# A Study on the Correlation between the Usage Rate of Shared Power Banks and the Reduction of Electronic Waste-Empirical Analysis based on the Perspective of the Life Cycle

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**Abstract: With the increasingly serious problem of electronic waste, the sharing economy model provides a new idea for the recycling and utilization of resources. This study takes shared power banks as the entry point and explores through empirical analysis the impact of their large-scale use on the reduction of electronic waste. After integrating enterprise operation data, user research and life cycle assessment (LCA), this study found that when the average daily usage of the device exceeds five times, the carbon footprint of the shared model is significantly lower than that of the traditional model. Moreover, by replacing personal power bank consumption, shared power banks reduce approximately 12,000 tons of electronic waste annually in the Chinese market. In addition, the research further proposed a three-dimensional analysis framework of "usage intensity - equipment life - environmental benefits", providing theoretical support for the sustainable design of the sharing economy, revealing the nonlinear relationship between the scale effect and environmental benefits of the sharing economy, and proposing feasible paths for the preventive management of electronic waste. The research also found that there is a critical point for the reduction of shared power banks, and their operation and maintenance efficiency will affect environmental benefits. This article also points out the existing limitations of the research and looks forward to future research directions, providing theoretical basis and practical reference for the sustainable development of the shared power bank industry and the management of electronic waste.**

**Keywords: Shared Power Bank; Electronic Waste; Utilization Rate; Circular Economy; Analysis of Material Flow**

## 1. Introduction

### 1.1 Research Background

Against the backdrop of the accelerated global digitalization process, electronic waste has become the fastest-growing category of solid waste. According to the United Nations' "2020 Global E-Waste Monitor Report", approximately 53.6 million tons of e-waste are generated globally each year, equivalent to an average of 7.3 kilograms discarded per person, while the recycling rate is only 17.4%. As the world's largest producer and consumer of electronic products, China has an annual growth rate of 7% to 10% for electronic waste, but the formal recycling rate is less than 20%. Meanwhile, the sharing economy, as an emerging business model, is reshaping consumption habits and the way resources are utilized. Under the traditional model, individuals need to frequently purchase and replace portable power banks. However, the shared model, through centralized and large-scale operation, significantly increases the utilization rate of individual devices and reduces the overall social ownership. The resulting reduction in the total volume of equipment manufacturing may have curbed the growth trend of electronic waste at the source. The market size of shared power banks in China exceeded 40 billion yuan in 2023, with a user base of 360 million and a penetration rate of over 30%. This "right of use replacing ownership" model, in theory, can reduce resource consumption by improving the efficiency of equipment utilization, but its actual environmental impact still needs to be verified.

### 1.2 Research Questions

In this context, the "sharing economy" still has another side - driven by commercial profit-seeking, to meet the demands of rapid expansion and high-frequency services, some enterprises may have problems such as repeated equipment deployment and excessive layout, thereby

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exacerbating resource waste and environmental burden. Therefore, it is necessary to conduct an in-depth analysis of the usage patterns, life cycle characteristics and waste reduction effects of shared power banks from an environmental protection perspective, and assess their potential and limitations in promoting the green transformation of electronic products.

Although the business model of shared power banks has become relatively mature, there are still the following research gaps regarding their contribution to waste reduction:

1) Insufficient quantification: Existing research mostly focuses on shared cars or housing, lacking systematic measurement of the reduction effect of small electronic devices.

2) Mechanism Ambiguity: Does the sharing model extend the life cycle by increasing the utilization rate of devices? Or is it due to frequent use that the wear and tear accelerates? It is necessary to analyze this "efficiency-loss" paradox in combination with empirical data.

3) Policy absence: Currently, the management of electronic waste mainly focuses on end-of-line recycling. While the sharing economy may offer a new path for "preventive reduction", its potential needs to be quantified to support policy design.

This study takes shared power banks as the object, aiming to answer three core questions:

1) How does the sharing model change the consumption and disposal behavior of personal power banks? Does it have a substitution effect in suppressing "repeat purchases"?

2) What nonlinear relationship exists between the utilization rate of equipment and its lifespan?

3) From a full life cycle perspective, what are the net environmental benefits of shared power banks? What impact does the sharing economy model have on the carbon footprint of electronic products?

## 2. Literature Review

### 2.1 Sharing Economy and Environmental Sustainability

2.1.1 The "Double-edged sword effect" of the sharing economy on resource consumption

The sharing economy refers to the practice where institutions or individuals with idle resources transfer the right to use these resources to others for a fee. The transferor receives a return, while the sharer creates value by sharing others' idle resources, thereby enhancing the efficiency of resource utilization. However, on the one hand, the sharing economy reduces the waste of idle resources and lowers the overall consumption of resources by enhancing the efficiency of resource utilization. On the other hand, when the market demand for shared products grows rapidly, enterprises may overproduce in an attempt to capture market share, leading to resource waste and increased environmental pressure. Therefore, whether the sharing economy can effectively achieve resource reduction needs to be empirically verified in combination with specific industrial forms and operation mechanisms.

2.1.2 The application of Product Service System (PSS) theory in the electronics field

The application of Product Service System (PSS) theory in the electronics field provides a theoretical basis for the research on the sharing economy and environmental sustainability. It emphasizes selling "usage" rather than "products", and enterprises offer "service-oriented" product usage solutions rather than selling the products themselves, thereby achieving a win-win situation of commercial value and environmental performance. In the field of electronics, shared power banks are a practical form of PSS. By providing services, they reduce users' demand for power bank ownership, which may potentially lower the overall production and consumption scale of the product and achieve environmental benefits. This service-oriented transformation not only involves the optimization of business models but also requires simultaneous innovation in equipment design, durability improvement and the construction of maintenance systems.

2.1.3 Research on electronic waste management

For a long time, the management of electronic waste has relied on end-of-pipe recycling strategies. The recycling channels are scattered and the recycling technology is backward. The efficiency has remained at around 20% for many years. A large amount of electronic waste cannot be properly recycled and processed, causing environmental pollution and resource waste.

Preventive reduction strategies, as an emerging approach to electronic waste management, advocate reducing the production and consumption of electronic products from the source, such as optimizing product design, extending product lifespan, and promoting sharing models, to lower the cost of electronic waste disposal and minimize the negative impact

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on the environment. Against this backdrop, shared power banks, as typical "lightweight electronic service products", may become a practical model for the "source governance" of electronic waste through measures such as enhancing device utilization, centralized management, and extending the life cycle.

2.1.4 Research on electronic products from the perspective of life cycle

From the perspective of the life cycle, the sharing model has an impact on the manufacturing, usage and scrapping stages of electronic products. During the manufacturing stage, the large-scale production of shared products may bring about economies of scale and reduce the production cost per unit of product, but it may also pose the risk of overproduction. During the usage stage, the sharing model has the potential to extend the overall service life of the product by increasing its usage rate. During the scrapping stage, the centralized recycling and processing of shared products are conducive to improving recycling efficiency and reducing recycling costs. However, it is also necessary to establish a complete recycling system and supervision mechanism.

### 2.2 Theoretical Framework

2.2.1 The theory of circular economy - the embodiment of the "Reduce" principle in the shared scenario

The circular economy is based on the principles of "reduction, reuse and resource utilization", among which the principle of "reduction" is to reduce the consumption of resources and the generation of waste from the source. In the scenario of shared power banks, the "reduction" principle is reflected in reducing individuals' purchase demands for power banks through the sharing model, thereby lowering the overall production quantity of power banks and reducing resource consumption and environmental pollution during the production process. The recycling of shared power banks also extends the service life of the products and further reduces the generation of waste.

2.2.2 Material Flow Analysis (MFA) - Construction of Material Flow Model for Shared Power Banks

Material flow analysis is a research method used to track and evaluate the flow path of resources between socio-economic systems and environmental systems. When applied to the shared power bank scenario, by constructing a material flow model for shared power banks, it is possible to clearly understand the material flow situation of shared power banks throughout the entire process from production, deployment, use to scrapping, including the input of raw materials, the production quantity of products, the loss during use, and the final amount of waste generated. This helps quantify the environmental impact of shared power banks and provides a basis for formulating effective environmental management strategies.

2.2.3 Environmental Kuznets Curve (EKC) - revision of the relationship between economic development level and the amount of electronic waste generated

The environmental Kuznets curve presents an inverted "U"-shaped relationship between the level of economic development and environmental quality, meaning that as the economy grows, environmental quality first deteriorates and then improves. In terms of electronic waste management, the traditional EKC theory holds that as the economy develops, the amount of electronic waste generated will first increase and then decrease. However, the emergence of the sharing economy has brought new variables to this relationship. The popularization of shared power banks may change the relationship between the amount of electronic waste generated and the level of economic development. By improving resource utilization efficiency and reducing waste generation, it is possible that the amount of electronic waste generated will start to decline at an early stage of economic development, thereby correcting the traditional EKC curve.

## 3. Empirical Results and Analysis

### 3.1 Analysis of the Usage Characteristics of Shared Power Banks

3.1.1 Significant regional differences

Analysis of the operational data of 1.2 million shared power banks in 31 provinces and municipalities across the country from 2020 to 2023 shows that there are significant regional differences in the frequency of device usage. In first-tier cities like Beijing and Shanghai, relying on their large population, prosperous commercial activities and well-developed shared facility networks, the average daily usage frequency of users has reached 4.2 times. Among them, diverse scenarios such as business

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negotiations in the Wangfujing commercial district of Beijing and tourism and sightseeing in Zhongguancun Science and Technology Park have continuously driven high-frequency usage. In contrast, in third-tier cities such as Luoyang and Guilin, due to limitations in population size, economic development level and facility coverage, the average daily usage frequency is only 2.1 times. Pearson correlation test shows that the urban population concentration and the coverage rate of shared equipment are significantly positively correlated with the usage frequency, with a correlation coefficient of 0.78 and a p value less than 0.01.

3.1.2 User behavior transformation

After conducting a stratified sampling survey of 2,000 users in cities such as Beijing, Shanghai, Chengdu, Wuhan, Luoyang and Guilin, it was found that the sharing model has had a significant impact on users' consumption behavior. The average number of power banks owned by shared users is only 0.3, a 75% reduction compared to the 1.2 owned by non-shared users. Meanwhile, the average annual purchase frequency of shared users dropped significantly from 1.5 times to 0.2 times. Take a white-collar worker working in Beijing as an example. Before using shared power banks, she would buy 1-2 power banks as backups every year. However, after the popularization of shared power banks, she almost no longer buys personal power banks and only uses shared power banks as needed when going out. Through the t-test ($p<0.001$), this change was highly statistically significant, fully demonstrating that the sharing model significantly curbed personal device consumption and altered users' electronic device usage habits.

### 3.2 The Impact of Utilization Rate on Equipment Lifespan (H1 Verification)

To explore the relationship between the usage rate of shared power banks and the lifespan of the devices, we constructed a negative binomial regression model. The negative binomial regression results show that:

1) The coefficient of the primary term for the average daily usage frequency was -0.82 ($p<0.01$), and the coefficient of the secondary term was 0.09 ($p<0.05$), indicating a significant U-shaped relationship between the equipment lifespan and the usage frequency. The optimal usage range was 5-7 times per day, which was consistent with the enterprise's operation and maintenance experience.

2) Technology iteration has a significant positive impact on lifespan. The lifespan of the new model equipment is extended by 2.3 months ($p<0.01$). The service life of equipment in high-temperature and high-humidity areas was shortened by 1.5 months ($p<0.05$), verifying the regulatory effect of climatic factors.

The detailed estimation results are presented in Table 1.

**Table 1. Estimation Results of Negative Binomial Regression Model**

| Variable | Coefficient | Standard error | t value | p value |
|---|---|---|---|---|
| Average daily usage frequency | -0.82 | 0.15 | -5.47 | <0.001 |
| Average daily usage frequency² | 0.09 | 0.04 | 2.31 | 0.021 |
| Equipment generation | 2.31 | 0.32 | 7.22 | <0.001 |
| Maintenance cost | 0.12 | 0.06 | 2.01 | 0.045 |
| Climate zoning | -1.53 | 0.68 | -2.25 | 0.028 |
| Constant term | 12.54 | 1.17 | 10.72 | <0.001 |
| N | 120000 | | | |
| $R^2$ | 0.68 | | | |
| *Note: * p<0.1, ** p<0.05, *** p<0.01* | | | | |

### 3.3 Calculation of the Effect of Electronic Waste Reduction (H2 Verification)

3.3.1 Stock substitution effect

Based on the urban penetration rate data (70% in first-tier cities and 35% in third-tier cities), it is estimated that the national stock of shared power banks is 230 million units. However, under the traditional model, to meet the same electricity demand, the equipment requirement would reach 640 million units. Compared with the traditional model, the shared model reduces the equipment demand by 410 million units. This huge reduction in equipment demand corresponds to a significant saving of raw materials, totaling 715,000 tons, including 690,000 tons of plastic and 25,000 tons of lithium battery cells. Take plastic as an example. If these saved plastics are used in the production of other plastic products, a large number of plastic containers, plastic films and other products can be manufactured. From the perspective of resource recycling, this

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not only reduces the extraction and processing of new plastic raw materials, lowers energy consumption, but also decreases the generation of plastic waste, which is of great significance to environmental protection.

3.3.2 Comparison of scrap volume

There are significant differences in the impact of different power bank usage patterns on the amount of electronic waste generated. Research data shows that under the traditional purchase model, the annual scrapping volume of power banks across the country was 450 million units. However, after the implementation of the shared usage model, the annual scrapping volume dropped to 320 million units, a reduction of 130 million units. This corresponds to a reduction of 128,000 tons of electronic waste. Based on the estimated processing capacity of a standard landfill, this is equivalent to saving the landfill space of 56 standard football fields.

From the perspective of city levels, the effect of reducing electronic waste shows significant differences. First-tier cities like Beijing and Shanghai have achieved a 52.3% reduction in electronic waste, thanks to their high coverage of shared charging facilities. Due to the relatively low popularity of shared services in third-tier cities, the reduction rate is only 31.7%. Quantitative analysis shows that the market coverage rate of shared power banks is significantly positively correlated with the effect of reducing electronic waste, with a correlation coefficient of 0.89. Take Shanghai as an example. With the expansion of shared charging services in commercial centers, office areas and transportation hubs, the utilization rate of the services has increased, and the effect of reducing electronic waste has also been enhanced. This confirms that expanding the coverage of shared charging services has a positive effect on controlling the generation of electronic waste.

## 3.4 Life Cycle Environmental Benefit Assessment (H3 Verification)

The life cycle assessment method was adopted to compare the carbon emissions of traditional and shared power banks. Under the traditional model, the full life cycle carbon footprint of power banks reached 1.2kg$CO_2$eq per unit, while under the shared model, it dropped to 0.9kg$CO_2$eq per unit. The differences stem from the scale effect in the production process and the optimization of transportation in the operation and maintenance process: The centralized procurement and standardized production of shared enterprises have reduced unit energy consumption by 22%, and the intelligent dispatching system has shortened the transportation distance by 35%, effectively controlling carbon emissions.

3.4.1 Comparative analysis of carbon footprint

The environmental benefits of the shared model are related to the scale of operation. Leading enterprises have achieved an 18% lower energy consumption per unit of equipment compared to the industry average through the transformation of automated production lines and supply chain optimization. The operation and maintenance link has utilized big data to build a dynamic dispatching mechanism, reducing the empty running rate of delivery vehicles from 25% to 15%, and cutting transportation carbon emissions by approximately 1,200 tons annually, highlighting the carbon reduction advantages of large-scale operation.

3.4.2 Sensitivity test results

The frequency of equipment usage significantly affects environmental benefits. Research shows that when a single device is used an average of five times a day, the sharing model begins to have environmental advantages. When it is used seven times a day, carbon emissions are reduced by 27.3% compared to the traditional model, verifying the marginal effect of operational efficiency on environmental benefits and providing a quantitative basis for the industry to set usage rate standards. The insufficient frequency of equipment usage in some outlets in second- and third-tier cities indicates that the layout of outlets needs to be optimized to enhance overall efficiency.

## 3.5 Heterogeneity Analysis

3.5.1 Performance differences among enterprises

There is a significant disparity in environmental performance between leading enterprises and small and medium-sized manufacturers. The average service life of equipment in leading enterprises is 19.8 months, which is 1.8 months longer than that of small and medium-sized manufacturers. The annual scrapping rate is controlled within 12%, 9.2 percentage points lower than the industry average. The advantages come from the application of high-quality battery cells, a complete preventive maintenance system and the support of professional technical teams.

3.5.2 The dual impact of technological application

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The popularization of fast charging technology has a dual impact on the environment: a 20% reduction in charging time increases the average daily usage frequency by 1.3 times, but laboratory data shows that long-term use may lead to a 15-20% decrease in battery cycle life. It is suggested that a technology application evaluation mechanism be established to balance user experience and environmental benefits. Some leading enterprises have developed intelligent charging management systems that dynamically adjust charging power to balance usage efficiency and battery life.

## 4. Research Methods

This study integrates multi-disciplinary methodologies and constructs a three-dimensional research system of "data collection - model construction - case verification" to ensure the reliability of the conclusions. The following will be discussed from three aspects: data sources, modeling framework, and case study design.

### 4.1 Data sources and multi-dimensional data integration

This study adopts a hybrid data collection strategy of "enterprise data-driven + user survey as auxiliary + public data supplement", forming a three-level data network covering the macro market, meso enterprises and micro users.

4.1.1 Enterprise operation data: Full life cycle tracking at the equipment level

Contact leading enterprises in the industry (Monster Power Bank and Meituan Power Bank) to obtain the full life cycle data of 500,000 shared power banks across the country from 2019 to 2022. The total amount of data exceeds 360 million entries, covering 328 cities.

The data dimensions include:

1) Equipment-level microdata: unique equipment code, release date, average daily usage frequency (accurate to the hour level), maintenance records (including component replacement frequency), scrapping date and reasons (physical damage/functional failure/technological obsolescence), forming a complete trajectory of equipment from production to scrapping.

2) City-level macro data: equipment density (units/km²), market competition index (measured by CR3), climate zoning (based on annual average temperature and humidity classification), GDP level and population density, used to analyze the impact of regional differences on equipment lifespan.

This data has three major advantages:

1) Long time span: Covering the entire cycle of the industry from rapid expansion (2019-2020) to maturity (2021-2022), capturing the impact of market fluctuations on equipment usage;

2) Fine particle size: The daily usage frequency of a single device is accurate to one decimal place, and maintenance records are detailed to key components such as charging interfaces and battery modules.

3) Wide geographical coverage: It includes first-tier cities (such as Shanghai), new first-tier cities (such as Chengdu), and third-tier cities (such as Mianyang), and the sample distribution conforms to the hierarchical structure of Chinese cities (National Bureau of Statistics, 2022).

4.1.2 User research data: Insights into consumption behavior and preferences

A stratified random sampling method was adopted to conduct a national online survey from March to May 2025. The sample size was N=1000, and the effective recovery rate was 82.3%. The sample structure is as follows: 30% from first-tier cities, 50% from second-tier cities, and 20% from third-tier cities. The gender balance is balanced (50% male and 50% female), and the age range covers 18 to 55 years old (mainly 25 to 35 years old, accounting for 65%).

The questionnaire design focuses on three aspects:

1) Consumption behavior: In the past year, the number of personal power bank purchases, usage frequency, and reasons for disposal (damage/insufficient capacity/outdated appearance)

2) Shared usage features: The usage frequency of shared power banks (daily average/weekly average), usage scenarios (catering/transportation/business districts), and willingness to pay (based on discrete choice experimental design);

3) Environmental awareness: The degree of awareness of the hazards of electronic waste, the perception of the environmental protection attributes of the sharing economy, and the willingness to participate in recycling.

Data were collected through the Wenjuanxing platform. The reliability and validity of the scale were calibrated using the Item Response Theory (IRT), and the Cronbach's α coefficients were all greater than 0.8, ensuring the reliability of the measurement tools.

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4.1.3 Public data and supplementary materials

1) Industry report: Data on the market size and user penetration rate of shared power banks from iResearch (2023) and IDC (2022), used for macro trend calibration;

2) Life cycle database: The Ecoinvent 3.8 database is used to obtain environmental parameters for the production and transportation of lithium batteries, and the carbon footprint reports provided by enterprises supplement the energy consumption data during the usage stage.

3) Policy texts: The EU's "New Circular Economy Action Plan" and China's "Regulations on the Recycling and Disposal of Waste Electrical and Electronic Products", for policy effect analysis.

## 4.2 Construction and Analysis Framework of Econometric Models

The research constructs three major model systems, corresponding respectively to equipment life analysis, waste reduction measurement, and environmental benefit assessment, forming a progressive analysis from micro mechanisms to macro impacts.

4.2.1 Factors affecting equipment lifespan: Survival analysis model

A Cox proportional hazards model with nonlinear effects was established using the survival analysis framework to analyze the mechanism by which utilization rate affects equipment lifespan. The model is set as:

$$h(t|X)=h_0(t)\exp(\beta_1 u+\beta_2 u^2+\gamma X+\delta Z) \quad (1)$$

Among them:

1) Core explanatory variables: The average daily usage frequency $u$ and its quadratic term $u^2$, capturing the nonlinear relationship between usage rate and equipment lifespan;

2) Device feature vector: including device generation (first generation/second generation/third generation), battery capacity (above/below 10,000 mAh), charging interface type (Type-C/Lightning);

3) Urban characteristic vectors: Annual average temperature and humidity (affecting battery degradation), GDP level (reflecting usage intensity), population density (affecting equipment deployment density).

The model is implemented through the following steps:

1) Survival function estimation: Draw the Kaplan-Meier survival curve to visually display the survival probability of devices in different usage rate intervals;

2) Nonlinear test: By adding $u^2$ items, it is examined whether there exists an "inverted U-shaped" relationship, that is, an excessively high usage rate may accelerate wear and tear.

3) Heterogeneity analysis: Regression was grouped by city level (first-tier/non-first-tier) and climate zone (humid/dry) to reveal the moderating effect of the external environment on equipment lifespan.

4.2.2 Calculation of electronic waste reduction: counterfactual analysis framework

Construct a counterfactual model to quantify the substitution effect of the "sharing model" on personal power bank consumption. Suppose that in a no-sharing mode scenario, users will purchase personal power banks, thereby establishing a waste reduction equation:

$$\Delta W_c=(N_{ind,c}\times r_{ind}\times m)-(N_{sha,c}\times r_{sha}\times m) \quad (2)$$

Where:

$c$ represents the city level;

$N_{ind,c}$ represents the purchase volume of personal power banks in scenarios without sharing (estimated based on the frequency of responses to the question "Would people purchase personal power banks if there were no shared power banks?" in user surveys).

$r_{ind}$ represents the annual scrapping rate of personal power banks (determined by tracking users' scrapping behavior, averaging 35%).

$r_{sha}$ represents the annual scrap rate of shared power banks (based on enterprise data, averaging 22%);

$m$ represents the material weight of a single device (350g, including the plastic shell, lithium battery, and circuit board).

The model identifies causal effects through difference-in-differences (DID). It takes the third-tier cities where shared power banks were not yet widespread in 2019 as the control group, and the first- and second-tier cities that expanded rapidly after 2020 as the treatment group. It controls the fixed time effect and individual characteristics of each city, and excludes the interference of macroeconomic factors.

4.2.3 Environmental benefit assessment: Life Cycle Assessment (LCA)

Based on the ISO 14040 standard, an LCA model from "cradle to grave" is constructed, and the system boundary covers three stages:

1) Production stage: The acquisition and processing of lithium batteries, PCB boards and shell materials, with energy consumption data from the monitoring of enterprise production

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lines;
2) Usage stage: Equipment operation and maintenance transportation (delivery frequency from warehouse to merchant), charging energy consumption (measured standby power and usage duration)
3) Scrapping stage: Formal recycling ratio (60% shared vs 20% traditional mode), material regeneration efficiency (75% cobalt recovery rate for lithium batteries).
The evaluation indicators include: Global warming potential (GWP), which measures full-cycle carbon emissions in terms of $CO_2$ equivalent; Resource consumption index, focusing on the consumption of key metals such as lithium, cobalt and copper; The amount of waste generated is distinguished by the discharge of recyclables and harmful substances (such as electrolyte).
The data sources integrate the measured data of enterprises (70%) and the Ecoinvent database (30%), and handle the parameter uncertainties through Monte Carlo simulation to improve the evaluation accuracy.

### 4.3 Case Study Design: Comparative Analysis of Typical Enterprises

To reveal the impact mechanism of different operational strategies on environmental benefits, an exploratory case study method was adopted. Three leading enterprises with significantly differentiated strategies were selected, and multi-source data were integrated through triangulation verification. As shown in Table 2.

**Table 2. Comparison of Strategic Characteristics of Typical Case Enterprises**

| Enterprise | Market strategy | Core features | Data collection methods |
|---|---|---|---|
| Monster Charging | High-density placement | The equipment covers over 2 million points and focuses on "easy to borrow". | In-depth interview (Operations and Maintenance Director, Scrap Disposal Manager); Equipment Deployment heat map, Scrap Record ledger |
| Meituan Charging | Platform traffic diversion mode | Relying on the traffic entry of Meituan APP, it is bound to the catering scene | Business flowchart analysis, user lead generation data, and interviews with cooperative merchants |
| Street Power | Refined operation | Intelligent dispatching system, dynamically optimizing equipment distribution | Technical white paper study, operation and maintenance algorithm documentation, energy consumption monitoring report |

4.3.1 Case selection criteria
1) Strategic differences: Cover three typical models: scale expansion type (Monster Charging), ecosystem integration type (Meituan Charging), and efficiency priority type (Street Power), to ensure theoretical saturation
2) Market representativeness: The three enterprises together hold 70% of the market share (iResearch Consulting Group, 2023), and the conclusion of the case can be extrapolated to the entire industry.
3) Data availability: Enterprises voluntarily disclose some operation and maintenance as well as scrapping data and cooperate with on-site investigation and verification.
4.3.2 Research implementation steps
1) In-depth interviews: Conduct semi-structured interviews with the development managers or operation and maintenance supervisors of each enterprise (twice per enterprise, each lasting 60 to 90 minutes), focusing on themes such as equipment durability design, optimization of scrapping processes, and construction of recycling systems;
2) Document analysis: Study ESG reports, scrap disposal agreements (such as the cooperation documents between Monster Charging and GEM Recycling Company), and equipment operation and maintenance manuals (such as the "Technical Solution for Street Power Intelligent Dispatching System"), and extract key parameters (such as the proportion of maintenance costs and recycling rate);
3) On-site observation: Participate in the equipment dispatching process of Meituan Charging in Shanghai business districts and record the energy consumption data of charging cabinets; Visit Monster Charging's Shanghai scrap disposal center, shoot videos of the disassembly assembly line, and verify data consistency.
4.3.3 Analytical framework
Adopting the case study logic of Yin (2014), the "strategy - behavior - performance" analysis chain was constructed:
1) Operation strategy: High-density deployment vs. precise scheduling affects the usage intensity and wear rate of equipment.
2) Management behavior: Preventive maintenance (regular battery inspection vs. replacement after failure), determining the equipment life cycle;
3) Environmental performance: Quantify the differences in carbon footprint and waste reduction under different strategies through the LCA model to identify the optimal practice path.

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### 4.4 Quality Control and Research Reliability Assurance

4.4.1 Data cleaning and calibration

Abnormal data with an average daily usage frequency of more than 20 times (accounting for 0.3%, mostly test equipment) were eliminated, and the multiple interpolation method (m=5) was adopted to handle missing values.

By comparing the equipment scrapping records of enterprises with the reasons for scrapping in user surveys, the scrapping rate parameters are calibrated to ensure data consistency.

4.4.2 Endogenous treatment

Regarding the issue that "there may be bidirectional causality between utilization rate and equipment lifespan", the density of urban subway stations was adopted as the instrumental variable (IV). This variable was significantly positively correlated with the utilization rate ($\rho=0.62$, $p<0.01$), but had no direct correlation with equipment lifespan.

The fixed effects model controls the characteristics of a city that do not change over time (such as industrial structure and consumption habits), reducing the bias of omitted variables.

4.4.3 Robustness test

Change the survival model settings (such as the Weibull model), and compare the coefficient signs with significance;

Divide the regions (South/North) and distinguish enterprises (Monster/Meituan) for sub-sample analysis to verify the universality of the conclusion;

The standard error is estimated by using Bootstrap sampling (1000 times) to ensure parameter stability.

### 4.5 Research Ethics and Limitations

The research strictly adheres to academic ethics, namely: anonymizing user data, signing confidentiality agreements for enterprise data, and the plan complies with the review standards of the university ethics committee (Approval No.: 2022-LW-045). Limitations include:

1) The sample enterprises do not cover small and medium-sized operators, which may underestimate the impact of the long-tail market.

2) The iteration of fast charging technology may change the expected lifespan of the equipment, and the parameters need to be updated dynamically in subsequent research.

3) There is recall bias in the user's self-reported data. The error can be reduced through cross-validation of enterprise data.

### 4.6 Summary of Research Methods

In this study, a hybrid research method system was first constructed, and then through the micro-data of enterprises, the inherent laws of equipment usage and scrapping were revealed. Then, the environmental benefits are quantified by means of econometric models, and the influence mechanism of differentiated strategies is analyzed through case studies. Such multi-dimensional and cross-level research design not only provides a methodology for the environmental impact assessment of shared power banks, but also offers empirical support for the "preventive reduction" strategy in the management of electronic waste.

Subsequent research can further incorporate blockchain technology to track the entire life cycle of material flow, or expand to other small electronic devices such as shared headphones and shared laptops, to deepen the research on the sustainability of the sharing economy.

## 5. Discussion and Policy Recommendations

The environmental benefits of the shared power bank application model are not automatically formed but are deeply constrained by multiple factors such as usage efficiency, operation and maintenance quality, and equipment recycling system. Based on the aforementioned analysis, the following discussion will be conducted from three aspects: business practice, policy framework, and user behavior, and corresponding optimization paths will be proposed.

### 5.1 Direction of Business Model Optimization

5.1.1 Shift from "leasing" to "high-frequency services" and reconstruct the profit logic

At present, the mainstream shared power bank enterprises rely on the profit model of "hourly billing + point commission". In most cities, the devices are frequently covered but the single usage is insufficient, resulting in a high idle rate of some devices. According to the research, in third-tier and lower cities, nearly 30% of the equipment is used less than twice a day. This not only reduces the intensity of equipment usage but also weakens the role of shared resource conservation at the environmental level. Based on this, it is suggested that the platform adjust the placement density and pricing strategy,

promote the "high frequency and low price" mechanism, and enhance the utilization efficiency of individual devices through subscription systems, membership systems and other forms.

5.1.2 Design for product maintainability and recyclability

At present, in most shared power banks, the design of the equipment still mainly focuses on "integration and convenience", with high difficulty in disassembly and low recycling efficiency. The lack of recyclable or updatable designs directly affects its life cycle and recycling value.

Enterprises should gradually adopt green design standards, reserve maintenance and recycling interfaces in the product design stage, and improve the reuse rate of materials. For instance, replaceable batteries and detachable casings can be applied to reduce maintenance and scrapping costs. At the same time, a cooperation mechanism with professional recycling institutions should be established and a closed-loop management system should be set up.

### 5.2 Policy Design and Institutional Guidance

5.2.1 Be included in the list of green product incentives

At present, most shared power bank enterprises have not yet been included in the assessment system for green and low-carbon products. It is suggested that the competent government departments include high-efficiency shared electronic devices in the "Green Product List" and the "Procurement List of Energy-saving and Environmental Protection Products", and provide support such as tax reduction and exemption, green credit, and priority in government procurement. Clarifying the environmental value of the sharing model at the institutional level can help guide capital into sustainable sharing industries and encourage enterprises to compete in a healthy environmental dimension.

5.2.2 Establish a "mandatory recycling + recycling responsibility" mechanism for shared equipment

At present, most shared devices do not fall within the scope stipulated in the "Regulations on the Recycling and Disposal of Waste Electrical and Electronic Products". Enterprises mostly adopt the "self-disposal" approach for waste devices, lacking external supervision. It is suggested that, drawing on the regulatory experience of electric bicycles and battery products, the "Guidelines for the Recycling Responsibility of Shared Electronic Devices" be issued, requiring:

Clarify the obligation of enterprises to report the recycling and scrapping of offline equipment. Set the minimum recovery rate of the equipment (such as 60%);

Promote the establishment of third-party recycling platforms to centrally handle shared electronic waste.

### 5.3 User Behavior Guidance Mechanism

The utilization efficiency of shared devices is ultimately determined by user behavior. Therefore, the platform needs to guide users towards a green usage path from the following aspects:

5.3.1 Information Disclosure and Green Guidance

Add a "Carbon reduction Points" prompt in the device's APP interface and usage records, for example: prompt "You have saved 0.06kg of carbon emissions compared to the self-purchased device this time", to enhance environmental awareness.

In addition, a "green User rating" system can be established to offer incentives such as points rewards and fee reductions to users with high usage frequency and timely returns.

5.3.2 Reduce the behaviors of "impulsive use" and "excessive circulation"

The convenience of "borrowing and returning at will" for shared devices has instead led to wasteful behavior of "borrowing from multiple points and using them unnecessarily" among some users. The platform can set a minimum billing duration or cross-point borrowing and returning restrictions to prevent excessive wear and tear on the equipment caused by "use once and return".

At the same time, promote integrated borrowing and returning package services (such as "monthly fee for borrowing within 2 hours"), reduce unnecessary circulation paths for equipment, and improve the efficiency of resource utilization.

## 6. Conclusions and Prospects

This study takes shared power banks as the entry point, systematically examines the intrinsic relationship between the usage rate of shared power banks and the reduction of electronic waste, and uses methods such as negative

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binomial regression model, material flow analysis (MFA), and life cycle assessment (LCA) to construct a three-dimensional analysis framework of "usage intensity - equipment life - environmental benefits", and draws key conclusions.

### 6.1 Main Findings of the Research

1) The sharing mode enhances the efficiency of equipment usage

2) Shared power banks have realized the logic of "multiple people sharing one device", effectively reducing the total demand for devices at the social level. Preliminary estimates indicate that the shared model across the country could reduce the annual demand for 460 million power banks, corresponding to a potential reduction of approximately 1.6 million tons of electronic waste.

3) The frequency of equipment usage and its lifespan show an inverted U-shaped nonlinear relationship

4) The regression model shows that the lifespan of equipment varies with the frequency of use in a trend of "first increasing and then decreasing": too low a frequency leads to an increase in idle wear, while too high a frequency causes overload wear. Empirical evidence shows that an average daily usage frequency of around 5 times is the optimal range. At this point, the equipment's life cycle can reach over 17 months, and the carbon footprint and usage cost are optimal. This discovery provides a quantitative basis for the platform's decision-making in terms of placement strategies, pricing mechanisms, and operation and maintenance frequencies.

5) The environmental benefits of the sharing model have scale prerequisites and management boundaries

6) When the average daily usage frequency of shared equipment reaches a certain critical value (5 times per day) and has a relatively high recovery rate (>60%), its carbon emissions per unit service are significantly lower than those of traditional equipment. Otherwise, it may instead lead to an increase in carbon emissions due to frequent maintenance, short-cycle scrapping and other issues. Therefore, the environmental advantages of the sharing economy do not manifest naturally but need to be guaranteed through corporate governance and institutional design.

7) The sharing economy builds a new path for the "right to use instead of ownership" of electronic products

8) The demand for using mobile power banks is essentially temporary, and ownership is not necessary. The sharing economy effectively guides consumers to shift from "owning devices" to "on-demand services" by reconfiguring the "usage logic".

### 6.2 Existing Research Deficiencies

1) The acquisition of enterprise data is restricted by business privacy: Some key variables (such as the disposal method of equipment after recycling and the actual scrapping rate) still rely on estimation or indirect derivation, which may affect the final accuracy.

2) User research data has recall bias and urban representativeness limitations: Users still have recall bias regarding the usage frequency and purchasing behavior of self-purchased devices. Meanwhile, some peripheral cities were not included, which may affect the representativeness of the national estimation.

3) Rapid technological changes pose challenges to the assessment of the device life cycle: The update speed of power banks has significantly accelerated, but the data based on the research is still based on the mainstream models in 2023-2024. If technological changes accelerate in the future, both the device life cycle and the degree of user dependence may undergo significant changes, thereby affecting the carbon emission path of the sharing model.

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