

Research on the Dilemmas and Optimization of Reverse Recycling of Express Packaging under the "Dual Carbon" Background

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Abstract

Against the backdrop of the "Dual Carbon" goal and the green development orientation of the 15th Five-Year Plan, the reverse recycling of express packaging has become a critical path to promote the low-carbon transformation of e-commerce logistics and implement the circular economy. Based on the dimensions of policy, market and technology, this paper systematically sorts out the current situation of reverse recycling of express packaging in China, analyzes the core problems existing in current express reverse recycling, and puts forward improvement suggestions. It proposes optimization measures such as improving the recycling network and supervision system, upgrading intelligent sorting and processing equipment, constructing a cost-sharing and benefit-sharing mechanism, enhancing consumers' participation enthusiasm, optimizing reverse transportation and motivating couriers, aiming to provide theoretical references for the standardized development of reverse recycling of express packaging.

Keywords

Reverse Recycling; Express Packaging; Dual Carbon; Circular Economy.

1. Introduction

China clearly put forward the goals of "carbon peaking and carbon neutrality" in 2020, and low carbon has become an important trend of economic development. The prosperity of self-media has also greatly increased the transaction scale of e-commerce. The supply chain logistics link of the e-commerce industry has become the key to energy consumption and carbon emissions due to its high usage, large consumption of materials and uneven efficiency. According to the State Post Bureau Inspection, China's express delivery business volume has exceeded 100 billion pieces for five consecutive years. At present, e-commerce logistics is dominated by a high-carbon model, and high carbon emissions have brought huge environmental pressure. The State Post Bureau has clearly proposed that during the 15th Five-Year Plan period, it will anchor the goal of green and high-quality development, coordinate the promotion of carbon reduction, pollution reduction, green expansion and growth, and strengthen the whole-chain governance of express packaging, which provides policy support for the reverse recycling of express packaging. The current one-way express packaging circulation mode can no longer adapt to the high-quality development of the industry, and the reverse recycling system has become a key link for the sustainable development of e-commerce enterprises. This paper systematically discusses the practical dilemmas of reverse recycling of express packaging in China and puts forward targeted optimization paths, enriches the application scenarios of circular economy theory and reverse logistics theory in the express delivery industry, transforms theories into implementable recycling implementation plans, and reduces the burden on the ecological environment.

2. Current Situation of Reverse Recycling of Express Packaging

2.1. Steady Progress of National and Local Policies

Following the world development trend, China has set the "Dual Carbon" goal. In recent years, China has continuously issued various policies to promote the reverse recycling of express packaging. The Outline of the 15th Five-Year Plan for National Economic and Social Development of the People's Republic of China clearly includes express packaging in the waste recycling system, and takes "conservation and intensification, recycling and reuse, green and innovative integration" as the general principle, requiring the improvement of circulation rules and standards. Zhang Qiqi (2025) effectively coordinated economic and environmental goals by adopting the Epsilon constraint method, providing theoretical and practical support for the construction of a green and efficient express packaging recycling system [1]. Xia Yuchen (2025) constructed an express packaging recycling system based on big data technology, which significantly reduced enterprise operating costs, efficiently optimized the recycling of packaging resources, and strongly provided intelligent technical support for the development of green logistics [2]. Cheng Zaoping (2024) constructed an evolutionary game model between government regulators and consumers under static and dynamic government reward and punishment measures respectively, and explored the influence mechanism of different government policies on consumers' participation in express packaging recycling [3]. Studies have shown that government policies are crucial to promoting reverse recycling. At the same time, the state promotes the application of green products and technologies such as circular packaging, new energy vehicles and photovoltaic power generation, and promotes green and low-carbon development through intelligent path optimization, intelligent packing algorithms and so on. Various regions have implemented specific measures one after another. For example, provinces such as Shanghai, Beijing, Guangzhou and Shenzhen have gradually promoted the setting of recycling facilities in express stations, communities and universities, and promoted the pilot projects of reuse of old cartons and circular express boxes. A small number of cities have incorporated express packaging recycling into the urban waste classification system. From national policies to local implementation, the reverse recycling of express packaging is gradually promoted.

2.2. Emergence of Market Profit Models

From the market level, with economic development, more profit models represented by environmental protection have emerged in the market, such as "green packaging reverse recycling services" and "circular box rental services". At the same time, China has increased support for new energy vehicle subsidies, green packaging certification, carbon emission labels and so on. However, there are few practical measures for the reverse recycling of e-commerce packaging at present, and the carbon emissions of reverse recycling are relatively high. Reverse recycling itself is an environmental protection and energy-saving behavior, but the carbon emissions generated in this process are no less than those generated by forward transportation. The reasons lie in the low coverage of express recycling outlets, scattered recycling conditions leading to high transportation emissions, and insufficient consumer participation. Most e-commerce packaging is discarded by consumers at will, and a small part is voluntarily delivered by consumers to stations or recycling bins. Reverse recycling of packaging also incurs certain costs, such as sorting, classification and disinfection. Some consumers may unpack violently, resulting in low secondary utilization effect of packaging. This situation will downgrade the packaging, such as cartons being made into pulp, and the recycling effect is not good.

Wang Xiuli (2025) constructed a tripartite evolutionary game model of government, logistics enterprises and community consumers, and found that the government can promote the benign evolution of the system by increasing the proportion of circular packaging and optimizing the

consumer incentive system [4]. Du Huanzheng (2025) visually analyzed the sustainable design directions and future trends of each stage in the whole life cycle of express circular packaging in China using VOSviewer and CiteSpace tools, and proposed to promote the rationality of material flow, transparency of information flow, appreciation of value flow and harmlessness of environmental flow in e-commerce, logistics, fast-moving consumer goods and other industries through policy guidance, technological innovation and model innovation [5]. These studies also show that the reverse recycling of express delivery requires the coordinated development of policy, market and other aspects.

2.3. Initial Achievements in Technology

From the technical level, with the development of science and technology, technologies such as the Internet of Things, artificial intelligence and automatic sorting have been gradually applied in the field of reverse recycling of express packaging. The application of these technologies can effectively solve most problems such as low efficiency and many errors of traditional manual recycling. However, for some refined sorting, such as anti-pollution issues, classification of clothing into new packaging and second-hand packaging, mixed loading of plastic and cartons, large packaging and small packaging, etc., most of these are manually classified, with low efficiency and pollution in the classification process, reducing the recycling utilization rate. Packaging recycling facilities are being gradually promoted and updated. First-tier cities such as Guangzhou have introduced intelligent recycling bins with automatic identification and point exchange functions. Users can obtain points after delivery to exchange for shipping discounts, life energy, etc., improving consumers' enthusiasm for participating in packaging recycling. However, due to equipment cost and regional issues, such intelligent recycling bins are not widely promoted and cannot be fully popularized.

At present, the reverse recycling of express packaging in China is at a critical stage of multi-party development in policy, market and technology. It has achieved certain phased results, but also faces various challenges in cost, awareness, mechanism, technology and so on. The serious dilemmas existing in reverse recycling restrict the large-scale and standardized development of reverse recycling of express packaging. To promote the high-quality development of reverse recycling of express packaging, this paper will combine the current situation sorted out above to deeply analyze the core existing problems and put forward practical solutions targeted, providing ideas and support for the optimization and improvement of the reverse recycling system of express packaging.

3. Problems Existing in the Reverse Recycling of Express Packaging

Through systematically sorting out domestic literatures related to reverse recycling of express packaging and combining field visits and investigations on express outlets, community terminals and e-commerce platforms, it is found that the reverse recycling of express packaging in China is currently facing multiple problems such as imperfect recycling network, lack of cost and benefit distribution mechanism for reverse logistics, backward recycling and processing technology, and insufficient consumer participation, leading to low recycling utilization rate and low recycling efficiency.

3.1. Imperfect Reverse Recycling System

(1) Low Outlet Coverage

In most third- and fourth-tier cities and rural areas, the coverage rate of packaging recycling facilities in express outlets is low. Consumers need to travel more than 1 kilometer to participate in recycling, which is extremely inconvenient, resulting in some consumers with environmental awareness not recycling due to trouble. In addition, recycling points are mostly concentrated in urban residential areas and urban centers. Slightly remote suburbs and

industrial parks, where there are a large number of staff and huge e-commerce orders generating a large amount of packaging, have a huge gap in recycling facilities, resulting in a large amount of packaging being discarded as domestic garbage. At the same time, the sizes and classification signs of recycling bins in different outlets are not uniform, which is easy to confuse consumers. Some stations only set up one packaging recycling bin for all packaging. Although this will not cause confusion for consumers, it will greatly increase the cost of subsequent sorting. The recycled cartons are not clearly marked with materials, recyclability and other signs, and the standards for disinfection and recycling times of recyclable packaging are not clear. Some enterprises simplify the disinfection process to reduce costs, and there are also potential health and safety hazards.

(2) Gap in Supervision and Traceability System

According to the stakeholder theory, reverse recycling requires multi-party cooperation and regulation. However, at present, there is no unified "Specification for the Quality of E-commerce Recycled Packaging" in China, and supervision is inadequate. The supervision of environmental protection departments on reverse packaging recycling focuses on "end treatment", and there is a lack of supervision on carbon emissions and pollution in the front-end recycling and transportation links. There is no traceability system for the whole process of packaging "recycling-transportation-processing", which cannot track the flow and treatment of packaging, and cannot make consumers rest assured of packaging recycling.

3.2. Backward Recycling and Processing Technology and Equipment

(1) Backward Sorting Technology

The sorting technology of reverse packaging recycling is backward. The sorting of reverse packaging recycling is not only to distinguish the degree of damage of packaging. Different e-commerce enterprises use different packaging, such as large packaging, small packaging, new packaging, second-hand packaging, plastic packaging, anti-fall packaging, etc., all of which need to be identified. It is highly dependent on manual labor, with low sorting efficiency and large errors. Most small and medium-sized processing centers still adopt manual sorting, with a per capita daily sorting volume of only a few hundred pieces and a high error rate. For example, recyclable express boxes are mixed into ordinary cartons, resulting in secondary sorting in the subsequent reprocessing link, increasing sorting costs, and there is a lack of environmental protection standards for sorting and processing.

(2) Unpopularity of Processing Equipment

At the same time, intelligent equipment with the functions of "material identification + automatic sorting" has a low popularization rate, high equipment cost and poor adaptability, and cannot directly sort packaging wrapped with tape. The carton processing technology is rough, mainly for downgraded utilization: only a small part of the recycled cartons can be reused as express boxes through "repair + disinfection", and most of them are made into pulp for the production of low-end paper products, resulting in great loss of resource value. For plastic packaging, due to high pollution, energy consumption and sorting costs, some processing centers directly incinerate it. However, the carbon emission of incinerating one ton of plastic packaging reaches 3.8 tons of CO₂e, and harmful gases are generated at the same time, increasing carbon emissions. Even if it is not incinerated, without advanced equipment, recycling can only be used to produce low-end plastic products.

3.3. Lack of Cost and Benefit Distribution Mechanism for Reverse Recycling

(1) Lack of Cost Distribution Mechanism

The incomplete system of reverse packaging recycling leads to higher costs than benefits. For example, direct costs include labor, transportation and sorting processing, while the reuse benefits of recycled packaging include the price difference of carton reuse and the reduction of

carton manufacturing costs. The implicit costs include site rent of processing centers, equipment depreciation and other costs, further pushing up the total recycling cost. Therefore, most small and medium-sized e-commerce enterprises regard it as an "additional burden", and there is no good distribution mechanism for these costs. For example, whether the 0.5-yuan packaging recycling cost can be shared among platforms, enterprises and consumers in different proportions. Coupled with the current policy subsidies for green packaging recycling, it will not impose too much burden on enterprises.

(2) Lack of Benefit Distribution and Incentive Mechanism

For e-commerce enterprises, the carbon emission reduction benefits of reverse recycling are not included in enterprise assessment, and there is a lack of policy incentives such as "carbon trading" and "tax preferences", resulting in insufficient motivation for enterprises to participate in recycling. For logistics and e-commerce platforms, couriers have no additional subsidies for recycling packaging, and are only promoted by "enterprise requirements", leading to inadequate implementation of recycling. Various private stations do not carry out express recycling without subsidies. Even if they do, they will sell the recycled cartons as waste products for money. For consumers, there are no effective incentive policies at present, such as accumulating points for recycling packaging that can be exchanged for household items when accumulated to a certain amount. Without such incentive policies, it is impossible to effectively drive consumers to participate continuously.

3.4. Insufficient Consumer Participation Willingness

(1) Weak Consumer Recycling Awareness

Consumers have weak recycling awareness, and their willingness to participate in express packaging recycling is not strong, even thinking that recycling packaging is a troublesome thing. In daily life, people have the habit of discarding at will, and prefer to throw express packaging into the garbage can together, making it difficult to effectively recycle express packaging. For example, after receiving an express delivery, people often unpack the package on the spot or unpack it while walking, and throw cartons, foams and other items into the garbage can at will, even not into recyclable garbage cans. Express items stained with oil and dirt increase the cost of subsequent recycling and sorting.

(2) Non-standard Consumer Recycling Behavior

Even if some consumers recycle packaging, their recycling behavior is not standardized, they do not understand the recycling standards, and cannot achieve correct environmental protection behavior even with environmental awareness. Most consumers do not pre-treat packaging, such as not removing tape or emptying residual items, resulting in recycled cartons being stuck with tape and contaminated by dirt. Some consumers put severely damaged packaging into recycling bins, reducing the reuse rate and increasing subsequent sorting costs. At the same time, the inconvenience of recycling channels also restricts consumer participation. For example, few old communities are equipped with special recycling facilities for express packaging, and residents need to go to distant express stations to put them; recycling bins in some city centers and office buildings are placed in remote corners, not easy to find, and lack obvious guidance signs, leading many people not to know the purpose of the bins, even as garbage bins.

3.5. Inefficient, High-Consumption and Insufficient Motivation in Recycling Transportation

(1) Inefficient and High-Consumption Reverse Recycling Transportation

Reverse transportation is disconnected from forward logistics. Most logistics providers need to arrange separate vehicles to recycle packaging. The empty driving rate of reverse packaging transportation is high, and route planning is not as reasonable as forward transportation. In

reverse packaging recycling, due to different packaging models and materials, they should be transported to different merchants to increase their utilization rate, but there will be situations where a vehicle is not fully loaded, also increasing transportation costs. At the same time, there will be secondary loss during packaging transportation. Because recycled packaging is loosely stacked, it will be squeezed, rained on and other problems during transportation, with a high damage rate, completely losing reuse value. Subsequent sorting also requires additional classification and processing, increasing energy consumption.

(2) Insufficient Motivation of Deliverymen for Recycling

In addition to consumers, couriers, as key executors of reverse recycling, their recycling willingness directly determines the coverage and efficiency of recycling. However, in actual work, couriers generally have insufficient recycling motivation, and recycling behaviors are mostly formalistic, failing to truly realize express packaging recycling. The reason is that couriers have heavy delivery tasks and focus on delivery timeliness. Recycling express packaging increases additional workload and time costs. For example, couriers of JD, SF Express and other companies that can deliver to homes often have residents requesting "home delivery" when delivering in communities. Some people unpack the express delivery and hand the packaging to the courier at will. In order to save time, couriers often do not collect it specially but discard it at will. Even with recycling requirements, they simply stack the packaging in the corner of the station without sorting and organizing. On the other hand, inadequate incentive measures of enterprises also make it difficult to mobilize couriers' recycling enthusiasm. At present, most express companies have small subsidies for couriers' recycling. For couriers, the income from recycling packaging is far lower than that from delivery, so they do not want to invest time and energy in packaging recycling. At the same time, enterprises lack recycling training for couriers. Many couriers are short-term workers without professional training, and do not even know the recycling standards. Even if they recycle packaging as required by enterprises, they cannot properly sort and process it. Some couriers randomly collect some unqualified packaging to meet recycling indicators and cope with inspections, without truly achieving effective recycling.

4. Suggestions for Improving Reverse Recycling

4.1. Improve the Reverse Recycling System

(1) Increase the Coverage of Outlets in Various Regions

The reverse recycling of express packaging requires joint efforts from multiple parties, and at the same time, strengthening supervision and unifying standards to achieve standardized and large-scale development. The government should vigorously promote and improve the reverse recycling system of "consumers-merchants or stations-merchants", encourage cooperation between express companies and recycling units, build multiple recycling networks such as platforms, logistics and communities, and increase various packaging recycling outlets. For example, set up packaging recycling points in express stations, public communities, downtown business places and other areas with large flow of people. Unified classification standards for recycled packaging can be indicated on the packaging or during transportation, such as directly reusable, repairable, degradable, etc., and clarify the recycling responsibilities and processes of each link.

(2) Improve the Supervision System

The government can establish a regular inspection mechanism to inspect the recycling work of logistics enterprises, express stations, etc., focusing on standardizing their recycling processes and practical measures. It should increase penalties for violations to form an effective restraint effect, and also reward departments that do well. Only with rewards and punishments can management be better.

4.2. Introduce Advanced Recycling and Processing Technology and Equipment

Upgrade recycling and processing technology and equipment, reduce manual operations, and improve the regeneration quality and utilization rate of packaging. Intelligent sorting equipment, such as AI intelligent identification system, can be introduced to improve the efficiency and accuracy of packaging material classification and reduce errors caused by manual operations. The government should increase support for recycling and processing enterprises, encourage enterprises to introduce advanced equipment and infrastructure, support enterprises to carry out R&D by means of tax exemption, and sort out the layout of packaging regeneration processing centers. The division of labor in each process needs to be clear, converting recycled cartons and plastics into recycled packaging materials that can be sold by merchants for secondary packaging, realizing closed-loop recycling. Preferential policies such as tax exemption and subsidies for enterprises can not only encourage the introduction of equipment but also reduce enterprises' processing costs, improve enterprises' profit space, and help enterprises develop on a large-scale and long-term basis.

4.3. Balance the Cost and Benefit Distribution Mechanism

(1) Establish a Cost Distribution Mechanism to Reduce Recycling Cost Pressure

Green transformation should balance costs while taking into account benefit distribution. Balancing costs is to promote the green transformation of merchants and reduce the psychological pressure of high costs caused by the use of green packaging. Formulate implementable measures combined with real life to promote the sustainable development of the recycling system. A "packaging recycling subsidy mechanism" can be established, where platforms, merchants and logistics enterprises share recycling costs in proportion, and consumers participating in recycling are rewarded with points, coupons, etc. A "packaging deposit system" can be tried. Specifically, consumers prepay a packaging deposit when placing an order, which is automatically refunded after recycling to enhance participation motivation. However, this deposit system also has two sides, and whether it will affect consumers' purchase decisions needs further exploration in practice.

(2) Improve the Benefit Distribution and Incentive Mechanism

Construct a fair and reasonable benefit distribution system so that all parties bearing costs can obtain corresponding benefits. Combine the recycling cost sharing mechanism with recycling intensity to share recycling benefits in proportion. Part of the sales income of recycled materials can be returned to front-end stations, couriers, etc., to increase the recycling enthusiasm and initiative of front-line workers. At the same time, government departments can take the lead in establishing a benefit distribution mechanism and supervision system to practically implement cost sharing and benefit sharing and promote the harmonious development of the whole industry.

4.4. Enhance Consumer Participation Willingness

(1) Publicity, Popularization and Process Optimization

Enhancing consumers' participation willingness will better ensure the integrity of the packaging recycling process. First of all, multi-channel publicity can be carried out to popularize environmental protection knowledge and significance of express packaging recycling, and deeply root environmental protection concepts in people's hearts. In addition, most consumers have the psychology of thinking that packaging recycling is troublesome, so it is imperative to simplify the recycling operation process, such as synchronous recycling of packaging when couriers pick up packages at home, one-click online appointment for recycling, etc. The layout of recycling facilities should also be improved to enhance the convenience of consumers' packaging delivery. Recycling bins should be placed in conspicuous locations with clear recycling contents marked. Recycling facilities should be maintained regularly, and recycling

bins and nearby areas should be cleaned in a timely manner to avoid dirty and messy phenomena, completely separating recycling bins from garbage bins in people's impression, and improving people's express recycling delivery experience.

(2) Increase the Incentive Mechanism

Logistics enterprises or packaging recycling departments should optimize the recycling incentive mechanism to mobilize consumers' participation enthusiasm. "Green recycling point exchange" activities can be carried out. Combined with residents' daily living needs, recycling points can be converted into products benefiting the public, such as points exchange for shopping vouchers, public welfare donations, express fee deductions, etc. Such incentives actually benefiting consumers can enhance consumers' sense of participation.

4.5. Optimize Transportation Process and Motivate Recycling Behavior

(1) Optimize the Reverse Transportation Process

How to carry out reverse transportation after packaging collection is also a major problem in the current green transformation. First of all, reverse logistics special lines should be planned. Use return vehicles of express delivery to carry recycled packaging or spare spaces of forward transportation vehicles to carry them, so as to reduce the empty driving rate of transportation and reduce the cost of reverse recycling transportation. At the same time, recycled packaging can be compressed and bundled to reduce space occupancy, improve transportation loading rate, and reduce unit transportation carbon emissions.

(2) Motivate Couriers' Recycling Behavior

Couriers are the key to end-of-line recycling. It is necessary to improve their recycling motivation and professional level through perfect incentive mechanisms and strengthened training. First of all, express companies can issue specific recycling incentive policies to increase the standard subsidy income for recycling and promote couriers' recycling motivation. For example, a subsidy of 0.5 yuan for a standard recycled packaging box, a daily subsidy cap, and timely monthly payment. A reward system can also be used to give additional rewards to couriers who recycle the most express packages each month, stimulating couriers' enthusiasm. Secondly, strengthen the training of couriers to improve their professional level. Express enterprises should ensure the stability of employees, minimize part-time short-term workers, and conduct regular training for employees, especially on recycling classification, so that couriers clearly understand what can be recycled and how to classify after recycling. At the same time, optimize the work process of couriers, reasonably allocate their jurisdiction, and divide the time between recycling work and delivery work to avoid conflicts and reduce couriers' recycling workload.

5. Conclusion

Taking the "Dual Carbon" strategy as the background, focusing on the field of reverse recycling of express packaging, combined with the relevant policy orientation of the 15th Five-Year Plan and the demand of green low-carbon consumption market, this paper systematically discusses the practical dilemmas of reverse recycling of express packaging in China and puts forward targeted optimization paths. The study finds that the current reverse recycling of express packaging faces multiple prominent dilemmas, such as imperfect recycling system, backward processing technology and equipment, lack of consumer incentive mechanism, etc., and puts forward improvement suggestions, such as improving the reverse recycling system, upgrading recycling and processing technology and equipment, improving consumer participation willingness, etc.

However, this paper also has certain limitations due to research conditions and capabilities. First, there are limitations in data acquisition. Some large-scale recycling data are not public,

and the coverage and representativeness are limited, which may affect the universality of the conclusions. Second, there are limitations in research depth. This paper has insufficient quantitative analysis on the feasibility of specific models and cost-benefit, has not carried out empirical tests combined with specific enterprises, and the implementation of the optimization plan still needs further verification.

In summary, through the research on the dilemmas and optimization of reverse recycling of express packaging under the Dual Carbon background, this paper clarifies the significance and core path of improving the recycling system, hoping to provide certain theoretical references and practical support for the green transformation of the express delivery industry and policy formulation, promote the continuous improvement of the reverse recycling system of express packaging, and help the implementation of the Dual Carbon goal and the development of circular economy.

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