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Efficiency and Economy of Express Box Recycling Scheme Based on Multi-Model Comparison

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Abstract: This study aims to tackle the issue of packaging waste in the courier industry and promote the development of green logistics by design an efficient recycling scheme for courier boxes to reduce resource waste and environmental pollution. The research employs three models: Logistics enterprise self-circulation (LESC) model, Resource recovery enterprise (RRE) model, and Third-party enterprise (department) recycling (TPEDR) model to simulate the recycling process of courier boxes. IoT technology and intelligent management systems are used to monitor and manage every step of the recycling process for courier boxes. Big data analysis is used to optimize recycling processes and routes by evaluating the efficiency, cost, and feasibility of different recycling strategies in practical operations. The study found that the LESC model achieved the highest recycling rate but faced challenges when scaling for large volumes of courier deliveries. The RRE model performed better in large-scale recycling but had higher transportation and sorting costs. The TPEDR model showed the best cost-efficiency and recycling efficiency by optimizing the distance from recycling stations to the central collection point, reducing transportation costs. From the perspectives of cost-efficiency and environmental protection, the TPEDR model provides the best balance, thus achieving high economic and environmental benefits. The choice of an appropriate recycling model should depend on specific courier services and environmental context, the scale of courier volumes, available resources, and environmental impact. This approach can effectively increase resource utilization rates, reduce environmental pollution, and promote the achievement of sustainable development goals.

1. Introduction

With the rapid progress of Internet technology, consumers have increasingly turned to online shopping, which has greatly promoted the rapid growth of the postal and express delivery industry. According to the data of 2023, the postal industry's mail delivery business volume is as high as 162.48 billion pieces, of which express delivery business accounts for 132.07 billion pieces. The paper and plastic waste generated by the courier industry each year exceeds 10 million tons and 2 million tons,

respectively, and shows an increasing trend year by year. It is expected that by 2025, the consumption of express packaging materials will reach 41.27 million tons. If packaging waste is directly discarded into the environment, it will not only cause waste of resources, but also impose a heavy burden on the environment [1-2]. To reduce resource consumption and promote the green development of the logistics industry, many companies in the industry have tried to adopt recyclable express boxes. For example, in 2016, the Cainiao Alliance launched a "Green Plan" aimed at replacing traditional single-use express cartons, followed by Jingdong's "Qingliu Plan", Suning's "Qingcheng Plan" and Shunfeng's "Fengjing Plan". However, unfortunately, although these recyclable boxes have been introduced to the market eight years ago, their popularity among consumers is still very limited, and even in terms of media exposure, the high profile has been greatly reduced.

With the deepening of green concepts in the industry, companies have continued to make attempts, and the academic community has also conducted in-depth research on express packaging and its environmental impact. At present, the research on express packaging includes consumer perception and management strategies [3], low-carbon packaging design [4-5], game evolution [6-7] and so on. In particular, U-Dominic et al. [8] identify and rank the factors that hinder reverse logistics. In addition to technical barriers, the first is organizational barriers. The material industry is constantly exploring more environmentally friendly ways to efficiently recycle reusable materials and solve technical difficulties. Zhang et al. [9] systematically discussed the environmental problems of express packaging waste in China. It could provide data support and policy recommendations for the long-term green development of the express delivery industry. Zhou et al. [10] compared the life cycle environmental impact of traditional and recyclable express packaging in China, and concluded that compared with cartons, the greenhouse gas emissions of recyclable boxes were found to reduce greenhouse gas emissions by 57.1%, while the comprehensive environmental impact value of box-type recyclable packaging was reduced by 63 % compared with the recycling path of carton-type express packaging. Therefore, the promotion of recyclable express boxes is undoubtedly an important step for the postal logistics industry to move towards sustainable development. This packaging method can not only significantly reduce the consumption of paper and plastics, but also help to reduce the generation of waste, thus having a positive impact on environmental protection.

In fact, if recyclable materials can be widely used, this will represent significant progress in solving the environmental impact of the express delivery industry. Although the impact of existing attempts on the market is not wide enough, they provide valuable experience and inspiration for future improvement directions. Based on these experiences, future research will focus on exploring a practical implementation plan to make the circular express box applied in a wider market. This will involve the optimization of existing processes, strategies to improve consumer acceptance, and cooperation mechanisms between different entities. Through these measures, it is possible to move towards more environmentally friendly and sustainable logistics solutions.

2. Recycling process model construction

2.1. Logistics enterprise self-circulation (LESC) model

As shown in Figure 1 this model aims to reduce disposable packaging by promoting reusable packaging solutions, minimizing environmental impact, and optimizing logistics resource utilization. It involves producing durable express boxes with unique tracking codes for easy identification. Once consumers place orders, goods are packaged in these boxes and delivered. After use, the boxes are recovered by the logistics company, cleaned, inspected, and maintained for reuse. The tracking system allows efficient management and scheduling of the boxes. When boxes are no longer usable, they are scrapped, classified, and recycled into new packaging materials.

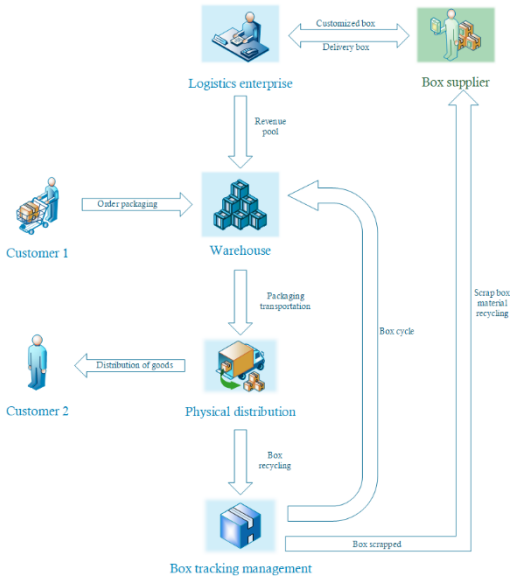

Figure 1: LESC model box loop flowchart

2.2. Resource recovery enterprise (RRE) model

The business scope of renewable resource recycling enterprises spans various fields, including intelligent electronic products, luxury goods, gold and silver jewellery, famous wine gifts, electronic waste, home appliances, paper, and plastic recycling. These businesses offer both online platforms and offline services, receiving customer applications for recycling, evaluating items, and either reselling, reprocessing, or recycling them. Specific services include recycling electronic products, luxury goods, and jewellery, processing e-waste and household appliances, and providing facilities for paper and plastic recycling. The REE model is shown in Figure 2, where the express box recycling in this study falls under "life debris recycling-paper recycling" within this system.

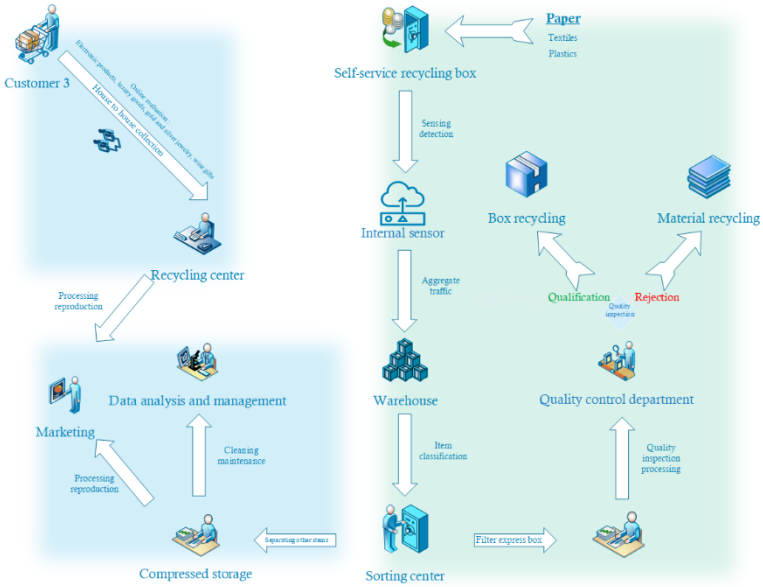

Figure 2: RRE model loop flowchart

2.3. Third-party enterprise (department) recycling (TPEDR) model

As shown in Figure 3, the Third-party enterprise (department) recycling (TPEDR) model involves the following process: Express boxes are delivered to customers, who then recycle the empty boxes either on-site at the delivery point or at the nearest recycling site. Third-party companies collect the empty boxes, clean, inspect, and decide whether to re-use or scrap them. Recovered boxes are centrally stored for further processing, after which they are either re-delivered for use by logistics companies or recycled into new boxes. Finally, reusable containers are supplied back to logistics enterprises for further deliveries.

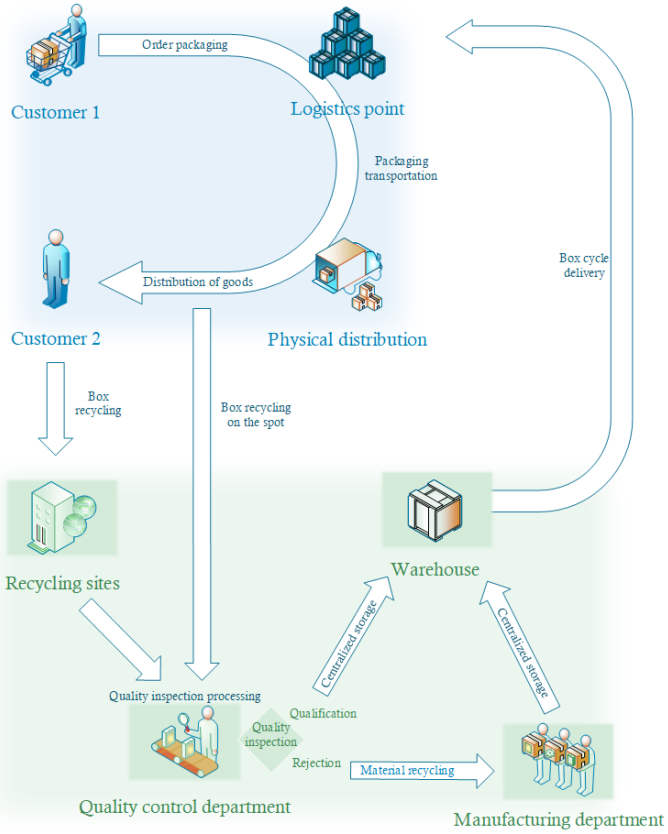

Figure 3: TPEDR model loop flowchart

3. Model deduction

3.1. Create a simulation environment

Usually, the proportion of roads in urban planning will vary according to the specific circumstances, but in general, about 20-30% of the land is used as roads and public areas. Typically, roads and public areas account for 25% of the total area. According to the above information, the distribution of units within 1 million square meters is simulated as shown in Figure 4.

Estimating express delivery volume in urban communities is influenced by factors such as population density, residents' shopping habits, and the service scope of delivery companies. Some areas may have higher volumes due to mixed residential and commercial zones, while remote areas may see lower volumes due to traffic limitations. Assuming a community of 10,000 square meters with 1,000 households, and each household sends or receives a parcel every two days, the estimated daily delivery volume would be 500 parcels.

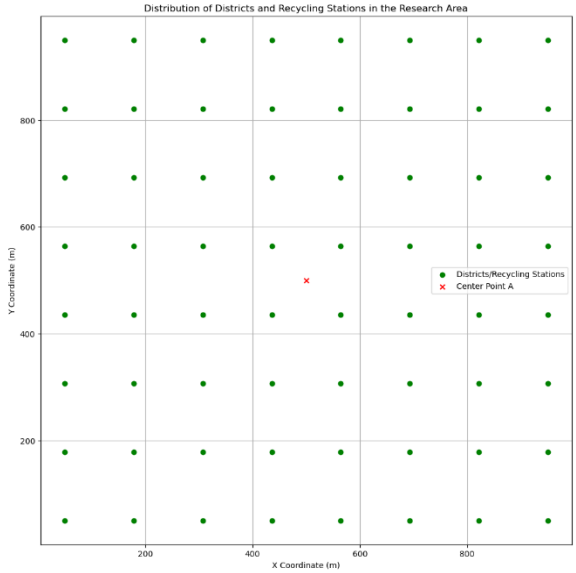

Figure 4: Simulated community distribution

3.2. Operation model

3.2.1. Logistics enterprise self-circulation model

In the LESC model, the purpose is to simulate a closed logistics system, in which the express company manages the recycling and reuse of the express box. The model is established as shown in Figure 5. In this model, a community with uniform distribution in the specified area is set. Each community is set to have a certain number of residents, and a fixed number of express boxes are used every day. In order to efficiently recycle and reuse express boxes, several logistics sites are set up in the model, and each site is responsible for a fixed number of communities. These sites are evenly distributed across the study area, with each site handling a fixed number of express boxes daily. Express boxes are distributed from central point A to each logistics site, and is recovered immediately after use, achieving a recovery rate of 100%. The express boxes recovered from each site will eventually be transported back to the centre point A. The transportation cost is calculated based on the number of express boxes and the distance from the site to the central collection point.

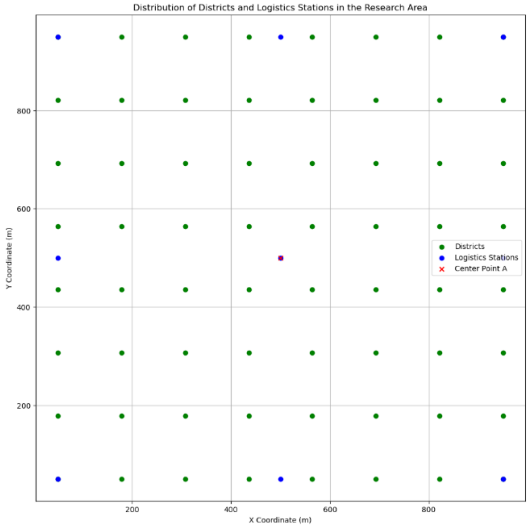

Figure 5: Distribution of LESC model

3.2.2. Resource recovery enterprise model

The RRE model is based on an open recycling system, which includes independently operated resource recycling sites. As shown in Figure 6, in this model, there are multiple resource recycling sites in each cell, and each site is located within a designated cell. The amount of waste handled by each site per day is fixed, but only a small proportion of this waste consists of express boxes.

This model assumes that not all residents recycle express boxes at these sites. The transportation of express boxes is limited to the distance from central point A to each site. The recycled express boxes will be transported back to point A, and the transportation cost is determined by the amount of recycled waste and the distance from the site to the centre point. All waste needs to be sorted after being transported back to point A, and the sorting cost is half of the total transportation cost. The total recycling cost is the sum of transportation and sorting costs.

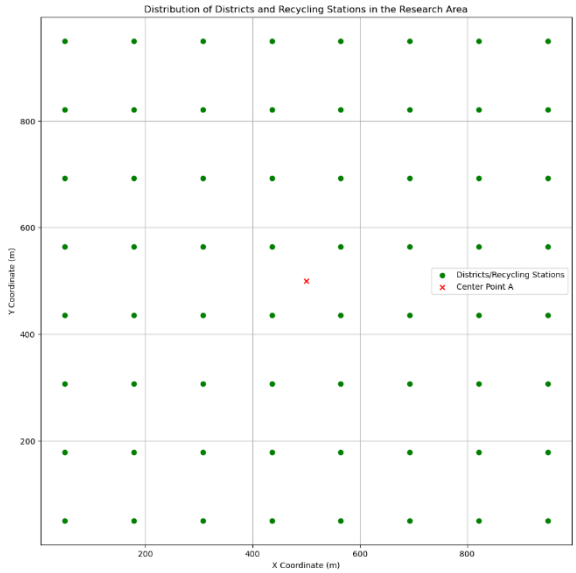

Figure 6: Distribution of RRE model

3.2.3. Third-party enterprise (department) recycling model

The TPEDR model simulates a third-party recycling process. As shown in Figure 7, in this model, each cell contains two express box recycling sites. The daily number of express boxes processed by each site is fixed, and this model assumes that not all residents will participate in express box recycling at these sites.

Similar to the first two models, the transportation of express boxes is limited to the distance between central point A and each logistics site, and the recovered express boxes are transported back to point A collectively. The transportation cost is determined by the number of recovered express boxes and the distance to point A.

4. Result discussion

This study evaluated the efficiency, cost, and feasibility of different recycling strategies in actual operation by through constructing three different express box recycling models, namely, LESC model, RRE model and TPEDR model. Each model involves 75 communities in the same area and processes the same total express volume every day, but the setting of recycling sites, the number of express boxes recycled daily and the recovery rate are different.

1) LESC model: In this model, a logistics station is set up for every 5 communities, and the daily

delivery volume is relatively small (3750). Although the recovery rate of this model reaches 100 %, it has poor scalability in dealing with large-scale express delivery due to the low total amount of express delivery processed.

2) RRE model: This model sets up four resource recovery sites in each community, and the number of express boxes processed is the largest among the three models (37500), with a recovery rate of 50 %. This model is more effective for large-scale recycling, but its recovery rate is not as good as the logistics enterprise self-circulation model, and the transportation and sorting costs are higher, which affects its overall cost-effectiveness.

3) TPEDR model: This model sets up two express box recycling sites in each community, the number of express boxes processed per day is more (37,500), and the recovery rate is 80 %, showing higher recovery efficiency and lower transportation costs, making this model the best performer in terms of cost-effectiveness and efficiency.

From the perspective of cost-effectiveness and environmental protection, the TPEDR model provides the best balance and can generate greater economic and environmental benefits. Choosing the appropriate recycling model should consider the specific application scenarios, the scale of express delivery, available resources and environmental impact. In this way, it can effectively improve the recycling rate of resources, reduce environmental pollution, and promote the realization of sustainable development goals.

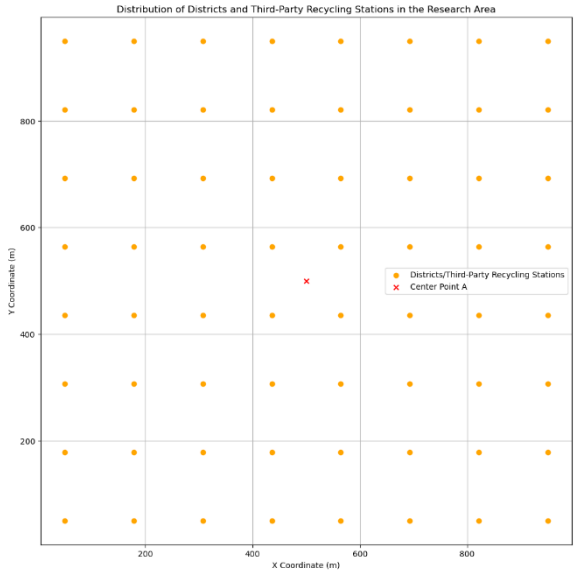

Figure 7: Distribution of TPEDR model

5. Conclusion

This study designed and evaluated three different express box recycling models to solve the problem of packaging waste in the express delivery industry and promote the development of green logistics. By using the Internet of Things technology and intelligent management system, combined with big data analysis to optimize the recycling process and path, the efficiency, cost, and feasibility of each recycling model in actual operation are studied and evaluated. The research results show that the TPEDR model performs best in terms of recycling efficiency and cost-effectiveness, and is suitable for large-scale application.

Future research should focus on further optimizing the recovery process and technology, improving recovery efficiency, and reducing costs. Additionally, it should aim to enhance consumer environmental awareness and the design of incentive measures to increase participation and coverage

of the recycling system. Furthermore, encouraging the development of policy support and industry standards is essential to promote the standardization of express packaging recycling.

In short, recycling express boxes is key to the sustainable development of the express delivery industry, but also an important way to achieve green logistics. Through collaboration among multiple stakeholders and technological innovation, we are expected to build an efficient and environmentally friendly express packaging recycling system to contribute to the sustainable development of society and the environment.

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