony between humanity and the environment, following a green and low-carbon development approach that emphasizes ecological sustainability. On the one hand, it promotes the adoption of green production methods and low-carbon lifestyles, aiming to fundamentally resolve the tensions between economic growth and resource-environment constraints. On the other hand, green development aligns with international and general trends, positioning the green economy at the forefront

of a new wave of global industrial competition (Wang, Chu & Hao, 2024).

Unlike developed countries that address environmental pollution first and then control carbon emissions, China's current green transformation strategy emphasizes a dual focus on pollution control and carbon reduction, acknowledging that the task of ecological protection remains challenging. Enterprises are considered the primary agents responsible for achieving China's carbon reduction goals, playing a crucial role in this endeavor. Green transformation and enterprise development have been established as key strategies to achieve China's "dual carbon" goals. However, there are still several bottlenecks that need to be overcome to fully achieve green transformation and development within enterprises (Krzywanski, Kijo Kleczkowska, SNowak, & De Souza Santos, 2023).

Green technology innovation serves as a fundamental driver for enterprises aiming to achieve low-carbon transformation. Achieving green development in enterprises requires leveraging technological innovation to guide and support the entire process. Through green innovation, enterprises can integrate green technologies and pollution control, thereby reducing pollutant generation and emissions throughout the entire production chain.

In 2019, the total assets of waste resource comprehensive utilization enterprises in China reached 247 billion yuan, an increase of nearly 60% compared to 2013. These enterprises are mainly engaged in the recycling and utilization of waste metals, waste paper, waste plastics, and waste electrical and electronic products and have made contributions to China's green development.

The application of Industry 4.0 technology can help China significantly reduce carbon emissions. By 2030, the emissions reduction brought about by digital technology is expected to reach 112 million tons of carbon dioxide equivalent per year. For example, real-time data can help

grasp resource consumption, optimization software applied to production processes can help save energy, and the integration of blockchain technology and Industry 4.0 innovation can promote new business models.

The key to the green transformation of enterprises lies in leveraging technological innovation to enhance efficiency. By applying technological innovation, companies can improve resource utilization rates, drive development towards both ends of the "smile curve," transition to technology-intensive and high-value-added industries, and facilitate the green development and optimization of industrial structures.

The concept of sustainable development was first proposed as early as 1980 in the World Conservation Strategy published by the International Union for Conservation of Nature (IUCN), United Nations Environment Programme (UNEP), and World-Wide Fund for Nature (WWF). China's transportation sector stands out in terms of the quality, reliability, sustainability, and resilience of infrastructure indicators (SDG9).

1.2. Literature Review

Bian and Yu (2022) took 211 transportation enterprises as research objects, based on stakeholder theory, high-order theory, and institutional theory, constructed a theoretical model between supplier green pressure, executives' environmental awareness, government environmental regulation, and enterprise green innovation behavior, and used hierarchical regression analysis and the bootstrap method to test and discuss the impact of supplier green pressure on enterprises' green innovation behavior. Furthermore, the mediating role of executives' environmental awareness and the regulating role of government environmental regulation were further analyzed. The results show that supplier green process collaboration and supplier green knowledge sharing have a significant positive impact on enterprise green innovation behavior. Executives' environmental awareness plays a part in mediating the role between supplier green process collaboration, supplier green knowledge sharing, and corporate green innovation behavior. Government environmental regulation positively regulates the relationship between supplier green process collaboration, supplier green knowledge sharing, and enterprise green innovation behavior.

Li (2021), through in-depth research on urban rail transit marketing models, aims to scientifically upgrade the established models. Managers should adopt a variety of methods to explore and study new ideas for the construction of new urban rail transit marketing models. In the end, the expected results and goals can be obtained in terms of marketing team building, marketing model optimization, and customer personalized demand satisfaction. It can not only design a deep-level marketing model according to market changes and customer needs but also actively respond to the national green development concept and build a characteristic green marketing plan.

Feng and Guo (2022) based on the 2015-2021 annual reports and social responsibility report information of listed transportation enterprises, conducted research and analysis on the relationship between social responsibility and corporate performance. It is found that under the condition of controlling the scale of the enterprise, the performance of employee responsibilities by the enterprise has a positive impact on the performance of the enterprise. The performance of consumer responsibilities by enterprises has a negative

impact on corporate performance; the performance of corporate responsibilities to the government has no obvious impact on corporate performance. of corporate responsibilities to the government has no obvious impact on corporate performance.

Wang and Wang (2021) built a sustainable development performance evaluation index system for hazardous chemical transportation enterprises from five dimensions: economy, safety, society, environment, and digitalization. On this basis, based on the interval intuitive fuzzy evaluation theory and analytic hierarchy method of TOPSIS, the sustainable development performance evaluation of hazardous chemical transportation enterprises is studied, and the feasibility of the sustainable development performance evaluation method of hazardous chemical transportation enterprises is empirically analyzed and verified.

Tu Jianjun (2021) believes that reducing fleet operating costs while improving transportation efficiency, reducing carbon emissions, and achieving sustainable mobility.

Collazzo, P., and Lozano, C. P. examine the interplay between green innovation and social responsibility in manufacturing competitiveness. The results are followed by structural equation models after adjusting and validating measurement models, in which the main assumptions are confirmed, providing empirical evidence that CSR and green innovation significantly affect manufacturing competitiveness in developing economies.

Khan, P. A., Johl, S. K., and Akhtar, S. (2022) explore the direct relationship between environmental and social sustainability goals and corporate financial performance and the moderating role of green innovation. Data from 67 companies on five continents (Europe, Australia and New Zealand, Asia, North America, and Africa) and their top five blue-chip companies were collected through content analysis. Generalized Least Squares (GLS) is used to test direct relationships. The results show that environmental sustainability goals are negatively correlated with environmental sustainability.

Khan, P. A. and Shireen Singh (2023) It is pointed out that to promote the "dual carbon" work in transportation, it is necessary to focus on the new energy of transportation vehicles, build an efficient and comprehensive transportation system as the key, ensure the construction of green transportation infrastructure as the guarantee, and supplement the construction of a green travel system. Multiple green and low-carbon policy measures should be combined and implemented to comprehensively promote the green and low-carbon transformation of transportation.

As a "pioneer of China's modernization," the transportation industry is guided by Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era, grounded in the overall situation of national development, aligning with global development trends, and closely following the theme of the times. It promotes self-confidence, self-improvement, openness, and common development while vigorously advancing innovation-driven and ecological priorities. This ensures smooth logistics chain operations, enhances industrial chain coordination, and promotes sustainable economic and social development in the transportation sector.

It can be seen that China's transportation industry needs to achieve sustainable development, and green innovation is an important starting point for achieving sustainable development. To foster sustainable development in China's transportation industry, it's crucial to embrace green

innovation. By prioritizing eco-friendly practices and investing in alternative transportation modes, China can mitigate environmental impacts and meet growing mobility needs. This shift towards sustainability not only benefits the environment but also promotes inclusive growth and enhances citizens' quality of life.

1.3. Problem Statement

Hence, with all the related literature stated above, the proponents aim to answer the following questions:

- (1) What is the current level of the green innovation of the transportation enterprise?
- (2) What is the current level on performance sustainability of the transportation enterprise?
- (3) Is there a significant relationship between the current level of green innovation and performance sustainability?
- (4) Based on the outcome of the study, what sustainable development model with the transportation enterprise can be proposed?

1.4. Hypothesis

The following null hypothesis was tested:

Ho1: There is no significant relationship between the current level of green innovation and performance sustainability.

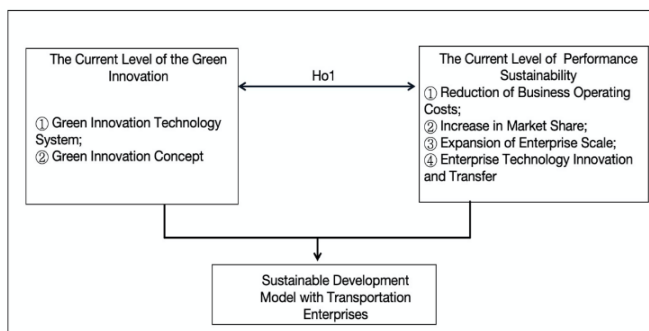


Figure 1. Conceptual Framework

2. Method

2.1. Research Design

A research design is the framework or guide used for the planning, implementation, and analysis of a study. Thus, it serves as the plan for answering the research questions and hypothesis. The design that will be used in this study is descriptive research design using the quantitative approach.

This study mainly uses descriptive correlation research designs, specifically to describe the current state of affairs statement through which researchers have no control over variables. These descriptive designs are mainly used in the profile of respondents. How may the level of green innovation of the transportation enterprise and the sustainable development level of the transportation enterprise, etc., discover relationships between variables and allow prediction of future events from current knowledge.

2.2. Data Management

This study employs a quantitative methodology to gain a deeper understanding and verify the reliability and validity of the findings. Quantitative data is collected through a questionnaire survey of six transportation companies in Guangdong Province that have implemented green innovations. To protect the privacy of the data, the names of the companies will not be disclosed.

Quantitative data is obtained through questionnaires to understand the current level of green innovation and the sustainability of the enterprises. The collected data is collated and cleaned to ensure accuracy and reliability. Rigorous data management procedures facilitate thorough analysis and insightful conclusions. A total of 280 questionnaires were collected, from which 13 were excluded due to incomplete or unreasonable responses, resulting in 267 valid samples.

A rigorous five-step validation method is employed to ensure the accuracy and effectiveness of the questionnaire. First, experts in green innovation and questionnaire design review the questionnaire to establish face validity, confirming its relevance and precision. Next, a presurvey among a small target group of 60 individuals assesses comprehensibility and applicability, guiding necessary adjustments to the questionnaire based on feedback. Subsequently, thorough data cleaning and preparation are undertaken to enhance data quality before formal data collection. Then, the questionnaire's reliability and validity are rigorously evaluated through calculations such as Cronbach's alpha and validity analysis, ensuring robustness. Finally, the questionnaire is revised as needed to enhance accuracy and improve measurement precision.

2.3. Respondents

In selecting respondents, three criteria are applied: respondents must work in transport enterprises in Guangdong Province, be in decision-making or key executive positions that can influence green innovation policies and practices, and work in areas closely related to green innovation, such as environmental management, energy saving and emission reduction, and sustainable logistics and supply chain management.

2.4. Research Instrument

The questionnaire design of this study is divided into three parts: the first part profiles the interviewee, mainly including basic information about their position; the second part measures the green innovation level of transportation enterprises; and the third part measures the sustainable development level of transport enterprises using a 5-point Likert scale (from "Not Implemented" to "Highly Implemented"). After sorting out the data collected by the questionnaire, descriptive statistical techniques, including mean value and frequency distribution, are used to evaluate the status quo of green innovation and sustainable performance of transportation enterprises and then discuss the correlation between the two.

This study selected 60 participants for the preliminary investigation. All scales used a 5-point Likert scale, with a maximum value of 5 and a minimum value of 1, indicating that higher scores on each scale correspond to higher evaluation levels. Internal conformance testing and CITC calibration were used to check the overall correlation of the items to the forecast data, verifying the internal reliability of each item. A Cronbach's Alpha value of 0.895 indicates that 30 items passed the internal conformance test.

The pre-survey concluded that the KMO test value of the measured data is 0.670, which is greater than 0.6, suggesting that the questionnaire is suitable for factor analysis. The Bartlett's sphericity test results show a chi-square approximation of 25.970, which is greater than zero and has a significant probability of 0.000 ($P < 0.01$). Therefore, the null hypothesis of the Bartlett's sphericity test was rejected,

and the scale was deemed suitable for factor analysis to obtain a better validity structure.

For data analysis in this study, SPSS 29.0 was utilized, including reliability and validity assessment, confirmatory factor analysis, mean analysis, and regression analysis.

3. Results

The statistical results of the data are taken from SPSS 29.0. The results of the quantitative study are presented first and analyzed, and finally the results are synthesized and discussed.

3.1. The Current Level of The Green Innovation of The Transportation Enterprise

Table 1. The current level of green innovation

Statements	Mean	Interpretation
Green Innovation Technology System	3.92	Implemented
Green Innovation Concept	3.93	Implemented
Note. 1.00-1.80 =Not Implemented, 1.81-2.60 = Less Implemented; 2.61-3.40 = Moderate Implemented; 3.41-4.20 = Implemented; 4.21-5.00 = Highly Implemented.		

Table 1 shows that the implementation of green innovative technology systems in the transportation industry shows that companies have demonstrated an active role in environmental protection and sustainable development, with a combined mean value of 3.92, which is within the range of 3.41 to 4.20, which signifies that the green innovative technology systems have reached the level of "Implemented." This suggests that the transportation enterprises maintain a neutral attitude towards green innovation technology systems, neither strongly embracing nor strongly rejecting them. The practice of transportation enterprises in Guangdong Province in green innovation technology systems has demonstrated a moderate level of acceptance. This suggests that these enterprises have achieved certain progress in adopting technologies like pollution control, energy efficiency, and resource recovery. Lin and Chen's (2021) study underscore the significance of green technology in boosting corporate environmental performance and competitiveness, aligning with the observed moderate level of green innovation technology system in this study (Lin & Chen, 2021).

In terms of the implementation of green innovation concepts, companies have demonstrated positive progress in the areas of environmental protection and sustainable development, with a mean score of 3.93, which lies within the range of 3.41 to 4.20, where companies have implemented green innovation concepts. Overall, companies have implemented measures in a number of key areas of the green innovation concept, which not only reflect their commitment to environmental protection but also demonstrate their in-depth practice of the sustainability concept. By continually reinforcing the concept of green innovation, companies can establish a leadership position in the global marketplace while making a positive impact on society and the environment. In terms of the concept of green innovation, enterprises have shown a positive attitude towards the integration of environmentally friendly principles, sustainable material use, and environmentally sustainable technologies. This is consistent with the findings of Zhu, Sarkis, and Lai (2022), who pointed out that the concept of green innovation is crucial for promoting sustainable development and enhancing the market competitiveness of enterprises (Zhu, Sarkis, & Lai,

2022).

3.2. The current level on performance sustainability of the transportation enterprise

Table 2. The current level of performance sustainability

Statements	Mean	Interpretation
Reduction of Business Operating Costs	2.79	Moderate Sustainable
Increase in Market Share	3.05	Moderate Sustainable
Expansion of Enterprise Scale	2.94	Moderate Sustainable
Enterprise Technology Innovation and Transfer	3.13	Moderate Sustainable
Note. 1.00-1.80 = Not Sustainable; 1.81-2.60 = Less Sustainable; 2.61-3.40 = Moderate Sustainable; 3.41-4.20 = Sustainable; 4.21-5.00 =Highly Sustainable.		

The overall composite mean score of 2.79 suggests that companies are moderately sustainable in terms of reducing operating costs, suggesting some variation in responses but a tendency towards the middle of the rating scale. When analyzing the current state of reducing operating costs for transportation enterprises in Guangdong Province, it was discovered that these enterprises have achieved notable success in reducing energy consumption, management costs, transportation costs, and pollution treatment costs. These accomplishments are closely tied to green innovation practices, highlighting the significance of green innovation in cost control. For instance, Zhang, Y., and Wang, H. (2023) noted in their study that by implementing green innovation measures, companies can effectively reduce operating costs and enhance resource utilization efficiency (Zhang & Wang, 2023).

This indicates that in market share, companies have a composite mean score of 3.05, reflecting the overall sustainability of market share gains, but with variations in the effectiveness of implementation in different areas. The increase in market share stands as one of the crucial indicators of the sustainability of corporate performance. This study reveals that, through green innovation, companies are able to expand their market influence, broaden their customer base, enhance market visibility, and boost customer loyalty. These discoveries align with the research conducted by Li, J., and Zhao, X. (2022), who underscored the positive impact of green innovation on bolstering market competitiveness and market share of enterprises (Li & Zhao, 2022).

This indicates that the composite means of 2.94 (moderately sustainable) suggests that the effectiveness of the company's expansion in terms of market size, customer base, and supply chain facilities needs to be strengthened in order to better promote employee confidence and acceptance of the company's expansion strategy and to further drive sustainable growth. The expansion of enterprise scale is closely linked to green innovation. Research findings indicate that green innovation not only contributes to the growth of enterprise scale but also promotes the expansion of supply chains and distribution networks. This viewpoint is supported by Wang, L., and Chen, H. (2021), who believe that green innovation is a key factor driving enterprise scale expansion and market expansion (Wang & Chen, 2021).

This indicates that the composite mean value is 3.13, indicating that the performance of enterprises in technology innovation and transfer is at a moderately sustainable level. In

terms of technological innovation and transfer in enterprises, research findings indicate that green innovation significantly impacts the enhancement of enterprises' R&D capabilities, application of new technologies, transformation of R&D results, as well as patent and technology transfer income. These discoveries align with the research conducted by Chen, Y., & Zhao, X. (2023), who noted that green innovation serves

as a crucial driving force for technological advancement and industrial upgrading in enterprises (Chen & Zhao, 2023).

3.3. The Significant Relationship Between the Current Level of Green Innovation and Performance Sustainability

Table 3. Multiple Regression Results Between the Current Levels of Green Innovation and Performance Sustainability

(1) Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.953 ^a	0.908	0.908	0.23234

a. Predictors: (Constant), Green Innovation Technology System, Green Innovation Concept

(2) ANOVA^a

Model	Sum of Squares	df	Mean Square	F	Sig.	
1	Regression	141.000	2	70.500	1306.021	<.001 ^b
	Residual	14.251	264	0.054		
	Total	155.251	266			

a. Dependent Variable: Performance Sustainability
b. Predictors: (Constant), Green Innovation Technology System, Green Innovation Concept

(3) Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.115	0.081		-13.684	<.001
	Green Innovation Technology System	0.568	0.04	0.542	14.32	<.001
	Green Innovation Concept	0.473	0.04	0.443	11.704	<.001

a. Dependent Variable: Performance Sustainability

Table 4. Summary of Multiple Regression Results Between the Current Levels of Green Innovation and All Dimensions of Performance Sustainability

Dependent variables	Independent variables	R Square	F-value	P-value	Null Hypothesis Decision
Reduction of Business Operating Costs	Green Innovation Technology System & Green Innovation Concept	0.625	220.349	<.001	Reject the Null Hypothesis
Increase in Market Share		0.716	332.169		
Expansion of Enterprise Scale		0.692	296.024		
Enterprise Technology Innovation and Transfer		0.686	288.09		
Performance Sustainability (Overall)		0.908	1306.021		

The multiple regression results in Table 3 show that green innovation technology systems and green innovation concepts have a significant effect on the level of performance sustainability (Sig. = 0.000, significance level 0.001). The R² of the model is 0.908, indicating that the model explains 90.8% of the variance in performance sustainability. This indicates that green innovation technology systems and green innovation concepts have strong explanatory power for firm performance sustainability. ANOVA analysis shows that the regression equation is statistically significant (F (2,264) = 1306.021, p < 0.001), which further validates that the independent variables have a significant explanatory power for performance sustainability.

In the t-test of the independent variables, the regression coefficient of the green innovation technology system is 0.542, which means that for every unit increase in the green innovation technology system, the sustainability level of performance sustainability performance will increase by an average of 0.542 units while controlling for other factors. The coefficient of the green innovation concept is 0.443. Keeping other factors constant, for every unit increase in the green innovation concept, the performance sustainability level will increase by an average of 0.443 units.

Overall, the impact of the green innovation technology system on performance sustainability is slightly higher than that of the green innovation concept. This means that by enhancing the application of green innovation technology, enterprises can more effectively improve the performance sustainability level. At the same time, the promotion of green innovation concepts can also further promote performance improvement by raising the awareness of enterprise management and employees on sustainable development. Therefore, the dual promotion of green innovation in terms of both technology and concept is crucial for realizing the long-term sustainable development goals of enterprises.

It can be seen that green innovation plays an important positive role in enhancing firm performance sustainability, both at the technological system and conceptual level. Therefore, firms should strongly promote green innovation to achieve higher performance sustainability.

Summarize the relationship between current green innovations (covering green technological systems and green conceptual innovations) and aspects of performance sustainability at a significance level of 0.05. It is summarized as follows: There is a significant correlation between green innovation (covering green technological systems and green

concepts) and reduction in operating costs. The results of regression analyses showed that both green innovation technology systems and green concepts had a significant positive impact ($p < 0.05$) on reducing the operating costs of the firms, which suggests that green innovation measures are effective in reducing operating expenses.

There is a significant contribution of green innovation (green technological systems and concepts) to market share growth. The regression results indicate that green innovation significantly contributes to market share growth ($p < 0.05$).

There is a significant correlation between green innovation (including green technology systems and green concepts) and firm size expansion. The findings show that green innovation technology systems and concepts have a significant positive effect on firm size expansion ($p < 0.05$), indicating the key role of green innovation in firm growth.

Green innovation (green technology systems and concepts) has a significant impact on technological innovation and transfer. In particular, green innovation technology systems showed a significant positive effect on technological innovation and transfer ($p < 0.001$).

There is a significant positive correlation between green innovation and the sustainability of corporate performance. Huang and Chan's (2023) study emphasize the crucial role of green innovation in promoting sustainable development in the transportation industry, which is consistent with the findings

of this study on the impact of green innovation on performance sustainability (Huang & Chan, 2023).

3.4. The Sustainable Development Model with The Transportation Enterprise

This study, using multiple linear regression analysis, explored the impact of green innovation technology systems and green innovation concepts on the sustainable performance of Guangdong transportation enterprises. The findings indicate that green innovation is advanced, demonstrating substantial accomplishments in green technology and conceptual application. Green innovation significantly improves sustainability performance by reducing operating costs, increasing market share, expanding enterprise scale, and enhancing technological innovation and transfer. The regression model indicates that both green innovation dimensions positively impact all performance aspects, with an R^2 of 90.8%. The contribution of green technology systems slightly exceeds that of green concepts, but their combined effect is critical. These findings highlight green innovation's key role in promoting sustainable business development by improving resource efficiency, reducing costs, and enhancing market competitiveness while supporting enterprise growth and long-term development.

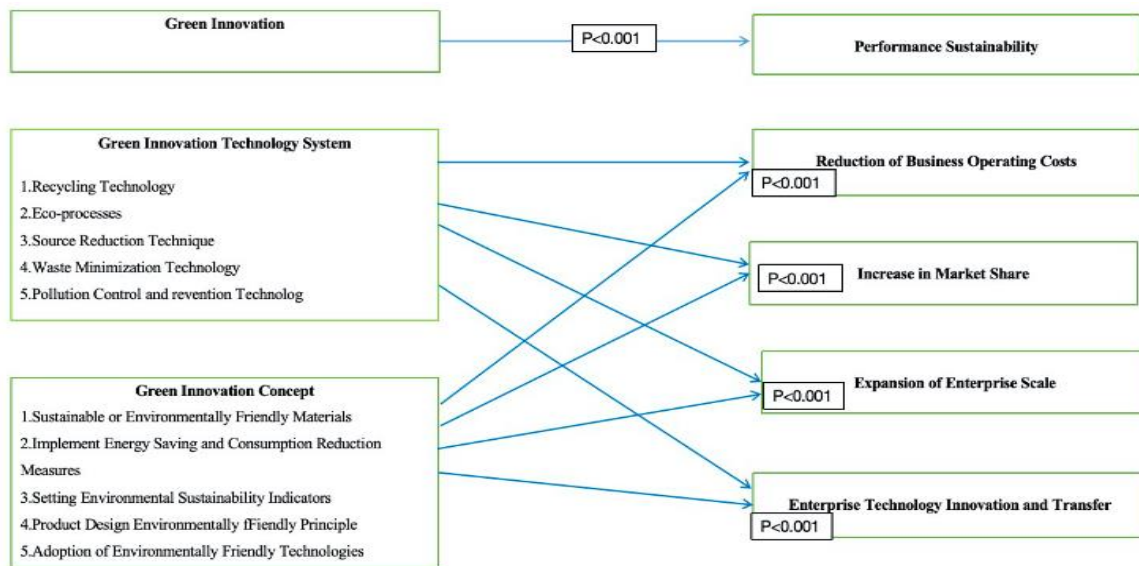


Figure 2. Sustainable Development Model

4. Conclusions

4.1. The Current Level of the Green Innovation of the Transportation Enterprise

4.1.1. Green Innovation Technology System

The analysis of the current status of green innovation technology systems in Guangdong's transportation enterprises has revealed that these systems had reached the implemented stage in practical applications. However, significant variations were observed in the level of application across different technologies. Specifically, recycling technologies exhibited the highest degree of implementation, followed by ecological process technologies. In contrast, the implementation levels of resource reduction and waste minimization technologies were relatively lower, while

pollution prevention technologies demonstrated the weakest implementation. These findings highlighted insufficient research and application in key green technology areas, particularly in complex domains such as pollution prevention, resource reduction, and waste minimization. Overall, the implementation of green technologies had not yet reached an advanced level, and further improvements were required to address weak areas. Additionally, shortcomings in the optimization of management mechanisms and the promotion of technological synergy within the green technology system constrained productivity and environmental benefits.

4.1.2. Green Innovation Concept

Based on an analysis of the current level of the green innovation concept among transportation enterprises in Guangdong. Although there are notable differences across a number of aspects, it was discovered that the adoption of green innovation has reached a modest level. Enterprises

scored the highest in the use of sustainable materials, indicating the active adoption of recyclable, biodegradable, and non-toxic materials in operations. Efforts to reduce environmental impact through cost-saving measures and the inclusion of sustainability indicators in decision-making also demonstrated relatively good application levels. However, the integration of environmental principles into product design and the application of sustainable technologies scored lower, with the latter being the weakest area. Overall, the current level of green innovation concept implementation is not yet highly implemented, especially in terms of product design and sustainable technology applications. Enterprises need to fully incorporate green concepts into their operations, focusing on improving renewable energy systems, water-saving technologies, and waste minimization systems.

4.2. The Current Level of Performance Sustainability of the Transportation Enterprise

4.2.1. Reduction of Business Operating Costs

The analysis of the performance sustainability of Guangdong's transportation enterprises in reducing business operating costs has revealed that these enterprises achieved a moderate level of sustainability. However, significant variations were observed across different dimensions. The performance in reducing transportation costs and improving operational efficiency through green technologies was relatively weaker, reflecting limited success in managing fuel and logistics costs and applying green technologies. Pollution control costs scored the lowest, highlighting substantial challenges in managing pollution control expenses and implementing relevant technologies. Enterprises need to increase investments and enhance technical support to improve pollution control efforts and drive the sustainable optimization of overall operating costs.

4.2.2. Increase in Market Share

Based on the analysis of the current level of sustainability of market share growth in transportation enterprises in Guangdong Province, it was found that the enterprises are at a moderately sustainable level in terms of market share growth, but significant differences exist across different dimensions. The sustainable performance in brand awareness enhancement and marketing coverage was relatively weak. The lowest sustainable performance was observed in service satisfaction and service optimization, indicating that improvements are still needed in customer service optimization and experience enhancement. These findings provide important guidance for enterprises to expand market coverage, enhance brand promotion, and optimize customer service.

4.2.3. Expansion of Enterprise Scale

Based on the analysis of the current sustainability level of scale expansion in transportation enterprises in Guangdong Province, it was found that the overall scale expansion of enterprises was at a moderately sustainable level, but there were certain differences across different dimensions. The upstream and downstream support facilities were relatively weak, and more resources were needed to consolidate the construction of the supply chain and distribution network. Additionally, the expansion of the customer base scored the lowest, indicating that enterprises faced certain challenges in acquiring new customers and expanding market coverage. Overall, enterprises should focus on expanding their customer

base and optimizing their supply chains.

4.2.4. Enterprise Technology Innovation and Transfer

Based on the analysis of the current sustainability level of technological innovation and technology transfer performance in transportation enterprises in Guangdong Province, it was found that the overall performance of technological innovation and transfer was at a moderately sustainable level, but significant differences existed across different dimensions. The ability to promote and apply new technologies scored second, while the improvement in innovation capacity and the ability to transform research results were relatively weak. In particular, the score for enhancing R&D capabilities was the lowest, suggesting that enterprises needed to increase investment in R&D to maintain and enhance their sustainable technological competitiveness. Overall, the performance of enterprises in technological innovation and technology transfer had not yet reached a highly sustainable level, particularly in the areas of R&D and research outcome transformation, which required further strengthening to achieve continuous scale expansion and long-term performance improvements.

4.3. The Relationship between Green Innovation and Performance Sustainability

This study utilized multiple regression analysis and identified a substantial positive relationship between green innovation and sustainable performance. The results demonstrate that the green innovation technology system and the green innovation concept together enhance the sustainability of performance in transportation firms in Guangdong. Furthermore, the influence of the green innovation technology system on sustainable performance is increasingly significant, especially in enhancing resource consumption efficiency and minimizing environmental effects. The green innovation concept significantly enhances the recognition of sustainable growth among employees and customers.

4.4. Proposed Sustainable Development Model

Based on the previous analysis, this study has constructed a model for the sustainable development of the Guangdong transportation industry, as shown in Figure 2. The model assesses how the green innovation technology system and green innovation concept influence the performance sustainability of enterprises. The study highlights the essential contribution of green innovation in advancing sustainable development within firms, with the green innovation technology system having a more pronounced effect on performance sustainability. Specifically, the green innovation technology system demonstrates notable effects in improving resource efficiency, reducing operational costs, increasing market share, and expanding enterprise scale, particularly in terms of technological innovation and results commercialization. While the green innovation concept is also important, its direct impact on performance is relatively smaller, mainly because its dissemination and internalization take a longer time to translate into tangible results. Consequently, firms ought to augment their investment in and utilization of green technological innovation systems while simultaneously enhancing the promotion and execution of green innovation principles to propel sustainable growth.

5. Recommendations

5.1. As to the Current Level of Green Innovation of the Transportation Enterprise

5.1.1. As to the Green Innovation Technology System

To improve the efficiency of green technology application, Guangdong transportation enterprises should adopt a phased approach to implementing green innovation technologies. Initially, enterprises should prioritize pollution prevention technologies by developing exhaust treatment systems and clean energy power solutions. Dedicated funding and collaboration with local research institutions can effectively enhance technology adaptability and practical application. Subsequently, emphasis should be placed on optimizing resource efficiency and constructing closed-loop recycling systems, integrating recyclable materials such as end-of-life vehicle components into production processes to reduce waste. Finally, enterprises should expand the application of ecological process technologies by increasing the use of renewable energy, optimizing transportation routes, and adopting intelligent logistics management systems to reduce overall energy consumption.

5.1.2. As to the Green Innovation Concept

Based on the current level of the green innovation concept implementation among transportation enterprises in Guangdong, it is recommended that companies address weaknesses such as the insufficient integration of environmental principles into product design and the limited application of sustainable technologies. To achieve a higher level of implementation, enterprises should combine technological optimization with management upgrades. Technological optimization should include greening product design processes, using lifecycle analysis tools to enhance energy efficiency and material recyclability, and increasing investments in renewable energy systems, water-saving technologies, and waste minimization systems. Key technologies, such as photovoltaic power generation, water recycling, and efficient waste treatment, should be prioritized. On the management side, enterprises should strengthen green supply chain practices, optimize logistics and procurement processes to improve resource efficiency, and incorporate sustainability indicators, such as carbon footprint and waste emissions, into decision-making and performance evaluations. Digital platforms should be leveraged for real-time monitoring and optimization of environmental performance.

5.2. As to the Current Level of Performance Sustainability of the Transportation Enterprise

5.2.1. As to Reduction of Business Operating Costs

To strengthen the sustainability of reducing business operating costs, Guangdong transportation enterprises are advised to prioritize green technology innovation, particularly in clean energy and intelligent transportation systems, to enhance energy efficiency and effectively lower transportation expenses. Additionally, optimizing management structures and streamlining administrative processes can help reduce management costs and improve overall operational efficiency.

5.2.2. As to Increase in Market Share

It is recommended that enterprises prioritize strategies to enhance customer loyalty by leveraging data analysis and

personalized services to strengthen customer retention. Additionally, they should focus on brand building and marketing promotion, utilizing digital marketing and social media to increase brand visibility. Enterprises should also concentrate on improving service satisfaction by optimizing service processes based on customer feedback and data analysis and enhancing staff training. Furthermore, enterprises should innovate their market expansion strategies, explore new market opportunities, and continuously optimize products and services to meet market demand.

5.2.3. As to Expansion of Enterprise Scale

It is recommended that enterprises prioritize strengthening their supply chain and distribution network, enhancing upstream resource security, and expanding downstream distribution channels to ensure operational stability. At the same time, businesses should focus on expanding their customer base through market research and strategic market development to acquire new clients and increase market coverage. While maintaining stability in investment and market scale expansion, optimizing production processes to support sustainable growth in production scale is also essential.

5.2.4. As to Enterprise Technology Innovation and Transfer

Based on the analysis of the sustainability of technological innovation and transfer performance in transportation enterprises in Guangdong Province, it is recommended that enterprises increase their investment in R&D, focusing on basic research and application development to enhance technological innovation capabilities. Furthermore, enterprises need to improve the commercialization process of R&D outcomes in order to expedite its development. Improving patent and technology transfer strategies, protecting intellectual property, and generating revenue through licensing and transfers are also crucial.

5.3. As to the Relationship between Green Innovation and Performance Sustainability

Based on the research conclusions, enterprises are advised to boost their funding in green technology innovation, particularly in improving resource efficiency and minimizing environmental impact, to enhance their sustainable competitiveness. Simultaneously, efforts should be made to enhance the integration of green concepts within the organization through training and incentive mechanisms, aiming to increase employees' awareness of sustainable development and foster an innovation culture with active participation. Additionally, enterprises should further integrate green innovation with business operations by optimizing resource allocation and operational processes to reduce costs and increase market share. It is also important to drive green supply chain management by enhancing cooperation with suppliers to ensure the effective implementation of environmental measures throughout the supply chain. Finally, a key performance indicator (KPI) monitoring system needs to be implemented to regularly assess the execution of green innovation, ensuring continuous improvement and adaptability to market changes. These measures will enable enterprises to effectively advance green innovation, enhance the sustainability of their performance, and further strengthen market competitiveness.

5.4. As to Sustainable Development Model Based on Green Innovation

Based on the research conclusions, enterprises are advised to boost their funding in green technology innovation, particularly in improving resource efficiency and minimizing environmental impact, to enhance their sustainable competitiveness. Simultaneously, efforts should be made to enhance the integration of green concepts within the organization through training and incentive mechanisms, aiming to increase employees' awareness of sustainable development and foster an innovation culture with active participation. Additionally, enterprises should further integrate green innovation with business operations by optimizing resource allocation and operational processes to reduce costs and increase market share. It is also important to drive green supply chain management by enhancing cooperation with suppliers to ensure the effective implementation of environmental measures throughout the supply chain. Finally, a key performance indicator (KPI) monitoring system needs to be implemented to regularly assess the execution of green innovation, ensuring continuous improvement and adaptability to market changes. These measures will enable enterprises to effectively advance green innovation, enhance the sustainability of their performance, and further strengthen market competitiveness.

5.5. As to Future Study

Future research should focus on the following areas: First, an extensive examination of the implementation of green innovation technology systems in various types of transport enterprises, particularly within public transportation, freight, and other sectors, focusing on innovations such as electrification and automation. The study should analyze the challenges and successes encountered by these companies regarding both the depth and breadth of innovation. Second, case studies should be conducted to identify the key factors and barriers to the successful implementation of green innovation concepts. Future research should also broaden performance analysis to include social and environmental impacts, using specific environmental indicators and social participation measures to offer a more comprehensive framework for evaluating the long-term benefits of green innovation. Future research should also broaden performance analysis to include social and environmental impacts, using specific environmental indicators (such as carbon emissions, resource consumption, and waste reduction) and social participation measures (such as stakeholder engagement, community impacts, and job creation in green sectors). These measures will offer a more comprehensive framework for evaluating the long-term benefits and societal contributions of green innovation. Lastly, empirical validation of the proposed sustainability model should be conducted across different contexts, providing concrete evidence to guide policy development, particularly in areas such as green technology support, fiscal incentives, and industry collaboration. This would foster the sustainable development of the transportation sector.

References

- [1] Bian, M., & Yu, H. (2022). The impact of supplier green pressure on the green innovation behavior of transportation enterprises. *Technical Economics* (05), 25-38.
- [2] Bian, M., Yu, H., & Zhang, Y. (2021). Environmental Regulation and Green Innovation in Transportation: The Mediating Role of Executives' Environmental Awareness. *East China Economic Management*(08),11-20. doi:10.19629/j.cnki.34-1014/f.210225006.
- [3] Chen, M., & Zhao, J. (2021). Stakeholder perspectives on sustainable performance in the transportation industry. *Journal of Cleaner Production*, 287, 125345. <https://doi.org/10.1016/j.jclepro.2020.125345>
- [4] Chen, Y., & Zhao, X. (2023). Green innovation and technology advancement in transportation enterprises. *Technology in Society*, 65, 101458. <https://doi.org/10.1016/j.techsoc.2023.101458>
- [5] Collazzo, P., & Lozano, C. P. (2021). "corporate social responsibility, green innovation and competitiveness - causality in manufacturing". *Competitiveness Review An International Business Journal incorporating Journal of Global Competitiveness*, ahead-of-print(ahead-of-print).
- [6] Doan, A. T., & Nguyen, T. T. (2021). Green innovation, green entrepreneurship, and vietnamese sme development: the role of market turbulence. *World Scientific Book Chapters*.
- [7] Feng, Y., & Guo, X. (2022). Research on the Impact of CSR on Corporate Performance in China's Listed Transportation. *Finance and Economics* (15), 149-151. doi:10.19887/j.cnki.cn11-4098/f.2022.15.003.
- [8] Guo, K., & Wei, W. (2023). Research on green innovation efficiency and its influencing factors of Chinese airlines. *Logistics Science and Technology*(17), 20-25. doi:10.13714/j.cnki.1002-3100.2023.17.006.
- [9] Guo, K. (2015). Research on sustainable development mode of metallurgical transportation enterprises. *Management Observation* (01), 97-99.
- [10] Hu, D., Huang, Y., & Zhong, C. (2021). Does environmental information disclosure affect the sustainable development of enterprises: the role of green innovation. *Sustainability*, 13.
- [11] Huang, L., & Chan, E. (2023). Linking green innovation to sustainable performance in the transportation sector. *Sustainable Development*, 31(2), 332-343. <https://doi.org/10.1002/sd.2100>
- [12] Katz, M. (2016). An analysis of cooperative research and development. *RAND Journal of Economics*, 17(4), 527-543.
- [13] Khan, P. A., Johl, S. K., & Akhtar, S. (2022). Vinculum of sustainable development goal practices and firms' financial performance: a moderation role of green innovation. *JRFM*, 15, 45-60.
- [14] Li, Y. (2021). Research on the innovation of urban rail transit marketing model in the new era. *Transportation Manager World* (16), 4-6.
- [15] Li, J., & Zhao, X. (2022). Green innovation and market share enhancement: A study on transportation sector in Guangdong Province. *Journal of Business Research*, 127, 111783. <https://doi.org/10.1016/j.jbusres.2022.111783>
- [16] Li, Y., & Zhang, W. (2023). Green innovation and sustainable development goals: A strategic analysis for transportation enterprises. *Journal of Sustainable Development*, 26(1), 23-34. <https://doi.org/10.1080/10980968.2023.11084>
- [17] Lin, R., & Chen, J. (2021). Green innovation in the transportation sector: A comparative study of China and the United States. *Journal of Environmental Management*, 283, 111963. <https://doi.org/10.1016/j.jenvman.2021.111963>
- [18] Miao, T. (2020). Research on Sustainable Development of Private Aviation from the Perspective of Policy Synergy (Master's Thesis, Shanghai Jiao Tong University).

- <https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD202202&filename=1021678568.nh>
- [19] Tu, J. (2021). Michelin joins hands with Sennder, a digital freight company, to promote green and sustainable road transport. *Auto Maintenance and Repair*(09),79. <https://doi.org/10.16613/j.cnki.1006-6489.2021.09.035>
- [20] Wang, Q., & Wang, Q. (2021). Research on sustainable development performance evaluation of hazardous chemical transportation enterprises. *Journal of Zhejiang Wanli University* (05), 1-7. <https://doi.org/10.13777/j.cnki.issn1671-2250.2021.05.001>
- [21] Wang, L., & Chen, H. (2021). The role of green innovation in enterprise expansion and market growth. *Journal of Sustainable Development*, 24(1), 34-45. <https://doi.org/10.1080/10980968.2021.1882345>
- [22] Wang, S., & Ren, J. (2020). Perceptions of green innovation in the transportation industry: A multi-stakeholder analysis. *Transportation Research Part A: Policy and Practice*, 135, 76-90. <https://doi.org/10.1016/j.tra.2020.03.011>
- [23] Zhang, Y., & Wang, H. (2023). The impact of green innovation on operational cost management in transportation enterprises. *Journal of Green Management*, 15(2), 45-59. <https://doi.org/10.1080/10638352.2023.1242345>
- [24] Zhao, H. (2020). Construction of sustainable development evaluation index of air transport of dangerous goods based on balanced scorecard. *Transportation Enterprise Management*(02), 85-88.
- [25] Zhao, M. (2017). Some thoughts on the sustainable development of the road transport management industry. *Research on Transmission* (05), 225+227.
- [26] Zhu, Q., Sarkis, J., & Lai, K. (2022). Green innovation and business performance: Evidence from the transportation industry in China. *International Journal of Production Economics*, 149, 66-78. <https://doi.org/10.1016/j.ijpe.2022.01.005>