DETERMINANTS AND OUTCOMES OF GREEN TECHNOLOGY INNOVATION ADOPTION AMONG THIRD-PARTY LOGISTICS FIRMS IN CHINA

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by

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LIST OF ABBREVIATIONS

1PL	First-Party Logistics
2PL	Second-Party Logistics
3PL	Third-Party Logistics
4PL	Fourth-Party Logistics
5PL	Fifth-Party Logistics
ANN	Artificial Neural Network
AVE	Average Variance Extracted
CFLP	China Federation of Logistics & Purchasing
CMV	Common Method Variance
CP	Cognitive Pressures
CR	Composite Reliability
CX	Complexity
CY	Compatibility
DAT	Data Acquisition Information
DDC	Data-driven Culture
DOI	Diffusion of Innovation Theory
EcO	Economic Outcomes
EI	Eco-Innovation
EnO	Environmental Outcomes
f^2	Effect Size
GC	Green Creativity
GCI	Green Customer Integration
GI	Green Innovation
GII	Green Internal Integration
GSCI	Green Supply Chain Integration
GSI	Green Supplier Integration
GTI	Green Technology Innovation
GTIA	Green Technology Innovation Adoption
HTMT	Heterotrait-Monotrait ratio
InO	Intangible Outcomes
InP	Institutional Pressure

IS	Information System
IT	Information Technology
LM	Linear Regression Model
MAE	Mean Absolute Error
NP	Normative Pressures
OS	Organizational Support
OpO	Operational Outcomes
PLS-SEM	Partial Least Squares-Structural Equation Model
Q^2	Predictive Relevance
QHR	Quality of Human Resources
R^2	Coefficient of Determination
RA	Relative Advantage
RP	Regulative Pressure
RSME	Root Mean Square of Errors
SCI	Supply Chain Integration
SCM	Supply Chain Management
SD	Standard Deviation
SEM	Structural Equation Modeling
SMEs	Small and Medium Enterprises
TOE	Technology-Organization-Environment
TT	Transportation Technology

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PENENTU DAN HASIL PENERAPAN INOVASI TEKNOLOGI HIJAU DI KALANGAN FIRMA LOGISTIK PIHAK KETIGA DI CHINA

ABSTRAK

Logistik pihak ketiga (3PL) memberi kesan besar kepada pelbagai sektor, tetapi operasinya sering merosakkan alam sekitar. Oleh itu, sektor 3PL memainkan peranan penting dalam memacu pembangunan mampan. Inovasi teknologi hijau (GTI) bukan sahaja mengurangkan kerosakan alam sekitar tetapi juga meningkatkan prestasi korporat. Walaupun manfaat ini, banyak firma enggan menerima penggunaan inovasi teknologi hijau (GTIA), dan penyelidikan mengenai faktor yang mempengaruhi penggunaannya dalam industri 3PL masih terhad, terutamanya di negara membangun.Kajian ini menangani jurang tersebut dengan mengkaji faktor penentu dan hasil GTIA dalam firma 3PL di China. Dengan menggunakan kerangka Teknologi-Organisasi-Persekitaran (TOE) dan teori Penyebaran Inovasi (DOI), penyelidikan ini meneroka kesan sokongan organisasi, kualiti sumber manusia, integrasi dalaman hijau, integrasi pembekal hijau, dan integrasi pelanggan hijau terhadap GTIA. Ia juga mengkaji peranan moderasi kreativiti hijau dan budaya berasaskan data. Kajian ini menggunakan reka bentuk keratan rentas, mengumpul data tinjauan daripada 544 firma 3PL di China untuk menjalankan penyelidikan kuantitatif. Pemodelan persamaan struktur kaedah kuasa dua kecil (PLS-SEM) menunjukkan bahawa kelebihan relatif, kesesuaian, sokongan organisasi, kualiti sumber manusia, tekanan institusi, dan integrasi hijau memberi kesan signifikan kepada GTIA. Kreativiti hijau dan budaya berasaskan data turut memperkukuhkan hubungan ini. Firma yang menggunakan GTI mencapai manfaat alam sekitar, ekonomi, operasi, dan tidak ketara, dengan firma yang lebih lama bertapak lebih

cenderung mengamalkannya. Untuk mengatasi keterbatasan dalam PLS-SEM, rangkaian neural tiruan (ANN) digunakan, yang mengesahkan tekanan institusi sebagai peramal terkuat dan kualiti sumber manusia sebagai yang paling lemah. Penemuan ini meningkatkan pemahaman tentang GTIA dalam 3PL, serta memberikan pandangan praktikal untuk pengurus dan pembuat dasar dalam mempromosikan kelestarian alam sekitar dan perniagaan. Kajian ini menekankan pentingnya memperkukuh integrasi pembekal dan memanfaatkan sumber yang dikongsi untuk memaksimumkan manfaat GTIA.

DETERMINANTS AND OUTCOMES OF GREEN TECHNOLOGY INNOVATION ADOPTION AMONG THIRD-PARTY LOGISTICS FIRMS IN CHINA

ABSTRACT

Third-party logistics (3PL) significantly impacts various sectors, yet its operations often harm the environment. Consequently, the 3PL sector plays a critical role in driving sustainable development. Green technology innovation (GTI) not only mitigates environmental damage but also enhances corporate performance. Despite these benefits, many firms are reluctant to green technology innovation adoption (GTIA), and research on the factors influencing its adoption in the 3PL industry remains limited, especially in developing countries. This study addresses these gaps by examining the determinants and outcomes of GTIA among Chinese 3PL firms. Using the Technology-Organization-Environment (TOE) framework and Diffusion of Innovation (DOI) theory, the research explores the effects of organizational support, human resource quality, green internal integration, green supplier integration, and green customer integration on GTIA. It also investigates the moderating roles of green creativity and a data-driven culture. This study adopts a cross-sectional design, collecting survey data from 544 Chinese 3PL firms to conduct quantitative research. Partial least squares structural equation modeling (PLS-SEM) revealed that relative advantage, compatibility, organizational support, human resource quality, institutional pressure, and green integrations significantly influence GTIA. Green creativity and a data-driven culture further strengthen these relationships. Firms adopting GTI achieve environmental, economic, operational, and intangible benefits, with longer-established firms being more likely to adopt. To

address limitations in PLS-SEM, artificial neural networks (ANN) were used, confirming institutional pressure as the strongest predictor and human resource quality as the weakest. These findings enhance understanding of GTIA in 3PL, offering actionable insights for managers and policymakers to promote environmental and business sustainability. The study underscores the importance of fostering supplier integration and leveraging shared resources to maximize GTIA benefits.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides an introduction to the background of the research, including green practices in the logistics sector in China. The transportation and logistics industry has experienced rapid development in recent years, leading to more severe environmental issues. Therefore, it is imperative for 3PL firms to promptly undertake environmental initiatives; this encompasses the GTIA. This chapter presents the problem statement, research questions, and research objectives, emphasizing the significance and importance of the study. Furthermore, a summary of the definitions of key terms used in this study is provided. Finally, the organization of the thesis is outlined.

1.2 Background of the Study

Consumers' consumption requirements and tastes have shifted toward using online marketplaces for purchasing and delivery as e-commerce has evolved. E-commerce has accelerated the growth of the logistics business (Wang et al., 2021). Logistics is an essential component of any economy, as illustrated by the impact of COVID-19 on logistics providers (Choi, 2020). Modern businesses rely heavily on logistics service providers as they provide consumers with a diverse array of services from basic transportation to comprehensive supply chain management (Giusti et al., 2019). The logistics industry covers various activities, such as storage, transportation, loading and unloading, handling, processing, distribution, and logistics information

management. Logistics firms offer a wide range of services (Hao et al., 2020). Transportation and logistics are crucial components of international commerce and significant contributors to the economic development of many nations (Evangelista, Colicchia, & Creazza, 2017), so their contribution is pivotal in both supply chain management and competitive business landscapes (Kovács & Kot, 2016). In addition, the contemporary role of third-party logistics (3PL) in the supply chain has become markedly more substantial (Perotti et al., 2015).

A company that manages the transportation of products and components from their origin to their final destination is known as a logistics service provider (Tran et al., 2019). A first-party logistics (1PL) provider offers transportation services for specific items in a given location, including carriers, ports, and warehouses. In contrast, a second-party logistics (2PL) provider offers nationwide logistics services using resources such as trucks, forklifts, and warehouses for transportation, handling, and warehouse management (Günther et al., 2005). Third-party logistics (3PL/TPL) providers, fourth-party logistics (4PL) providers, and fifth-party logistics (5PL) providers are three other types. According to Hertz and Alfredsson (2003), 3PL is defined as an external provider that is responsible for managing, controlling, and executing logistics activities on behalf of the shipper. According to Hao et al. (2020), 3PL providers primarily offer logistics services. The 3PL providers served as the foundation for the development of 4PL providers (Yao, 2010). Concurrently, 5PL providers are characterized as entities leveraging system optimization theory, e-commerce platforms, and advanced information network technologies to orchestrate logistics functions (Giusti et al., 2019). The outsourcing of logistics services to 3PL providers is advantageous for manufacturers, distributors, and supply chain firms (Wang et al., 2021). Table 1.1 summarizes the range of

concepts from 1PL to 5PL.

Table 1.1 Definition descriptions from 1PL to 5PL

Item	Definition description
1PL	1PL provider offers transportation services for specific items in a given location, including carriers, ports, and warehouses (Günther et al., 2005).
2PL	2PL provider offers nationwide logistics services using resources such as trucks, forklifts, and warehouses for transportation, handling, and warehouse management (Günther et al., 2005).
3PL	3PL is defined as an external provider that is responsible for managing, controlling, and executing logistics activities on behalf of the shipper (Hertz & Alfredsson, 2003).
4PL	4PL is defined as "an integrator that assembles the resources, capabilities, and technology of its own organization and other organizations to design, build and run comprehensive supply chain solutions" (Foster, 1999. p.35).
5PL	5PL refers to logistics service providers that use system optimization theory, e-commerce, and information network technology to manage logistics operations for multiple supply chains (Giusti et al., 2019).

Logistics, procurement, and manufacturing are the primary drivers of environmental issues (Beamon, 1999). The service industry is the largest contributor to the global GDP (gross domestic product). Meanwhile, the ecological sustainability of service process design could potentially have a substantial influence on environmental protection (Aslam & Jawaid, 2023). Logistics operations, particularly those related to freight, exert considerable adverse impacts on the environment (Evangelista et al., 2017). According to Kommenda (2019), global aviation transportation is the second-largest source of greenhouse gas emissions on the Earth's surface and in the atmosphere. Furthermore, an International Energy Agency report stated that the transportation industry is a major contributor to carbon

emissions, representing 27% of global emissions (Chen et al., 2020). As an environmental concern, the effects of climate change have received considerable attention worldwide from governments, businesses, and civil society (Campiglio et al., 2018; Zhang et al., 2018). The effects of climate change may be mitigated, postponed, or even prevented by lowering greenhouse gas emissions (Du & Li, 2019). Many packaging residues contain non-biodegradable substances, and mishandling these residues can lead to significant environmental consequences (Li et al., 2017; Janjevic et al., 2019). End customers are also increasingly demanding that shippers use green/sustainable supply chain management (Berg & Langen, 2017). Due to the externality of ecological deterioration and the depletion of natural resources, it has been difficult to achieve sustainable economic development through market systems alone. Because other industrial sectors and the logistics sector are interconnected, 3PL activities would add to the supply chain's sustainability (Chu et al., 2018). The green practices of the logistics sector will significantly influence the green practices of other sectors.

Corporations are being tasked with emergency measures to mitigate their environmental impact. Adopting green technologies is a potential solution (Shahzad et al., 2022). Green technology innovation may minimize pollution, energy use, and environmental issues (Shen et al., 2022; Du & Li, 2019). It may also lower emission reduction costs via the deployment of superior technologies (Popp & Newell, 2012), for waste reduction, pollution reduction, and sustainable development (Novkovska, 2019). To stay ahead, businesses are increasingly relying on green innovation (Fernando et al., 2019). To counteract the detrimental effects of conventional growth models, an increasing number of firms are incorporating green innovation into their corporate strategy (Guo et al., 2020; Afshar Jahanshahi et al., 2020).

1.2.1 The logistics industry in China

China is undergoing rapid expansion as a leading global economy and a market for manufactured goods (Wong et al., 2020; Li et al., 2017). Following China's accession to the World Trade Organization in late 2001, there has been a swift expansion observed in its transportation and logistics industries (KPMG, 2016). The 3PL sector was first established in China in the mid-1990s. It has progressed rapidly (Chu, 2012), growing more quickly than in other emerging nations (Tan et al., 2014). The market size of China's 3PL industry reached USD 203.2 billion in 2018, representing 21.8% of the global market. In 2014, 730,000 3PL businesses were in operation. The logistics sector has been identified as a key industry by the Chinese government (PRC, 2016). China holds a substantial market share among all logistics companies (Gupta & Barua, 2018). According to the most recent Pitney Bowes parcel shipping index (2020), the global parcel transport volume exceeded 131 billion. In 2021, the Chinese market delivered 83.4 billion packets, making it the leading market worldwide. According to the National Bureau of Statistics of China (NBSC, 2020), China's express delivery volume reached 83.36 billion parcels, maintaining its position as the global leader for the seventh consecutive year.The added value of transportation, warehousing, and postal services was expected to expand by 12.1% to reach 4706.1 billion yuan in 2021 (NBSC, 2022).

Based on data from the NBSC (2022), as illustrated in Figure 1.1 below, the freight volume of China's logistics industry demonstrated a consistent upward trend from 2019 to 2020, as well as over the 20-year period from 2002 to 2021. COVID-19 had an impact on freight volumes, causing them to exhibit a declining trend. More than 75% of the logistics industry's transportation volume is comprised of road freight traffic. However, the total amount of cargo transportation has increased

significantly over time, indicating a major rise in China's logistics demand.

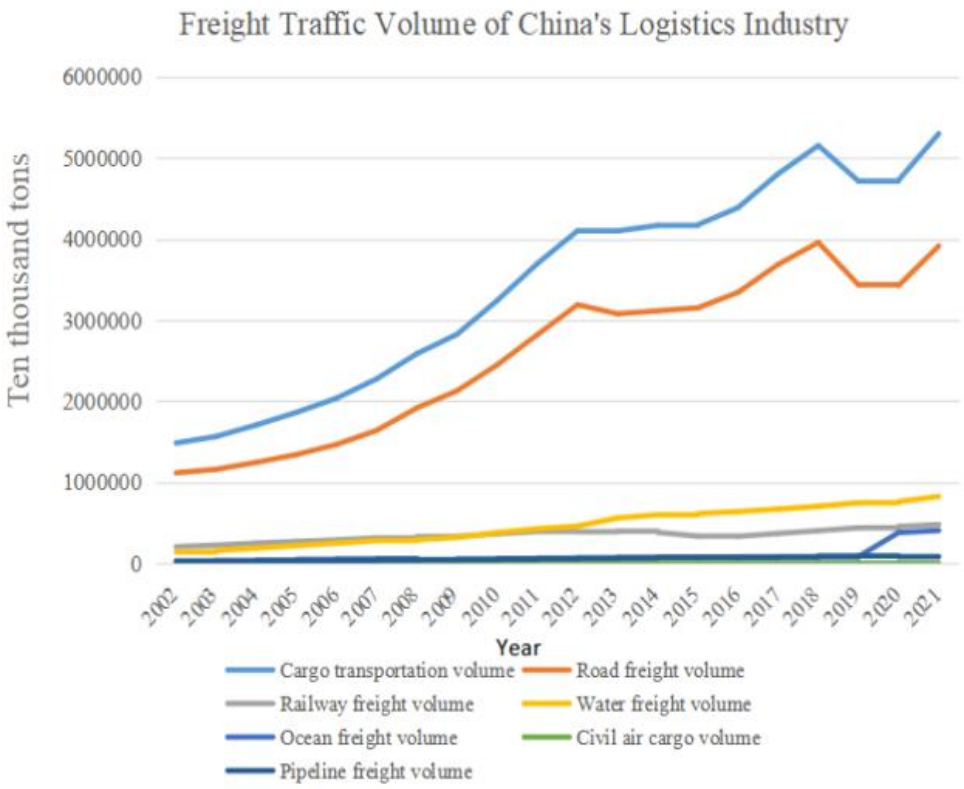

Figure 1.1 Freight Traffic Volume of China's Logistics Industry
Source: Data from the National Bureau of Statistics of China (2022)

Despite its significant market capacity, the 3PL industry in China has low market concentration because the majority of firms are small or medium-sized businesses (Zhang et al., 2022). According to the 2019 White Paper on Logistics Financial Innovation Practice in China, 90% of 3PL firms in the country are small or medium-sized organizations. The operating efficiency of these firms is influenced more by market prospects and expert technologies than by the size of the organization. As the world's largest developing country and the largest emitter of greenhouse gases, China poses unique challenges for environmental sustainability. At the same time, China is also the world's largest investor in renewable energy (Zhang et al., 2016).

Meanwhile, the competitiveness distribution of urban logistics in China is

unbalanced. According to the Competitiveness of City Logistics in China Report (2020), Jiangsu Province has the top 25 cities and top 100 cities with the largest logistics competitiveness in China (shown as Figure 1.2).

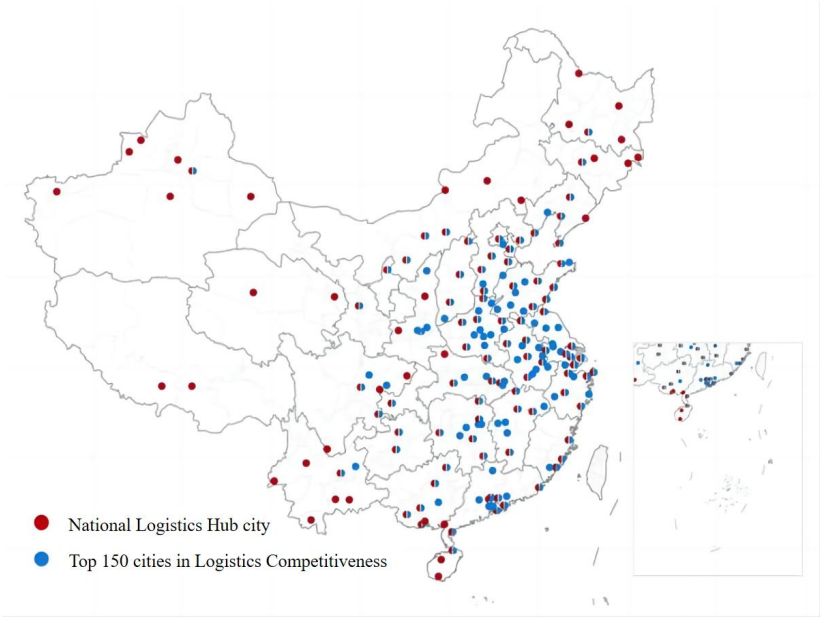

Figure 1.2 Distribution Map of China's Logistics Hub Cities
Source: Competitiveness of City Logistics in China Report (2020)

Zhao et al. (2006) divided China into seven regions: Pearl River Delta, Yangtze River Delta, Bohai Rim Economic Zone, Northeast, Central, Southwest and Northwest (Shown as Figure 1.3). The development of these regions is uneven. Compared with other regions in China, the eastern and southern regions of China are the most prominent regions in Chinese participation in globalization, high-tech use and supply chain outsourcing (Tan et al., 2014).

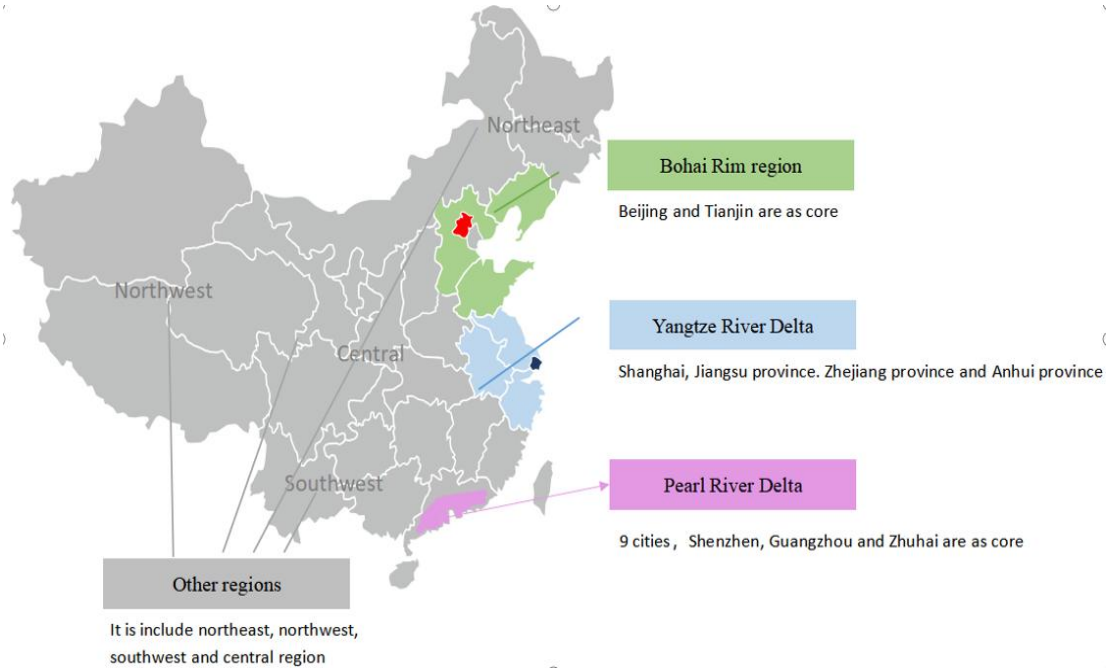

Figure 1.3 Seven Regions of China
Source: Based by Zhao et al (2006)

1.2.2 Green practices of 3PL firms in China

The Environmental Performance Index (EPI) offers a data-driven overview of the current state of global sustainable development. It assesses the climate change performance, environmental health, and ecosystem vitality of 180 countries using 40 performance indicators across 11 issue categories. According to the 2020 Global Environmental Performance Index Report, China was ranked 120th out of 180 economies (Wendling et al., 2020). However, in 2022, China's EPI dropped to 160th place (https://epi.yale.edu/epi-results/2022/country/chn). The environmental problems in China must be urgently addressed (Zhang et al., 2018).

The associated environmental issues in China have not been resolved and are increasingly becoming a constraint that hinders the country's long-term economic growth (Miao et al., 2019). Some scholars and practitioners have studied 3PL providers in China (Chu et al., 2019). Zhang et al., (2016) conducted a qualitative analysis of the environmental damage caused by packaging waste from online shopping in China. Meanwhile, Fan et al., (2017) calculated the environmental

impact of China's express packaging materials and found that the country would face significant environmental burdens as a consequence of the express business. Several renowned Chinese 3PL companies are actively pursuing green technology innovation. In 2021, SF Express, a leading Chinese logistics company, made significant strides in green technology innovation by purchasing 8,000 new energy vehicles and securing 20 green packaging-related patents, reducing 279,000 tons of greenhouse gas emissions (SF, 2023).

Green innovation is now regarded as the main strategic tool to address these issues (Chu et al., 2018). China, being the largest developing country in the world, confronts a significant contradiction between its rapid economic growth and the need for environmental protection. Consequently, there is an urgent requirement for companies to actively participate in green innovation practices (Chen & Liang, 2023). In 2021, the Asian Development Bank (ADB) approved China's new Country Partnership Strategy (CPS) for 2021-2025, the overall goal being to support China in achieving high-quality and green development. The 19th National Congress of China also proposed a roadmap for green development (Kong et al., 2020). Over recent decades, China has made significant progress in eradicating absolute poverty and achieving strong economic growth. However, some of these advances have come at a high environmental cost (ADB, 2021). Green technology innovation improves efficiency and technology without compromising economic activity (Du & Li, 2019). Emerging nations should prioritize emissions-reduction strategies that balance economic growth, efficiency, and technology, rather than focusing solely on reducing production to cut emissions (Li & Lin, 2017).

1.3 Problem Statement

Although an increasing number of 3PL providers view environmental

sustainability as a critical management issue, substantial ambiguity remains about how 3PL firms implement environmental strategies and how green initiatives should be put into practice (Evangelista et al., 2017). Logistics and transportation systems are intricate and necessitate sustainable innovation (Roukouni et al., 2020). Within the logistics sector, innovation serves a twofold objective of mitigating environmental impact and bolstering competitiveness (Cosimato & Troisi, 2015). GTIA faces significant challenges in accomplishing the sustainable development of manufacturing organizations due to various decision-making factors (Shahzad et al., 2022). The same holds true for green innovation adoption in service organizations. In recent years, an increasing number of scholars have focused on green innovation in logistics and transportation industry (Ngo et al., 2022; El Baz & Laguir, 2017; Orji et al., 2019; Rossi et al., 2013; Lin & Ho, 2008; Hartmann et al., 2022; Chen et al., 2023),and the outcomes of green innovation,such as economics outcomes (Chen et al., 2020), social (Chen et al., 2020; Zhang et al., 2020), and environmental outcomes (Chen et al., 2023; Du, Cheng, & Ali, 2023). In developed nations such as those in Europe, research on ecological innovation in small and medium-sized businesses is increasing, while emerging nations are still awaiting in-depth studies in this area (Jun et al., 2019). Additionally, few empirical studies have been undertaken on GTIA (Dangelico, 2016; Aloise & Macke, 2017). Hence, it is imperative to scrutinize the GTIA within China's logistics sector, given its status as a developing economy. While previous studies have examined the general benefits of green innovation, few have investigated the specific factors influencing its adoption in 3PL firms, particularly in the context of China. This gap calls for a deeper understanding of both the drivers and outcomes of green technology adoption.

Firstly, green technology innovation adoption is influenced by a complex

interplay of internal and external factors. The high cost and investment required for environmental innovation discourage some companies from integrating green technologies effectively (Long & Liao, 2022). Passive adoption can adversely affect financial performance, challenging long-term viability (Qing et al., 2024). While some firms actively adopt these innovations, others lag due to unsuitability with corporate structures or environmental constraints (Hao et al., 2020; Khan et al., 2021).Previous research primarily emphasized external drivers, such as market forces, regulatory pressures, and government policies (Pacheco et al., 2017). However, to successfully implement green strategies, firms must understand the determinants influencing stakeholder acceptance (Shahzad et al., 2022). Internal capabilities also play a critical role in GTIA, highlighting the need for in-depth exploration of these organizational factors (Aboelmaged & Hashem, 2019). Addressing these challenges provides valuable insights into fostering broader green innovation adoption and ensuring its alignment with corporate objectives.

The relationship between green creativity and the adoption of green technology innovation remains underexplored, especially in the service sector, despite its potential significance. Organizations identifying as “green” under external environmental pressures often develop innovative solutions, enhancing their ecological innovation capabilities (Chen, 2011). Green creativity, defined as generating original and useful ideas for green products, services, or processes (Chen & Chang, 2013), is seen as foundational for innovation. However, while it is recognized as a driver for green innovation and sustainable development (Awan et al., 2019), research has not sufficiently addressed its role in facilitating green technology adoption, revealing a critical gap in the literature (Arici & Uysal, 2022).

The integration of digital technology into business operations has transformed

organizational models, driving innovation in ideas and business practices (Mariani & Nambisan, 2021; Chaudhuri et al., 2024). A data-driven culture (DDC) optimizes data usage to create business value, fostering innovation and enhancing organizational decision-making (Chatterjee et al., 2021; Al-Khatib, 2022). However, despite the potential of DDC to boost innovation and productivity, research on its impact remains limited (Loukis et al., 2019). Specifically, its influence on the adoption of green technology innovation remains uncertain, signaling a gap in the literature.

Lastly, the potential outcomes of adopting green practices, particularly innovation in green technology, merit further examination. For instance, researchers have investigated the environmental performance and cost savings associated with green innovation (Wong et al., 2020), operational performance (Xue et al.,2019), financial performance (Junaid et al., 2022), and overall performance (Junaid et al., 2022; Chang et al., 2022). Eltayeb et al., (2011) investigated the environmental, economic, and operational consequences of green supply chain planning. Researchers have not conducted studies to determine the intangible outcomes of 3PL firms in adopting green technology innovation.

1.4 Research Questions

The following questions are proposed to resolve the research problem. In addressing the research questions, the following inquiries are outlined:

1. What is the relationship between determinant factors (relative advantage (RA), compatibility (CY), complexity (CX), organizational support (OS), quality of human resources (QHR), green internal integration (GII), institutional pressure (InP), green supplier integration (GSI), green customer integration (GCI)) and green technology innovation adoption?

2. Does green creativity moderate the relationship between determinant factors and green technology innovation adoption?
3. Does data-driven culture moderate the relationship between determinant factors and green technology innovation adoption?
4. What is the direct relationship between green technology innovation adoption and its outcomes (environmental outcomes(EnO), economic outcomes(EcO), operational outcomes(OpO), and intangible outcomes(InO))?

1.5 Research Objectives

The research objectives discussed in the previous section raise several important questions that are worthy of closer examination. These objectives are listed below:

1. To investigate the relationship between determinant factors (relative advantage (RA), compatibility (CY), complexity (CX), organizational support (OS), quality of human resources (QHR), green internal integration (GII), institutional pressure (InP), green supplier integration (GSI), green customer integration (GCI)) and green technology innovation adoption.
2. To determine the moderating effect of green creativity between determinant factors and green technology innovation adoption.
3. To measure the moderating effect of data-driven culture between determinant factors and green technology innovation adoption.
4. To examine the direct relationship between green technology innovation adoption and its outcomes (environmental outcomes(EnO), economic outcomes(EcO), operational outcomes(OpO), and intangible outcomes(InO)).

1.6 Significance of the Study

The contributions of this study primarily include theoretical contributions and practical contributions.

1.6.1 Theoretical Contribution

The research framework based on the Technology-Organization-Environment (TOE) framework and the theory of innovation diffusion (DOI). The study aims to analyze and discuss the determining factors and outcomes of Chinese 3PL firms adopting GTIA. Additionally, it examines the moderating variables of green creativity and data-driven culture. The findings offer empirical evidence regarding the correlation between determining factors and GTIA. These empirically tested variables can be further analyzed and utilized by the academic community to promote the framework.

An important observation from the literature review reveals that while many researchers have attempted to understand the general factors that influence adoption, there is a lack of research on the influence of green internal integration on GTIA in terms of organizational factors. Additionally, given the significance of 3PL firms in internal departmental relationships, supplier relationships, and customer relationships in implementing practical actions for green sustainable practices.

Meanwhile, prior research on the adoption of green innovation has predominantly emphasized economic aspects (Chu et al., 2019), environmental performance (Zailani et al., 2014; Chen et al., 2023), and social outcomes (Zhang et al., 2020). However, there is a dearth of research examining the Operational outcomes and intangible outcomes associated with the adoption of green innovation. According to Eltayeb et al. (2011), This study incorporates the measurement of intangible outcomes into the research domain of GTIA, thereby contributing valuable

empirical insights to the expansion of relevant concepts.

Furthermore, the literature review in this research field indicates that empirical research has been utilized to validate and draw conclusions regarding the hypotheses linking the determining factors and the adoption of green innovation, which ultimately impact third-party logistics companies (Lin & Ho, 2011; Zailani et al., 2014). However, the influences on the determining factors have not been ranked. This study fills this research gap by utilizing the ANN model to rank the determining factors according to their impact following hypothesis testing.

1.6.2 Practical Contribution

Firstly, in the research context of China, this study aims to assist managers of 3PL firms to improve their comprehension of GTIA and enhance their understanding of the consequences associated with doing so. The findings are expected to benefit the broader social environment, providing valuable insights for policymakers, 3PL managers, supply chain partners, and researchers in the context of promoting ecological innovation adoption among 3PL firms in China. This will enable 3PL firms to develop and implement effective environmental policies and strategies. More specifically, the study provides new empirical evidence for the determinants affecting the GTIA in 3PL firms in emerging economies. The main scientific value is its contributions to the implementation of green innovation practices in emerging economies, as well as 3PL and other service-oriented enterprises in other countries.

Secondly, policymakers could use the results of this research in that the key determinants driving enterprises to GTIA can be specified in policy. The study might also provide a basis for policymakers' decision-making. Decision-makers of 3PL firms could take into account the usual conventional decision factors. By collaborating with companies at various stages to achieve GTIA, these companies

could attain positive economic, environmental, social, and intangible outcomes.

Thirdly, this study focuses on 3PL in China, an emerging economy. The study aims to address the gap in the existing literature by examining the moderating impact of green creativity and DDC in the service sector of China's 3PL industry. This also demonstrates the influence of high-quality talent and talent creativity on the implementation of green technology innovation. Moreover, this study specifically examines the utilization of big data-driven approaches in industry enterprises that have a cultural background centered around big data, the aim being to facilitate the adoption of green technology innovation. This offers significant practical implications, such as providing policy recommendations for environmental governance in China, particularly for achieving the "double carbon" target, as well as supporting global green and sustainable development.

Overall, this study could help 3PL firms and stakeholders to benefit from the adoption of green technology innovation.

1.7 Definition of Key Terms

To facilitate comprehension of the research model of this research, below presents definitions for the constructs of interest and key terms examined in this study.

Relative Advantage refers to "the degree to which individuals perceive an innovation as being superior to other available options" (Nath et al., 2022).

Compatibility: the definition can be found in Lin and Ho (2011, p.70), The degree to which an innovation is perceived as aligning with the existing values, experiences, and needs of firms.

Complexity:the definition can be found in Lin and Ho (2011, p.70), is the extent to which a new idea is thought to be challenging to comprehend and apply. It is typically thought to have a negative relationship with innovation adoption and will make knowledge transfer and innovation dissemination more difficult.

Organizational Support can be defined as technical innovation will be influenced by a company's support for its employees' use of a certain technology or system (Lin & Ho, 2011, p.71).

Quality of Human Resources can be defined as technical innovation adoption calls for skilled workers with capable learning and creative faculties (Lin & Ho, 2011, p.71).

Green Internal Integration can be defined as the degree to which a manufacturer uses internal environmental management techniques to control the processes within the organization (Kong et al., 2021, p.2).

Institutional pressure: refers to the collective effect of the social notion, rule, norm, or culture that makes up the institutional environment. This environment has a significant impact on the rationality, acceptability, and supportability of an organizatio's form, structure, or conduct. Regulative pressure, normative pressure, and cognitive pressure are the three main types of institutional pressure (Liao, 2018).

i. **Regulative Pressure** describes the enforceable provisions of several written laws, rules, and policies that the government has

issued (Liao, 2018).

ii. **Normative Pressure** describes the standards and beliefs that are formed in a community and among customers, as well as the procedures and working circumstances that are peculiar to a given industry (Liao, 2018).

iii. **Cognitive Pressure** refers to the mental strain or stress experienced when engaging in cognitive tasks or activities that require intense mental effort and concentration. Cognitive pressure is the process of imitating several commonly observed or already perceived experiences and behavioral patterns within the same industry, in order to achieve consistency in a firm's behavior (Liao, 2018).

Green Supplier Integration refers to the extent to which a manufacturer cooperates with its suppliers' partners to oversee the inter-organizational environmental practices (Kong et al., 2021, p.2).

Green Customer Integration is the level of collaboration between a manufacturer and its customer partners in managing environmental practices that occur between organizations (Kong et al., 2021, p.2).

Green Creativity is the process of generating fresh and innovative ideas related to environmentally friendly products, services, processes, or behaviors that are considered to be both original and beneficial (Mittal & Dhar, 2016, p.119).

Data-driven Culture can be defined as the degree to which individuals within an organization, including high-ranking executives, middle managers, and lower-level staff, use data-driven insights to inform their decision-making processes (Gupta & George, 2016, p.1053).

Green Technology Innovation Adoption: the objective is to create novel and economical products, processes, systems, services, and methodologies that fulfill human requirements and improve the overall quality of life, while reducing the consumption of natural resources (such as energy and surface area) per unit of output over the entire lifespan, and minimizing the emission of harmful substances. (Zailani et al., 2014).

i. **Data acquisition Information:** logistics service providers typically handle a substantial volume of goods and data. The collection and exchange of data are crucial for the management and control of logistics information. Ensuring high-quality data acquisition can assist logistics service providers in delivering customers' goods with greater accuracy and efficiency (Zailani et al., 2014).

ii. **Information technology:** Information technologies refer to the devices or infrastructures that are utilized to enhance the efficiency of communication of business information among multiple organizations (Zailani et al., 2014).

iii. **Transportation technology:** Transportation is a highly visible component of logistics operations. Its primary function is to facilitate the movement of products (Zailani et al., 2014).

Environmental Outcomes: the tangible effects of adopting green technological innovation on a firm's environmental performance include adherence to environmental regulations, decreased air pollution, reduced resource consumption, and less use of hazardous materials (Perotti et al., 2012).

Economic Outcomes: the tangible effects of adopting green technological innovation on a firm's financial performance include enhanced profitability, productivity, sales growth, and cost savings (Perotti et al., 2012).

Operational Outcomes: the tangible effects of adopting green technological innovation on a firm's operational performance include reduced costs, improved product quality, enhanced delivery, and increased flexibility (Perotti et al., 2012).

Intangible outcomes: the tangible effects of adopting green technology innovation on intangible factors such as the firm's and product image as perceived by external and internal stakeholders, including customers, suppliers, employees, and the general public (Eltayeb et al., 2011).

Third-Party Logistics: when opposed to basic services, a relationship between a shipper and a third party contains more customized offerings, includes a broader variety of service functions, and is characterized by a longer-term, mutually advantageous relationship (Marasco, 2008. p.128).

1.8 Organization of Thesis

This chapter introduces the research background by delineating the problem statement, specifying the research objectives, formulating the research questions, and

elucidating the significance. Chapter 2 presents an overview of previous models of technology adoption and relevant literature. This chapter also includes the theoretical foundations on which the research was based, such as the TOE-DOI framework. Chapter 3 describes the methods and evaluation tools used in this study, including an explanation of the research paradigm, research process, research design, sampling techniques, instrument development, and data collection procedures. Subsequently, Chapter 4 reports the analysis of the data using PLS-SEM and ANN methods. Finally, Chapter 5 delves into the research findings. Furthermore, it clearly outlines the constraints of the research and provides recommendations for future research initiatives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter commences by providing an explanation of the different types of models in the technology acceptance theory and their evolution. The most suitable technology acceptance model is then chosen to accomplish the primary research objectives of this study. Next, this study examines previous research on the factors that influence technology adoption, relevant studies on GTIA, and literature on the outcomes of GTIA. The text provides a summary of these findings. Additionally, it establishes connections between the variables that have been selected, explains the underlying theoretical framework, and formulates research hypotheses. Finally, a summary is provided.

2.2 Overview of the Theoretical Underpinning

2.2.1 Green Technology Innovation Adoption (GTIA)

Technological innovation, which is linked to fundamental activities, encompasses products, services, and production process technology (Damanpour, 1991). Consequently, organizations can consider the adoption of green practices as a process of technological innovation (Lin & Ho, 2011). The first studies on innovation may be dated back to Schumpeter (1934)'s classification of the idea in his book "Theory of Economic Development". The development of technology has always been important to the corporate world. According to Skare et al. (2021), the primary characteristics of green technology are systematic, emphasizing ecological

protection, economic compliance, and increased efficacy.

Green innovation (GI) may take many different forms, including green non-technical innovation, which includes management innovation and organizational structure (Hilkenmeier et al., 2021). A technical framework known as "green technology" promotes recycling, pollution avoidance, resource conservation, and efficiency improvement. Research on green technology has witnessed a surge due to environmental degradation, prompting an increasing number of nations to prioritize energy conservation and emissions reduction in their pursuit of sustainable development (Hao et al., 2020).

In the past, the determinants of green innovation adoption primarily focused on external factors like regulatory pressure, government policies, environmental regulations, competition, and market demand (Demirel & Kesidou, 2011; Pacheco et al., 2017). To successfully encourage businesses to employ green innovation, it is necessary to investigate these factors. Feng et al. (2022) identified five theoretical perspectives that explain green supply chain innovation: cost-efficiency, innovation diffusion, institutional, and resource-dependence. Jum'a et al. (2021) investigated a variety of factors, including market, financial, supplier, government, environmental, internal, customer, and cost factors, that influence the intent to adopt GSCM. Lin and Ho (2011) surveyed the use of green practices by Chinese logistics companies. Regardless of their origin, any environmental management practices adopted by 3PL providers are regarded as innovative (Chu et al., 2019). Hao et al. (2020) consider automatic warehousing systems to be a green technology that is essential for logistics enterprises to endure and flourish in a sustainable environment by creating sustainable development value. Table 2.1 as below shows the previous literature on green innovation adoption:

Table 2.1 Literature Review of Green Innovation Adoption

Author /Year	Dependent Variables	Theory	Method	Sector	Country /Sample Size	Type of Analysis	Result
Qin et al (2023)	Green Innovation Adoption	INT, Organizati -onal Learning	Questionnaire Survey	Events Industry	China /685	PLS-SEM	Future orientation partially mediated the relationship between coercive pressure and willingness to adopt, as well as the relationship between normative pressure and WTA. Furthermore, the study found that past experience moderated the relationship between institutional pressure and willingness to adopt.
Shahzad et al (2022)	Green Innovation Technology Adoption	UTAUT	Questionnaire Survey	Various manufacturing industries	Pakistan /516	PLS-SEM & ANN	Larger organizations can leverage economies of scale to adopt green initiatives by improving production levels. Green innovation adoption is a long-term effort that requires organizations to create significant improvements in their processes and products, which can inevitably lead to environmental risks.
Fahad et al (2022)	Green Innovation Adoption	FAHP & FTOPSIS	AHP & TOPSIS	N.A.	Pakistan /15	three-phase framework	Among the six major barriers, legal barrier is the most critical barriers for Pakistan's SMEs to adopt green innovation. Information barrier is the second key barrier/barrier for SMEs to adopt green innovation, followed by technical barrier, managerial barrier, economic barrier and market barrier.
Chang et al (2022)	Green Innovation Adoption	SNT	NLP and network analysis	Heavily Polluting Industry (The textile industry)	China /20,530 (items of patent data)	Natural language process, network analysis and econometric regression	Explores inter-knowledge recombination, know-ledge rearrangement, and business development. Enterprises must balance reorganizing, integrating, and linking information, extending knowledge depth and breadth, and establishing a deep and comprehensive knowledge base to improve GIA performance.