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A Study on the Optimization of Reverse Logistics for Waste Household Appliances

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ABSTRACT

This paper focuses on the reverse logistics of waste household appliances. Based on relevant theoretical analysis, it examines the current status and existing issues in China's reverse logistics for waste household appliances, such as: the fragmentation of collection entities and the low proportion of formal channels; unreasonable layout of collection points; rudimentary transportation organization and high costs; and weaknesses in the transfer and sorting stages. Based on this analysis, the paper proposes solutions including the optimization of the overall logistics structure; the optimization of community collection layouts; the optimization of regional transfer and sorting centers; and the optimization of the layout and capacity matching of processing facilities.

KEYWORDS

Waste Household Appliances; Reverse Logistics; Recycling System.

1. THEORETICAL FOUNDATIONS OF REVERSE LOGISTICS FOR WASTE HOUSEHOLD APPLIANCES

(1) The Concept of Reverse Logistics

Reverse logistics is a concept contrasted with traditional forward logistics, referring to the process by which products flow back from the consumer end to the supply end. It primarily includes stages such as collection, inspection, sorting, repair, remanufacturing, recycling, and environmentally sound disposal. For waste household appliances, reverse logistics is not merely simple transportation and collection; rather, it is a complex system integrating logistics, information flow, and capital flow, with the aim of achieving resource reuse and environmentally sound disposal[1].

(2) Characteristics of Reverse Logistics for Waste Household Appliances

Reverse logistics for waste household appliances exhibits distinct industry-specific characteristics. First, the sources of waste household appliances are dispersed; they originate from residences, factories, office buildings, and other locations, resulting in a wide distribution range and significant challenges in collection. Second, the product categories are complex. Different appliances vary significantly in size, weight, and materials, resulting in distinct requirements for transportation, warehousing, and sorting. Third, there is a disparity in value: some appliances can be repaired and reused, while others can only be dismantled to extract resources, creating a clear difference in value. Finally, environmental standards are stringent. Since WEEE contains hazardous substances, it must be processed in accordance with environmental regulations; otherwise, it may cause secondary pollution. These characteristics dictate that the reverse logistics network must be systematic, professional, and secure.

(3) Circular Economy Theory

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The circular economy is based on the principles of reduction, reuse, and recycling, emphasizing the closed-loop flow and efficient utilization of resources. The recycling and processing of waste home appliances represent a typical application of the circular economy. By establishing a comprehensive reverse logistics network, discarded home appliances can be reintegrated into the economic cycle, creating a closed-loop model for resources, products, waste, and recycled materials. This maximizes resource utilization efficiency and reduces environmental pressure.

2. CURRENT STATUS AND CHALLENGES OF REVERSE LOGISTICS FOR WASTE HOUSEHOLD APPLIANCES IN CHINA

(1) Fragmented Collection Entities and Low Proportion of Formal Channels

Currently, the recycling of waste household appliances in China is still dominated by individual collectors and vendors. These collectors are highly mobile, offer opaque pricing, and lack standardized management. Although they provide flexibility and convenience, they struggle to achieve economies of scale[2]. Formal recycling enterprises, due to high costs, limited service points, and insufficient publicity, have limited appeal to residents, resulting in a large volume of waste household appliances being collected through informal channels. This not only disrupts the overall order of the industry but also makes it difficult to uniformly plan and manage the reverse logistics network.

(2) Irrational layout of collection points

Most existing collection points have emerged spontaneously and lack unified planning. While some older residential areas and urban-rural fringe zones have a high density of collection points, coverage in newly developed urban areas and distant suburbs is insufficient, resulting in a situation of local oversupply and overall shortage. Additionally, these collection points serve only basic functions, such as temporary storage, and lack capabilities for sorting, testing, and interim storage, making it difficult to support efficient reverse logistics.

(3) Extensive and Inefficient Transportation Organization, Resulting in High Costs

Waste appliances typically undergo multiple transfers from residents' homes to processing facilities. The overall transportation routes urgently need optimization, as high vehicle empty-run rates and redundant transport are widespread. Coupled with the large size and weight of appliances, which inherently drive up transportation costs, these inefficient routes further inflate overall logistics expenses, impacting corporate profitability.

(4) Weaknesses in Transfer and Sorting Operations

Many regions lack specialized, large-scale regional sorting centers. Recycled WEEE is often stored in mixed piles, making it impossible to achieve precise sorting. This results in low efficiency in subsequent processing and low resource recovery rates. Insufficient sorting capacity also leads to inventory backlogs, occupying large amounts of space and increasing warehousing costs.

(5) Mismatch Between Processing Enterprises and Front-End Collection

Some formal dismantling and processing enterprises have substantial production capacity but are located in suburban areas, where front-end collection volumes are insufficient. This results in low equipment utilization rates and high operating costs. Conversely, collection shops in densely populated areas often face issues such as insufficient processing capacity and excessively long transportation distances. Lack of transparency in upstream and downstream information, mismatches between collection volumes and processing capacity, and excessively high transportation costs are key factors limiting the efficiency of the WEEE collection network.

(6) Low Level of Digitalization and Weak Coordination

Currently, the overall level of digitalization in the WEEE reverse logistics sector is low. Information across the various stages-collection, warehousing, transportation, and processing-is fragmented, and there is a lack of a unified information platform. Companies are unable to accurately forecast collection volumes, making it difficult to scientifically dispatch vehicles and plan routes. Government oversight also struggles to achieve full traceability throughout the process.

3. OPTIMIZATION DESIGN OF REVERSE LOGISTICS FOR WASTE APPLIANCES

(1) Optimization of the Overall Logistics Structure

The overall layout is optimized by establishing a three-tier reverse logistics system for waste appliances[3]. These tiers are: the front-end community collection tier, the mid-tier regional transfer and sorting tier, and the back-end specialized processing facility tier. Each tier has a clearly defined role and operates in coordination with the others to form a complete closed-loop system. The front-end community collection tier serves as the foundation of this logistics structure, primarily responsible for collecting waste appliances from residents. This includes fixed community collection points, smart recycling bins, property management collection points, and door-to-door collection services, with the goal of enhancing coverage and convenience. The mid-tier regional transfer and sorting tier acts as the hub of the logistics structure, responsible for consolidating, inspecting, sorting, packaging, and temporarily storing dispersed collected goods before transporting them to the processing facility. Through large-scale sorting, transportation efficiency is improved and costs are reduced. The back-end professional processing facility layer is the core of the reverse logistics system, responsible for the dismantling of waste appliances, resource regeneration, and the safe disposal of hazardous materials, thereby achieving a balance between resource recovery and environmental safety.

(2) Optimization of Community Recycling Layout

The layout of community collection points should consider factors such as population density, transportation conditions, residential area types, and resident habits. Collection points should be densely distributed in older neighborhoods and densely populated areas; in newly developed communities, they should be co-located with waste sorting stations and property management service centers; and in suburban and urban-rural fringe areas, mobile or fixed collection points should be established in conjunction with convenience stores. At the same time, recycling methods should be diversified by promoting online scheduling, door-to-door collection, trade-in programs, and “deliver new, collect old” models to increase resident participation[4]. Recycling points should be equipped with basic sorting, registration, weighing, and temporary storage capabilities, and should feature standardized signage, unified management, and consistent pricing to build residents’ trust.

(3) Optimization of Regional Transfer and Sorting Centers

Transfer and sorting centers should be located in areas with convenient transportation, close to major recycling zones, and away from residential areas, balancing coverage and land costs. A single sorting center can serve multiple community collection points, creating economies of scale. The sorting center should be divided into functional zones such as collection, inspection, sorting, packaging, and temporary storage areas. Standardized processes should be adopted for sorting, separating appliances into those that are reusable, disassemblable, or requiring special treatment, thereby improving subsequent processing efficiency. Through centralized packaging and unified distribution, vehicle empty-run rates can be significantly reduced, along with the number of transport trips and associated costs.

(4) Optimization of Processing Facility Layout and Capacity Matching

The layout of processing facilities must strictly comply with environmental protection, safety, and urban planning requirements, with priority given to locations within industrial parks or specialized circular economy industrial parks. The number and scale of processing facilities should be determined based on regional WEEE generation volumes to avoid overcapacity or shortages. At the same time, efforts should be made to promote technological upgrades among processing enterprises, improve automated dismantling capabilities, increase the recovery rates of metals, plastics, and rare materials, and reduce the risk of hazardous substance leakage. Through large-scale, standardized processing, unit processing costs can be reduced, and overall economic efficiency improved.

(5) Optimization of Transportation Routes and Organization

Transportation optimization is key to cost reduction. Methods such as unified dispatching, centralized distribution, and circular collection should be adopted to plan optimal transportation routes, thereby reducing transport distances and empty-run mileage. Vehicle types should be selected reasonably based on the volume and weight of appliances to improve loading efficiency. A transportation information monitoring system should be established to track cargo locations in real time, enhancing transportation safety and controllability.

(6) Optimization of Information Technology and Digital Operations

A unified reverse logistics information platform should be established to integrate information across the entire process, including collection, sorting, transportation, and treatment. Residents can schedule collections through the platform, collection personnel can receive orders in real time, and enterprises can monitor collection volumes in real time. Through data analysis, it is possible to predict collection trends, optimize the layout of reverse logistics points, and schedule vehicle resources, thereby enhancing the intelligence of the entire network.

4. SUPPORT MEASURES FOR IMPLEMENTING THE OPTIMIZATION PLAN

(1) Industry Regulations and Standards

Regarding industry regulations and standards, efforts should be accelerated to establish a unified, comprehensive, and practical standard system for the reverse logistics of waste household appliances. Detailed regulations should be formulated covering the construction of collection sites, sorting procedures, transportation safety standards, environmental treatment requirements, and information recording and traceability, thereby driving the entire industry toward standardization, professionalization, and refinement. For the collection phase, unified standards for collection site construction, service specifications, and price guidance mechanisms should be established to ensure transparent and public collection pricing, standardized service processes, and clear operational standards. In the sorting and processing phases, standardized classification catalogs and operational procedures should be implemented to improve the accuracy of waste appliance classification and processing efficiency, thereby reducing resource wastage and environmental risks. At the same time, a robust industry credit evaluation system will be established to dynamically monitor and rate the operational status, environmental performance, service quality, and compliance of recycling enterprises, sorting centers, and treatment facilities. Evaluation results will be linked to policy support and market access, guiding enterprises to voluntarily standardize their business practices and driving continuous improvement in the industry's overall standards.

(2) Social Participation and Public Awareness

Regarding social participation and public awareness, the efficient operation of WEEE reverse logistics relies on the active participation and support of the general public. Through various channels such as community outreach, media campaigns, public service initiatives, and school education, we should raise awareness about the environmental hazards and resource waste caused by improper

disposal of WEEE. This will enhance the public's environmental awareness, resource consciousness, and sense of social responsibility, guiding residents to proactively choose formal recycling channels for disposing of WEEE.

(3) Corporate Operations and Management Support

Regarding corporate operations and management support, enterprises involved in reverse logistics should proactively enhance their operational capabilities and management standards to meet the requirements of standardized and scaled development. Enterprises should establish and improve internal management systems, refine training, evaluation, and incentive mechanisms for recycling personnel, enhance the professional competence and service awareness of employees, and establish a corporate image characterized by standardization, integrity, and efficiency. During operations, enterprises should promote resource sharing and complementary advantages among peers. Through joint establishment of collection points, shared routes, shared warehousing, and joint distribution, they can reduce individual operational costs and improve resource utilization efficiency. Large-scale recycling and processing enterprises can increase industry concentration by integrating small and medium-sized recycling entities, thereby creating operational advantages in terms of scale, networked operations, and branding, and enhancing market competitiveness and risk resilience. At the same time, enterprises should strengthen environmental awareness and safety responsibilities, strictly adhere to environmental protection requirements in conducting recycling, storage, transportation, and processing activities, prevent environmental pollution and safety incidents, and achieve a balance between economic and environmental benefits.

(4) Technical and Information Technology Support

In terms of technological and IT support, the application of digital and intelligent technologies in reverse logistics should be vigorously promoted to provide technical support for the efficient operation of the network. Efforts should be accelerated to build a reverse logistics information management platform covering the entire chain of collection, sorting, transportation, and processing. This platform should integrate information from multiple sources—including public drop-off points, corporate operations, and government oversight—to achieve integrated functions such as collection scheduling, order allocation, vehicle dispatch, inventory management, traceability, and data statistics. Through big data analysis, accurately forecast the volume of waste appliances generated in different regions and at different times to provide a scientific basis for adjusting the layout of collection points, optimizing transportation routes, and allocating processing capacity, thereby reducing blind planning and resource waste. At the same time, encourage enterprises to introduce intelligent collection equipment, automated sorting equipment, and environmentally friendly processing technologies to reduce labor costs and safety risks. Through informatization and intelligent upgrades, information barriers between various stages of reverse logistics are eliminated, enabling upstream-downstream coordination and enhancing the overall response speed and operational efficiency of the reverse logistics system.

5. CONCLUSION

This study explores the reverse-logistics optimization of waste household appliances based on reverse-logistics and circular-economy theories. It points out that prominent bottlenecks exist within the current system, such as fragmented collection sources, poorly-planned collection-point distribution, inefficient transportation, inadequate transfer-and-sorting capacity, capacity mismatch between collection and processing links, as well as insufficient digital coordination across the whole chain.

A three-tier logistics network composed of community-level collection, regional transfer-sorting centers and specialized processing facilities is proposed as the core optimization framework. Targeted adjustments for site layout, transportation organization and digital information construction can

effectively mitigate high logistics costs, scattered recycling channels and low resource-utilization efficiency. Corresponding operational guarantees covering industry standards, public awareness, corporate internal governance and technical upgrading are essential for the network to function as intended.

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