Factor Technological Innovation Affects Green Logistics Performance of Small and Medium-sized Manufacturing Enterprises in the Pearl River Delta of China

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ABSTRACT. The purpose of the research to study the level of factor technological innovation affects the green logistics performance of small and medium-sized manufacturing enterprises in the Pearl River Delta of China and to analyze the factor technological innovation affects the green logistics performance of small and medium-sized manufacturing enterprises in the Pearl River Delta of China. This study integrates qualitative and quantitative research techniques. In-depth interviews with business and the development of effective and reliable questionnaires as a tool for quantitative research to collect objective empirical research on the development level of green logistics of 30 small and medium-sized manufacturing enterprises in the Pearl River Delta region of China, Sample size of 400 copies, using Taro Yamane's formula at a tolerance level of 0.05. Data were analyzed using percentage, mean, and inferential statistics descriptive statistics for regression analysis.

The research revealed that: the results show that technological innovation in green packaging, green warehousing, green transportation, green supply chain and green production all have a positive correlation on green logistics performance. In particular, the cost of green packaging has a significant impact on green logistics, and also has a positive impact on the current business performance. For the technological innovation of enterprises in all aspects of the operation process, the impact on green logistics is long-term. For the long-term operation of enterprises, the green packaging of products from design to production line is a topic that enterprises need to do well in production links and supply chain management; Enterprise leaders and employees need to jointly establish the awareness of full participation, including using green concepts to guide the planning and transformation of product structure, formulating "green plans", implementing "green projects", cultivating "green production", "green consumption", "green products", etc., so that front-line employees cherish the awareness of human living environment, and let the logistics management concept of "environmental protection, ecology and green" be deeply rooted in the hearts of the people.

Keywords: Green packaging, green logistics, green production, technological innovation.

F. Cao et al. (eds.), *Proceedings of the 2023 5th International Conference on Economic Management and Cultural Industry (ICEMCI 2023)*, Advances in Economics, Business and Management Research 276,
https://doi.org/10.2991/978-94-6463-368-9_52

1 Introduction

In recent years, global warming is intensifying at an unprecedented rate. The main factor behind the intensification of climate warming is the large amount of carbon dioxide emissions caused by high energy consumption, and the main industry with high carbon emissions comes from the logistics industry. Due to economic globalization, the logistics industry has become the new driving force of the global economy, but whether logistics can be green and low-carbon development is the key to reducing carbon emissions, scholars(Tian Shizhong & Tong Mengmeng 2023)[1] research that green and low-carbon recycling development of innovation is very necessary. Technological innovation is a fundamental way for enterprises to implement sustainable development strategies and green logistics. This study investigates the impact of technological innovation on the green logistics performance of small, medium and micro manufacturing enterprises in China(Ma Zhuang & Lin Dong. 2023)[2] conducted an objective empirical study on the impact of technological innovation on the green logistics performance of small and medium-sized manufacturing enterprises in China, identified the main key factors affecting the development of green logistics in enterprises, and utilized technological innovation to help small and medium-sized manufacturing enterprises to improve their understanding of the meaning of "green logistics", and put forward a proposal to achieve green and sustainable development（Anil Kumar.2015）[3], reduce logistics costs, and reduce the cost of logistics （Zong Rui-Hua. 2023)[4], and improve the level of customer service and satisfaction and other long-term development proposals. This study analyzes the main factors affecting green logistics technological innovation in small and medium-sized manufacturing enterprises, and puts forward countermeasures and suggestions to promote their green technological innovation. At the same time, it also provides suggestions and bases for the government to formulate policies and standards for "green logistics" industry planning, which is of certain practical significance.

2 Research Objective (s)

(1) To study the impact of the level of factor technological innovation on the green logistics performance of small and medium-sized manufacturing enterprises in the Pearl River Delta region.

(2) Analyze the factors of technological innovation affecting the green logistics performance of small and medium-sized manufacturing enterprises in the Pearl River Delta region.

3 Research Hypotheses

H1: The technological innovation of green packaging has a positive impact on green logistics performance.

H2: The technological innovation of green storage has a positive impact on green logistics performance.

H3: The technological innovation of green transportation has a positive impact on green logistics performance.

H4: The technological innovation of green supply chain has a positive effect on green logistics performance.

H5: The technological innovation of green production has a positive impact on green logistics performance.

4 Scope of Research

This research is a study which contains the following variables:

Independent Variable:

X1 Green Packaging; X2 Green Storage; X3 Green Transportation; X4 Green Supply Chain; X5 Green Production;

Dependent Variable:

Green Logistics Performance;

Scope of Population: A Sample of 30 Physical Enterprises of Micro, Small and Medium-sized Manufacturing Enterprises in the Pearl River Delta Region of China.

Scope of Area: Cities in the Pearl River Delta region of China.

Scope of Time: From January through October 2023.

5 Research Methodology

On the basis of analyzing the technological innovation of green packaging, green warehousing, green transportation, green supply chain, green production, etc., the impact on green logistics performance is studied and analyzed; In order to improve the green management of enterprises and improve the performance of green logistics, the researchers conducted the following research procedures.

5.1 The Population and the Sample

The Population

This study selects 30 representative SME from China's Pearl River Delta (PRD) urban agglomeration (PRD), including the cosmetic industry, automobile parts industry, and small home appliance manufacturing industry, which are very representative of the products sold to various regions around the world. China's Pearl River Delta (PRD) city cluster includes three new metropolitan areas: Guangzhou, Foshan and Zhaoqing (GFZ); Shenzhen, Dongguan and Huizhou (SZDH); and Zhuhai, Zhongshan and Jiangmen (ZZJ). The Pearl River Delta (PRD) is one of the most dynamic economic zones in the Asia-Pacific region, creating 85% of the province's GDP with 70% of the population of Guangdong, China, the world's most influential advanced manufacturing base and modern service base, the gateway to open up the

southern region of China, and the main area of China's participation in economic globalization.

5.2 The Sample

The sample group used in this study was 398 employees working in manufacturing enterprises in the Pearl River Delta of China. According to the sample size of the study, a limited population sample size was determined to make a table, 398 people were used as the sample size of the study, a total of 430 questionnaires were distributed, 400 were recovered, the recovery rate was 93%, and 398 valid questionnaires were obtained, with an effective rate of 99%.

5.3 Research Instruments

The study on the impact of factor technological innovation on the green logistics performance of small and medium-sized manufacturing enterprises in the Pearl River Delta of China is a combination of quantitative and qualitative research.

There are two types of data collection tools:

1) in-depth interviews and 2) questionnaires.

The questionnaire and interview form are created with the following steps:

1. Collect data through online and offline data analysis. The online questionnaire is sent to the questionnaire link via the "Questionnaire Star" platform (data collection software) to be completed. In the offline questionnaire, visit the enterprise customer to fill out the questionnaire to achieve the purpose of data collection.

Table 1. Questionnaire structure of the impact of technological innovation on green logistics performance of green packaging, green warehousing, green transportation, green supply chain, and green production

Variable	Number of verses	Clause	Data	Measurement
Part 1				
Basic information	(4)	1-4		
Part 2				
About the willingness and demand of small and medium-sized manufacturing enterprises for green technology innovation;	(4)	5-14		
Part 3				
1. green packaging	(4)	15-18	Likert Scale	5 opinion levels
2. green warehousing	(4)	19-22	Likert Scale	5 opinion levels
3. green transportation	(4)	23-26	Likert Scale	5 opinion levels
4. green supply chain	(4)	27-30	Likert Scale	5 opinion levels
5. green production	(4)	31-34	Likert Scale	5 opinion levels
6. Performance of green logistics	(6)	35-40	Likert Scale	5 opinion levels
Total	**40**			

Table 1 Part1 Basic Information: Sex. The sample group of respondents totaled 398 people. The majority were males, numbering 301 people, accounting for 75.6

percent, followed by Females, numbering 97 people, accounting for 24.4 percent.Age: The sample group of respondents was 398 participants. Most were 41-49 years old, with 161 people accounting for 40.5%, followed by 25-40 years old, 122 people (30.7%), under 25 years old, 111 Occupation: Highest Education Level: Of the 398 respondents to the sample group, 239 (60.1%) had bachelor's degrees, followed by associate degrees, 105, accounting for 26.4%, followed by those with lower high school education, 39 (9.8%), and 15 with postgraduate education or above, accounting for 3.8%.posts: The sample group of respondents who visited the survey consisted of 398 people, most of whom were financial managers of private companies, and 175 (44%); followed by purchasing managers and sales managers of the business department, with 126 people, accounting for 31.7%; followed by employees in other positions, with 87 people, accounting for 21.9%; General manager or plant director, 10 people, accounting for 2.5%.Table 1 Part2 About the willingness and demand of small and medium-sized manufacturing enterprises for green technology innovation. Table 1 Part3 Questionnaire structure research options on the impact of technological innovations in green packaging, green warehousing, green transportation, green supply chain and green production on green logistics performance.

2. Interview Group 3: Interview with Professor Huang Shizheng, an industry scholar with many research results in the green logistics industry; Interview with Professor Sun Caiping, an expert with professional knowledge and ability in the field of business research; Mr. Yuan Zhi, General Manager of Guangzhou Baomeng Cosmetics Co., Ltd., was also interviewed, and a total of 3 people (as shown in Appendix A) analyzed and integrated the interview results as a guide for establishing a quantitative questionnaire.

3. Determine the issues and scope of questions to be consistent with the objectives. and the benefits of research by structuring the questionnaire. as the following table 1.

Proceed to create questions based on in-depth interviews with experts. Along with studying, researching, and working definitions, then taking them to the advisor to consider and verify the appropriateness of the questions. Language used and typing formatting along with bringing improvements and corrections.

4. The completed questionnaire is given to experts for measurement and evaluation to check the validity of the content. People with knowledge and expertise in the field of business research check security, matching content coverage and linguistic accuracy, and consistency with research objectives. For the list of content validators (listed in Appendix A), the researchers used an IOC index (Project Goal Consistency) with the following scoring characteristics:

+1 means that you are sure that the questions are consistent with the research objective.

0 means you are unsure whether the question is consistent with the research objective.

-1 means that you are certain that the questions are inconsistent with the research objective.

5.The selection of question items uses criteria to judge content validity, which specifies that the calculated IOC index value must be greater than 0.6 (IOC>0.6). It is

therefore considered that the question items are consistent with the message to be measured.

6. The researcher brings a draft questionnaire that has been edited by a qualified person. presentation of advisors considers the completeness again and bring it to the trial (try-out) with a group of people who are like the sample you want to study 30 people, then bring it to the reliability value. (Cronbach's alpha coefficient).

7. The researcher brings the defects from the experiment to the final improvement. to be printed as a complete questionnaire used to collect data for research.

Scoring criteria

The questionnaire with question characteristics is a 5-level estimation scale of Likert, with the meaning of the score and its implications as follows:

Score level 5 means highest level of agreement. Score level 4 means high level of agreement. Score level 3 means medium level of agreement. Score level 2 implies a low level of agreement. Score level 1 implies the lowest level of agreement.

The criteria for interpreting the mean scores of the observed variables are categorized into the following five levels.

Average score ,4.50 – 5.00highest level;3.50 – 4.49, high level;2.50 – 3.49, moderate level;1.50 – 2.49, low level;1.00 – 1.49, lowest level;

The reasons for setting such rules are as follows:

1. The calculated arithmetic mean can be any value in the range 1-5, such as 1.75, 4.50...., 5.00.

2. The score level 1-5 is a continuous value represented by a straight line. And can be defined as a continuous scoring range which is represented by a straight line and can be defined as a continuous scoring range Each period is separated by 1 unit as follows:

3. Based on the actual data collected from the scores The minimum value is 1 and the maximum is 5, so use the criterion 1.00 – 1.50 instead of .50 – 1.50 and use the criterion 4.50 – 5.00 instead of 4.50 – 5.50.

4. In the case where the calculated arithmetic mean ($\overline{X}$) has a value corresponding to the interval between the levels the opinions to be interpreted are at a higher level of opinion, for example, the arithmetic mean = 4.50 will mean that there is the highest level of opinion on that matter, etc.

Determining the quality of research tools.

To get quality tools The researcher therefore brought a questionnaire that was created. Go test for validity and reliability. (reliability) as follows.

1. Determination of validity the researcher will check the content validity of each text to ensure that it meets the objectives of the study. by consulting with 5 subject matter specialists to examine the clarity of language, wording, and accuracy in the content Consistency of the questions in the questionnaire with the objectives (index of item objective congruency--IOC) with the following scoring criteria:

+ 1 when the expert or expert is sure that the question is consistent with the content.

0 When the expert or expert is not sure that the question is consistent with the content.

-1 when the expert or expert is sure that the question is inconsistent with the content.

follow formula:

$$IOC = \frac{\sum R}{N}$$

IOC Instead, it indexes the consistency between queries. with research objectives

∑R Instead, The sum of the opinions of experts or experts.

N Instead, of the number of experts or experts.

2.Calculation of the consistency index between questionnaires. with research objectives Must have an Index of Conformity (IOC) value greater than 0.6. It can be concluded that the questionnaire The content accuracy is within acceptable criteria. can be used to collect further data.

3.Determination of reliability (reliability) by using the questionnaire that has been verified by the advisory committee. and experts with expertise have revised and tested (try out) with 30 test recipients of the questionnaire that have similar characteristics to the sample group to be studied before using it with the sample group. To analyze sentiment (reliability) using the Alpha coefficient method of Cronbach (1990), generally, the Cronbach's a coefficient above 0.7 is acceptable. If the reliability coefficient is greater than 0.8 , which indicates that the questionnaire is reliable and can be used in the study. From the data analysis results, the results are summarized in Table 2.

Table 2. Questionnaire confidence value.

Factors		Number of questions (N)	Confidence value (R)	Interpretation
X1	green packaging	30	0.790	
X2	Green warehousing	30	0.837	
X3	Green transportation	30	0.737	
X4	Green supply chain	30	0.810	
X5	Green production	30	0.814	
Y	Performance of green logistics	30	0.979	
Factors Total		30	0.905	

From Table 2 it was found that the confidence values of all factors and the total factors of the questionnaire were over 0.7 Therefore, it can be concluded that Questionnaires can be used to collect real data. with confidence values that pass the acceptance criteria.

6 Result

Table 3. Results of regression coefficient analysis

Model	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.
	B	Std. Error			
	5.86	1.54	-	4.858	0.001
X1	2.169	0.254	0.17	4.665	0.003
X2	-2.279	0.336	-0.266	-5.831	0.002
X3	1.708	0.313	0.486	2.265	0.043
X4	-0.771	0.401	-0.943	-1.922	0.079
X5	1.108	0.368	1.265	3.008	0.011

R2 = 0.817, *P< .05 ,**P< .01

From Table 3 The results of the regression coefficient analysis from Table 4. 25 are: green packaging technology innovation X1, green storage technology innovation X2, green transportation technology innovation X3, green supply chain technology innovation X4, green production technology innovation X5.

From the table, it is known that the Sig value of green packaging technology innovation X1, green storage technology innovation X2, green transportation technology innovation X3, and green production technology innovation X5 is less than 0.05 is statistically significant.

The R-squared of the model is 0.817, indicating that X1, X2, X3, X4 and X5 can explain 81.7% of the green logistics performance impact Y.

The estimated coefficient of the B value of X1 is 2.169 (t = 4.665, Sig = 0.003<0.05), indicating that X1 has a significant positive impact on green logistics performance (Y).

The estimated coefficient of X3 value is 1.708 (t = 2.265, Sig = 0.043 >0.05), indicating that X3 has a significant positive impact on green logistics performance (Y).

The estimated coefficient for the B-value of X4 is -0.771 (t = -1.922, Sig = 0.079<0.05), indicating that X4 has no significant impact on green logistics performance (Y).

The estimated coefficient of the B value of X5 is 1.108 (t = 3.008, Sig = 0.011<0.05), indicating that X5 has a significant positive impact on green logistics performance (Y).

At the value level B = 5.86.

This paper studies the impact of technological innovation in green packaging, green warehousing, green transportation, green supply chain, and green production on green logistics performance. Based on the quantitative qualitative analysis results mentioned above, we can further verify whether the hypotheses H1, H2, H3, H4, and H5 in this paper are valid, as shown in table 4.

Table 4. Summary table of study hypothesis validation results

number	research hypothesis	conclusion
H1	The technological innovation of green packaging has a positive impact on green logistics	Accepted
H2	The technological innovation of green warehousing has a positive impact on green logistics	Accepted
H3	Technological innovation in green transportation has a positive impact on green logistics	Accepted
H4	Technological innovation in green supply chain has a positive impact on green logistics	Accepted
H5	The technological innovation of green production has a positive impact on green logistics	Accepted

data source: based on the rational analysis

7 Conclusion and Discussion

7.1 Conclusion

After conducting regression linear statistics for the impact of technological innovations in green packaging, green warehousing, green transportation, green supply chain, and green production on green logistics performance, the survey found that:

H1: The technological innovation of green packaging has a positive impact on green logistics performance.

H2: The technological innovation of green storage has a positive impact on green logistics performance.

H3: The technological innovation of green transportation has a positive impact on green logistics performance.

H4: The technological innovation of green supply chain has a positive effect on green logistics performance.

H5: The technological innovation of green production has a positive impact on green logistics performance.

8 Discussion

Discussion of the findings of this study It is a discussion based on the conclusions of the research. It can be divided into, main points as follows:

1. The results of the study show that technological innovation in green packaging has a positive impact on green logistics performance.

The results show that: There is a positive correlation between technological innovation of green packaging and green logistics performance, which is consistent with the viewpoint obtained by (Lin Manqi, Yang Junming, Lai Guanhong, Shi Lijing & Gan Chubin.2023)[5]. At the same time, combined with the current research experience, the summary of the future green packaging material innovation, technological innovation design, etc. This is also consistent with the concept and theory of the "Development trend of green packaging design" published by Guan Hua in Modern Food2. It is found that the technological innovation of green warehousing and green transportation has a positive impact on the performance of green logistics.

2. It was found that technological innovations in green warehousing and green transportation have a positive impact on the performance of green logistics.

The research results show that the storage equipment technology of energy saving and environmental protection mainly involves the implementation of photovoltaic power generation on the top of the warehouse floor, energy-saving technology of cold storage, intelligent shuttle and intensive shelf system. It is also found from the research results that technological innovation of green transportation has a positive correlation effect on green logistics, which is consistent with the conclusion (Zhang Z Y,2023)[6] in China's Green Shipping Logistics Law and Policy Research. Green transportation is a green behavior, which is similar to (Li Qian,2023)[7]. The conclusion of "Multi-modal transport to achieve one-stop full chain" door-to-door "green transport" is consistent.

3. The results show that technological innovation in green supply chain and green production has a positive impact on the performance of green logistics.

Proposing green supply chain technological innovation can enhance the performance of green logistics to achieve the carbon reduction initiatives of enterprises(Krzysztof Zovada. (2020)[8], and at the same time help enterprises to realize the overall carbon emission reduction targets. Green production is a necessity for ecological development and an inevitable choice for the high-end development of Chinese manufacturing. Green production refers to a comprehensive measure to minimize the generation of pollutants by implementing pollution control in the whole process of industrial production with energy saving, consumption reduction and pollution reduction as the goal, and management and technology as the means. In line with the "Made in China 2025" officially issued by the State Council of China in May 2015, the requirements of "building green factories, realizing the intensification of plants, harmless raw materials, clean production, resourcefulness of wastes, and low-carbon energy" are clearly put forward(Dong Y C. 2023)[9],(Li Qiang & Hu Ren.2023)[10].

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