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Research on union mode of e-waste reverse logistics in China

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RESEARCH ON UNION MODE OF E-WASTE REVERSE LOGISTICS IN CHINA

By

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China

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Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me,

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Research on Union Mode of E-waste Reverse Logistics in China**

Degree: **MSc in International Transportation and Logistics**

A high speed of technology development improves the mass production, shortened the cycle of renovation and increased the structure of consumption. Consequently, the replacement speed of electronic products and quantity of electronic waste are increasing. And the attendant problems have become increasingly prominent - the increasingly serious energy crisis, energy shortage, the deterioration of the ecological environment. It is extremely critical to deal with it. Although developed country's successful experience and theoretical analysis tell us that reverse logistics can effectively deal with the problem of electronic waste, we should search for an appropriate operational mode in China.

To develop reverse logistics for electronic waste in China, I urge the Union Mode in which manufacturer, third-party logistics, and retailers cooperate with each other. In Chapter 3, I firstly analyze the three traditional operational modes of reverse logistics based on the characteristics of electronic wastes. And then, in Chapter 4, I prove the feasibility of Union Mode through studying value chain and transaction cost theory and mathematical calculation. In Chapter 5, I will discuss the construction of Union Mode in the respect of organization alliance and flows design.

KEY WORDS: Electronic Waste Reverse Logistics, Union Mode, Value Chain and Transaction Cost Theory, Construction of Union Mode.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RL	Reverse Logistics
E-waste	Electronic Waste
WEEE	Waste Electrical and Electronic Equipment
REVLOG	The European Working Group on Reverse Logistics
TPL	Third-party Logistics
TPRL	Third-party Reverse Logistics
TPT	Third-party Take-back
RT	Retailer Take-back
MT	Manufacturer Take-back
GM	General Motor Corporation
IBM	International Business Machine
3M	Minnesota Mining and Manufacturing
EPR	Extended Producer Responsibility

1. Introduction

1.1 Background

With the improvement of human living standards, high population expansion, unlimited growth of consumption, humanity have to use modern means of natural resources to meet the urgent needs of social development. And the attendant problems have become increasingly prominent - the increasingly serious energy crisis, energy shortage, the deterioration of the ecological environment. How to change this situation and sustain the economic stability and development? The industrial countries in practice find an effective way to solve this problem. This way is to develop and utilize the renewable resources and establish mechanisms for recycling resources resulting from consumers to producers. To achieve circular economy and sustainable development, the reverse logistics is widespread concern in recent years.

Previously, there ware no relevant legislations mandating corporation to recycle the product that have been end of their life cycle. And the rate of the return product was low. Therefore, people paid a little attention to RL. However, the increasing resource depletion prompted enterprises to think about a new concept of recycle to replace “only once use” concept. And the development of e-commerce and direct sale network brought high rate of return products and the raising the requirement of no-reason return from customers. These realities make enterprises more attention to

the research and development of reverse logistics.

After experiencing the “mass production, mass consumption, and mass abandoned”, the developed country has the growing emphasis on circular industry and economy. And relevant legislation came into effort. There are several reasons of development of RL. Many developed countries order manufacturer to be responsible for the while life of the product through related mandatory legislations. Manufacturers are required to recycle the products and packages, which promote manufacturers to attach importance to building the RL. Otherwise, company without the development of RL will lost lots of customers. Because, nowadays, citizens have stronger awareness of environmental protection and safeguarding legal rights and interests. Lastly, RL create substantial profit. Some experts described the RL may be the last virgin land of profit.

And we can see that developed country’s practices show that successful RL will bring the following benefit: improving the level of customer service, enhancing the conference of customers, lowering the cost of purchasing of raw material, amending the environment, promoting the image of corporate, improving the design of product, increasing the quality of product, etc. For example, Estee Lauder, GM, IBM, 3M, Sears, and Johnson & Johnson have gained the benefits from the mentioned above.

1.2 Literature Review

Dr. Stock J R is the one of the earliest scholars to research on reverse logistics. He and Lambert gave us his first definition of RL in 1981. This definition is also one of the earliest discussions of the RL. They defined RL as "going the wrong way on a one-way street because the great majority of product shipments flow in one

direction" (Lambert and Stock, 1981, pp. 19). 1992, Dr. Stock described RL in *Reverse Logistics: White Paper* as a process of logistics activities which contains return of product, material of replacement, reusing of goods, treatment of waste, re-treatment, maintenance and re-manufacturing. 1998, Reverse logistics has been defined as“...the term most often used to refer to the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal, and refurbishing, repair and remanufacturing.”(Stock J R, 1998, p6)

In *Reverse Logistics: A Second Chance to Profit*, *Reverse Logistics as Competitive Strategy*, and *Reverse Logistics Strategy for Product*, Andle (1997), Mrien (1998) and Klausner(2000) respectively considered that reverse logistics is a strategy that can bring economic benefit and competitive advantages to enterprises. In *Environmentally Responsible Logistics System*, Wu and Dunn (1995) put forward reverse logistics is an effective method of environmental protection. Henceforward, some scholars discussed deeply the reverse logistics system design and process management, for example, Realff and Ammons (2000) discussed these in *Strategic Design of Reverse Production System.*

With the development of studying on reverse logistics, scholars began to discuss how to achieve recycle materials and re-processing products through reverse logistics. The representative studies of re-processing and recycle parts and materials are listed in the following table.

Table 1: Representative Study of Re-processing and Recycle of Reverse Logistics

Content of research	Representative Study
Re-processing Products	Krikke and other scholars studied on the re-processing of Xerox machine. They analyzed some factors related to transportation cost and other operation costs in 1999.
	De Koster has a research on re-processing of "White Products" (washing machine and refrigerator) and "Brown Product" (TV-set, Xerox machine, and fax) in 2001.
	Jayaraman (1997) analyzed the reverse logistics network of electronic equipment garage in U.S. He discussed the investment, transportation and operation costs of this network of reverse logistics.
	Jade Lee studied the OEM (Original Equipment Manufacturer) problems of cost and management from the manufacturer's view. And he pointed out the importance of reverse logistics construction by manufacturers.
Recycle Parts and Materials	Van Burik designed a plan of motor vehicle recycle in 1998. He suggested that customer should pay a certain expense used for future recycle and treatment. And some reusable parts and materials can be collected and reused.
	In 1997, Spengler researched the recycle of steel and building materials' by-products in Germany and he gave a circular scheme.

The Electronic Waste Recycling Act of 2003 was signed into law in September 2003 in California, which aim to reduce the use of hazardous materials in some electronic products sold in the state. July 1st 2007, The Waste Electrical and Electronic Equipment Regulation (2006) came into effect. This regulation "imposes the responsibility for the disposal of WEEE on the manufacturers of such equipment." "And those companies should establish an infrastructure for collecting WEEE, in such a way that 'Users of electrical and electronic equipment from private households should have the possibility of returning WEEE at least free of charge'. Also, the companies are compelled to use the collected waste in an ecological-friendly manner, either by ecological disposal or by reuse/refurbishment of the collected WEEE."

(FromWWW:http://en.wikipedia.org/wiki/Waste_Electrical_and_Electronic_Equipment_Directive)

From these regulations, we can see that developed countries have paid more attention to the problem of electronic waste. And they give manufacturers a legal obligation to deal with it. So manufacturers invested in electronic waste reverse logistics. Some famous enterprises established special department to control reverse logistics actions, such as IBM (Ed Grenchus, Shirley Johnson, and Dan McDonnell, p.236-240). And these manufacturers gain the economic and social benefits from reverse logistics.

In China, many scholars began to research on the electronic waste reverse logistics. Zhangli (2006), in *Study on the Reverse Logistics System for the Waste Household Appliances and Electronic Products in Qingdao*, analyzed the current situation and problems of e-waste reverse logistics system in Qingdao. And he provided some reasonable suggestions to electronic products manufacturers. Many experts discussed and analyzed operation modes of electronic waste reverse logistics in recent years. For example, *Research on Operation Modes of Reverse Logistics for Electronic Product*, *Research on System of Reverse Logistics Transportation for Waste Household Appliances*, *Research on Reverse Logistics for the Recycling of WEEE*, *The Research on Reverse Logistics Model Decision-making Based on the End of Life Electronic Products*, authored by Yang Yongchao (2006), Chen Yangdong (2007), Han Xuebing (2005), Yang Xiaoping (2006) respectively. They discussed the common operational modes of reverse logistics for electronic products, which are Self-Supporting Mode, Outsourcing Mode and Union Mode. At same time, these papers put forward some suggestions of revere logistics network construction for electronic products.

However, majority authors elaborated the main traditional operational modes of reverse logistics based on forward logistics. They think about the characteristics of

electronic products and reverse logistics less enough when they analyzed the operational modes. And the current situation of electronic manufacturer and logistics industry are not considered fully. Therefore, majority authors didn't provide a reasonable operational mode for electronic waste reverse logistics.

1.3 Objective of Dissertation

As a developing country, China produces and consumes enormous electronic products, which give great pressure to the environment and resources. In order to complete the sustainable development of China and even world economy, we need urgently a development of electronic waste reverse logistics. How to choose the most suitable mode to develop this industry in China? Reverse logistics has been carried out for a short time in developed counties. However, in China, reverse logistics just begin to attract scholars' attention.

The objective of this paper is to find out the most suitable mode to develop electronic waste reverse logistics in China through theoretical analysis and mathematical calculation. At the same time, construction of Union Mode will be discussed later.

1.4 The Framework and Content of Dissertation

This paper introduces the basic concepts and characteristics of electronic waste reverse logistics. In addition, the chapter 3, 4 and 5 are the focal points in this paper.
To complete the objective of the dissertation, this paper will focus on the following main issues:

- Research on the feasibility of e-waste reverse logistics development.
- Analysis of Self-Supporting Mode, Outsourcing Mode and Union Mode.
- Analyze the Union Mode by value chain and transaction cost theory.

- Utilize mathematical calculation to prove Union Mode
- Construct the organization alliance in Union Mode
- Design the flow of Union Mode

2 Theoretical Analysis of E-waste Reverse Logistics

2.1 Forward Logistics, Reverse Logistics, and E-waste Reverse Logistics

2.1.1 Forward Logistics and Reverse Logistics

Logistics is not new ideas. Logistics is “the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfillment orders”. (Martim Christopher, 2005, pp4). In this definition, materials, production and information transfer by forward flow. When they are building their logistics system, many manufacturers always think over a series of activities that include raw materials purchasing, manufacturing support, physical delivery, and meet customers’ need. They transfer the various materials in forward flow step by step. In such a logistics system, the products left the logistics system once they reach the customers. The return and the used products are less considered, not even considered.

However, more and more enterprises adopted liberal return policies to face the intensification of competition, which brings an increasingly serious problem of return in original logistics system. At the same time, with the enhancement of people’s awareness of environmental protection, people pay more attention to waste materials reclaim. To deal with all of these problems, development of reverse logistics is

necessary.

The European Working Group on Reverse Logistics (REVLOG) uses the following definition: The research area of Reverse Logistics covers “the process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal.”(De Brito and Dekker,2004)

And Stock, James R. (1998) defined the reverse logistics as “… the term most often used to refer to the role of logistics in product return, source reduction, recycling, materials substitution, reuse of materials, waste disposal, and refurbishing, repair and remanufacturing.”

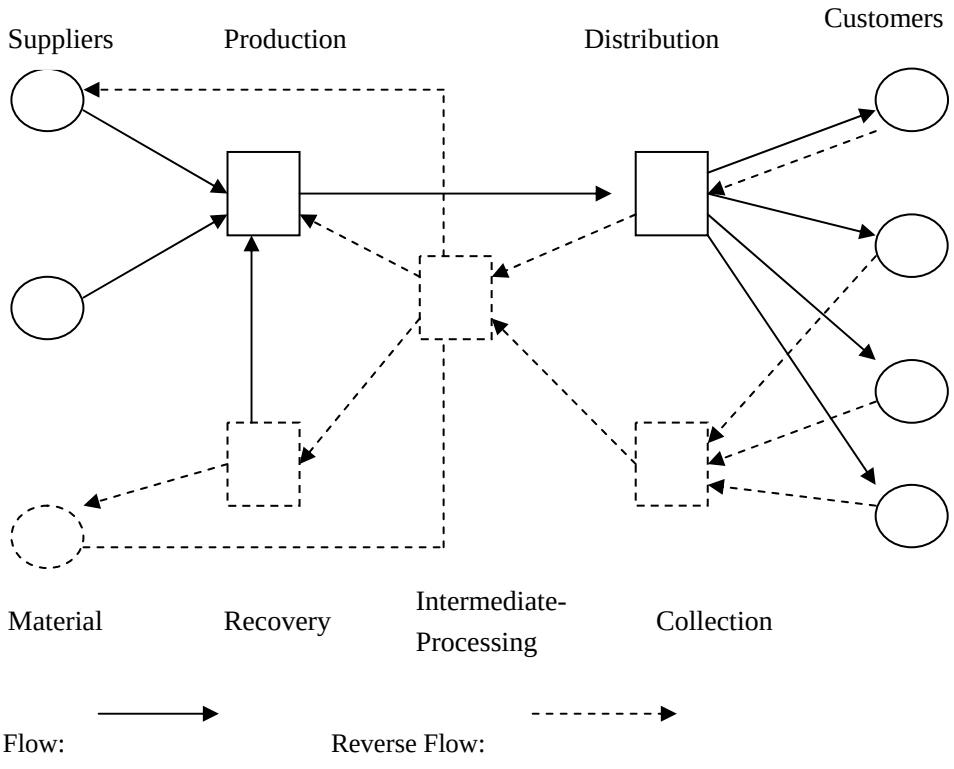

Figure 2-1: A Framework of Logistics System with Reverse Flows

Source: Zhiqiang Lu, Nathalie Bostel and Pierre Dejax.(2006). Simple Plant Location Problem with

Reverse Flows. Supply Chain Optimization. P151-166.

To understand reverse logistics better, the differences between forward logistics and reverse logistics are listed in following table.

Table 2-1: The Differences between Forward and Reverse Logistics

Differences Between Forward and Reverse Logistics	
Forward Logistics	Reverse Logistics
Forecasting relatively straightforward	Forecasting more difficult
One to many distribution points	Many to one distribution point
Product quality uniform	Product quality not uniform
Product packaging uniform	Product packaging often damaged
Destination / routing clear	Destination / routing unclear
Disposition options clear	Disposition not clear
Pricing relatively uniform	Pricing dependent on many factors
Importance of speed recognized	Speed often not considered a priority
Forward distribution costs easily visible	Reverse costs less directly visible
Inventory management consistent	Inventory management not consistent
Product life cycle manageable	Product life cycle issues by several factors
Negotiation between parties straightforward	Negotiation complicated by several factors
Marketing methods well known	Marketing complicated by several factors
Visibility of process more transparent	Visibility of process less transparent

Source: http://www.rlec.org/

We can understand the reverse logistics from broad and narrow perspectives. Broadly speaking, reverse logistics represents all of the interrelated operations of products and materials, management of operation and reclaim, which relate to reprocessing and re-polished and other activities. And reverse logistics is not just the reuse the packaging and containers to recycling. It also includes re-design the packages in order to reduce use of raw materials and consumption of energy during transportation and other important activities. Reverse logistics also deal with the return that be

caused by damage, seasonal inventory and excessive stock and so on. The recycling and hazardous material plan, disposal of obsolete equipment and resources recycling are also the part of reverse logistics broadly.

Narrowly speaking, reverse logistics is defined as a process. The dynamic chain from the customer to original output will be efficiently planned, implemented and controlled. And the related information, such as raw materials, inventory and finished products, will flow smoothly. In this paper, I study of e-waste product reverse logistics in a narrow sense, and the e-waste product is limited in discarded electronic products by first-hand customers. The return and recall from customers for the problem of quality and are not the object of this dissertation.

2.1.2 E-waste Reverse Logistics

E-waste reverse logistics is that the object of reverse logistics is electronic waste. All operation of reverse logistics aims to electronic waste business. E-waste reverse logistics refers to effectively plan, implement and control the process of recycling, testing, sorting, transportation, inventory, and reprocessing of e-waste to achieve minimizing logistics costs, reduce environmental pollution, recycle the parts and components of e-waste.

To understand e-waste reverse logistics better, definition and characteristics of e-waste is necessary to be discussed.

2.1.2.1 Definition and Characteristics of Electronic Waste

Electrical and electronic equipment “means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment

for the generation, transfer and measurement of such currents and fields falling under the categories set out in Schedule 1 to these Regulations and designed for use with a voltage rating not exceeding 1,000 volts for alternating current and 1,500 volts for direct current". (The Waste Electrical and Electronic Equipment Regulations 2006 (2006)).

Waste electrical and electronic equipment means "electrical or electronic equipment which is waste … including all components, subassemblies and consumables which are part of the product at the time of discarding. (The Waste Electrical and Electronic Equipment Regulations 2006 (2006))

"Electronic waste (e-waste) or 'Waste Electrical and Electronic Equipment' is a waste type consisting of any broken or unwanted electrical and electronic device. 'Electronic waste' includes all secondary computers, entertainment devices electronic, mobile phones and other items, whether they have been sold, donated, or discarded by their original owner. This definition includes used electronics which are destined for reuse, resale, salvage, recycling or disposal."
(From WWW:http://en.wikipedia.org/wiki/Electronic_waste)

According to the definition of electrical and electronic equipment in the above regulation, electronic products are widely used, may cause serious pollution, have high value of recovery, and will be recycled by state legislation. These e-waste products include household electric appliances, personal computers, mobile phones, cameras, etc. These electronic wastes are collected form private, commercial, industrial and institutional households. And, in this paper, e-waste products are limited in the range of used and abandoned by first-hand customers, which includes end-of-life electronic products and reusable end-of-use electronic products that

replaced by new products before useful life.

The industrial electrical and electronic products, such as Radar, electronic medical instruments, have strong characteristics of special and technical confidentiality and are destroyed by manufacturers strictly in confidence. Therefore, the industrial electrical and electronic products are not this dissertation's object.

E-waste product is a special kind of waste or garbage. Electronic product is a comprehensive industrial product that is composed by metals, plastics and chemical materials, and other materials. The scrap of electronic products should be listed in the range of poisonous, explosive and easy leakage of hazardous waste areas. Compared to the general waste or garbage, e-waste products have not only the common characteristics but also own peculiarities. E-waste product has obvious dual nature of potential environmental harmfulness and renewable resources. The mainly characteristics of e-waste are listed as following.

1. Nature of high reusable value

According to the research, the typical e-waste product is composed by metals, plastic and oxidizing materials. Although e-waste products contain large number of toxic and harmful substances, it also contains a lot of recyclable non-ferrous metal, ferrous metal, plastic, glass and some other valuable parts. E-waste product has higher recyclable value. Renewable resources with high purity can been separated from used refrigerator, air-conditioner, washing-machine, computer, mobile-phone and other electronic products, such as Iron, Copper, Gold, Tin, Steel, Aluminum, Lead. It is important for China that is deficient in resources and has large number of population to reuse these resources. According to scholars' study, the value of one tons e-waste products that are reclaimed and reused fully is about ten thousand dollar.

Circular using has great strategic significance, which promotes sustainable economy development, society, resources and the environment.

2. Nature of pollution and harmfulness

E-waste product would pollute environment and endanger Human, if it was maxed with city waste and burned directly without necessary protective measures. For example, CFE-12 and CFC-11 in refrigerator is poisonous substances that would arouse the destruction of ozone layer. TV image tube is explosive items, the Lead and waste lubricating oil in screen can produce pollution. Waste circuit boards will contaminate water and soil seriously. At the same time, the poisonous heavy metals that are included in e-waste products will be detained in eco-system once they enter into environment. And these poisonous heavy metals will enter the body through various channels at any time, which bring great threat to human health. Therefore, e-waste product would lead to harm to the ecology if it was treated by unsuitable disposal methods. In view of this, e-waste product has been listed in special category that needs hazardous waste management.

“Basel Convention” has listed the waste computer and electronic equipment in the item of dangerous waste. E-waste product contains lots of hazardous substances that are prohibited from crossing the boundary movement. In 2004, an non-profit organization “Silicon Valley Toxic Substances Alliance” estimated that there were about 500 million kilogram Lead, 0.9 million kilogram Cadmium, 0.18 million Mercury and 0.54 million kilogram Chromium in 315 million obsolete computers in U.S.A. These computers would bring incalculable damage to ecology, if these were not handled through proper methods.

3. Nature of difficult treatment

To convert the e-waste product into resource, the advanced technology, equipment and a higher investment are necessary. The components of e-waste are complex and the life cycle of electronic products are different, or for decades, or just only for once. All of these bring considerable difficulties to recycle and reuse. The rate of recycle is much lower than that of city waste. The reason of the lower rate of recycle is mainly the difficulties of reclaim and disposal. The components, materials, structure principle of different electronic products that designed and produced by various manufacturers are very different. These differences between electronic products bring huge challenge and difficult to e-waste recycle operation.

4. High growth of e-waste products

With the rapidly increasing level of electronic technology and social demand of the new electronic products, the speed of discard and eliminate is faster. And the e-waste products increase by 16% to 28% every year that it is three faster than common solid waste. In recent years, the number of consumption of mobile phone surge. Some related departments estimated that the social maintain of refrigerators, washing-machines, TV set and computers are about 120 million, 170 million, 400 million and 16 million respectively. A considerable portion of these appliances that are used from the late 1980s and the early 1990s has spent the vast of majority of the period.

2.1.2.2 Unique Characteristics of E-waste Reverse Logistics

E-waste reverse logistics is a special kind of reverse logistics, so it still hold some general characteristics of reverse logistics. And these natures of e-waste reverse

logistics have been noted when I discussed difference between forward logistics and reverse logistics. But the e-waste reverse logistics holds some unique characteristics because of its special object --- electronic wastes. Electronic waste has nature of pollution and high reusable value, so e-waste reveres logistics hold some unique characteristics.

1. Strong social characteristics

With the development of technology and national and international economy, customers have increasing requirements of electronic products' multiformity and personality. So the life of electronic products is shorter, the rate of updated is faster and the quantity of electronic waste is larger and larger. And the electronic waste can seriously affect society. For example, they will pollute weak environment, occupy the limited land to store. So this is not a personal business. Fortunately, people constantly enhance the awareness of environmental protection and environmental regulations are increasingly perfected.

2. High recycle value

Electronic products are generally of high-end product with advanced technology, and the life of these is shorter than ordinary household goods' life. So the parts and materials of e-waste are still in a good condition. At the same time, such electronic product is composed of high-end metal, precious metals and high value-added components, which will produce a lot of reusable materials with high value-added. And this is one of main purposes of e-waste reverse logistics.

3. Complex treatment

Firstly, the whole process of e-waste reverse logistics is divided into four major steps that are recycling, delivery, storage, disassembly and disposal. All of these steps embody the economic, ecological, technical and social factors. We have to coordinate

these four steps to ensure e-waste reverse logistics to operate well. Secondly, the operations of reverse logistics, such as repackage and reprocessing, are more complex than general manufacturing. Before testing, the treatments of e-waste are unknown by comparison with the traditional manufacturing. Different states of e-waste demand different operation time, quantity of materials and components, which brings more risk of operation and cost management. Thirdly, the quantity of e-waste reverse logistics is difficult to forecast. From the individual customers' micro point of view, the recycling process of e-waste reverse logistics is not continuity. And the decision factors of reverse logistics are collected by qualitative and quantitative indicators, so the quantitative forecast models cannot solve the problem wholly.

4. Slow Economic return

Most of e-wastes collected are used by materials for reprocessing, which is derived demand. This derived demand of reusable material is an indirect demand, so the period of economic return is long. Forward logistics can achieve rapid value-added in links of packaging, transportation, distributing and storage, however the e-waste reverse logistics cannot. At present, manufacturers don't pay enough attention to this area and the quality and quantity of e-waste are not ascertained easily, which increase the risk especially at the initial stage. Besides, e-waste distributed in the community of different consumers, and e-wastes are produced in every day continuously. All of these increase relatively the cost of recycle, lengthen the period of economic return.

2.2 The Feasibility of E-waste Reverse Logistics Development

At present, China has become the world's largest production and consumption of electrical and electronic products. Millions of tons of electrical and electronic products will be abandoned and replaced. Therefore, the problem of recycling and

disposal of e-waste is quite prominent. It is time to develop the e-waste reverse logistics. At the same time, China, especially in Shanghai, has held the basic condition to development of e-waste reverse logistics.

Development of e-waste reverse logistics has not only great theoretical significance and practical significance, but also is feasible in current situation.

2.2.1 The Commercial Potential of E-waste Reverse Logistics

Recycling and processing of e-waste contains a great deal of business benefits. In the United States, European, Japan and other developed countries, many companies and individuals have gained a lot of business interests by investing this industry. And more and more foreign and domestic investors aim to China's huge market. According to research reports, e-waste is rich in recoverable resources, including metals, plastics, glass, etc. Certain Japan metal company analyzed the components of waste mobile phone and found that average 100 grams of waste mobile phone contains 14 grams of Copper, 019 grams of Silver, 0.03 grams of Gold and 0.01 grams of Palladium. In addition, the Lithium battery of mobile phone can be recovered Lithium. Denmark expert separated 286 pounds of Copper, 1 pound of Gold, 44 pounds of Tin from one ton of random collection of the electronic boards. And the value of 1 pound Gold is $6000.

Government, enterprises and society are enthusiastic about developing the e-waste reverse logistics for the huge potential commercial profits. In terms of policy and tax, the e-waste recycling and processing industry will be given some preferential treatment. Besides the stable supply of e-waste and potential business profits guarantee the investment return.

2.2.2 Increasing Number of E-waste Requires E-waste Reverse Logistics

The base of China's population is huge, and China is the largest consumption country of electrical and electronic products. With the improvement of life quality and aging of the electronic products, there is increasing number of electronic products eliminated. We can see the follow table. This table gives us some information on electronic products production, consumption and discarded in Shanghai.

Table 2-2: Forecast of Main Electronic Products Sales in Shanghai (2008-2012)

Forecast of Main Electronic Products Sales (2008-2012)									Unit: Million
Year	camera	TV set	Washing Machine	Air Conditioner	Video camera	Refrigerator	Micro -wave oven	PC	Mobile Phone
2008	48.82	177.39	86.43	198.49	11.72	78.67	91.37	28.19	305.43
2009	52.49	195.34	97.04	239.95	14.56	87.34	102.18	30.68	342.9
2010	56.79	215.29	107.9	290.07	17.9	97.13	114.27	33.29	380.38
2011								36.23	417.86
2012									455.34

Source: Wang xi. (2007). Study on the Recycling Network System of Waste Electrical and Electronic Equipment Based on GIS in Shanghai. Unpublished PhD.Dissertation, East China Normal University, Shanghai, China.

From the above table, we can see that the sales of main electronic products in Shanghai are still increasing. For example, the sales of mobile phone in 2012 are 1.5 times as much as that in 2008. The electronic products sales are the base of the forecast of electronic waste. So we can forecast that the number of e-waste is larger and larger. To gain the relative accurate forecast, the service lives of various electronic products and percent per year of discarded electronic products have been formed. As showed in the following table.

Table 2-3: Service Life and Waste Percent per year Of Main Electronic Products in Shanghai

	camera	TV set	Washing Machine	Air Conditioner	Video camera	Refrigerator	Micro-wave oven	PC	Mobile Phone
Service Life	6-8	8-12	12	8-10	7	13-16	11	6	3-5
Percentage of Waste(%,years)	15(6)	10(8)	15(11)	10(8)	10(6)	5(12)	10(10)	15(5)	15(3)
	25(7)	15(9)	40(12)	15(9)	45(7)	15(13)	35(11)	40(6)	35(4)
	35(8)	15(10)	35(13)	40(10)	35(8)	25(14)	40(12)	35(7)	45(5)
	25(9)	25(11)	10(14)	35(11)	10(9)	30(15)	15(13)	10(8)	5(6)
		35(12)				25(16)			

* 15(6) refers to 15 percent of camera will be discarded after using 6 years.

Source: Wang xi. (2007). Study on the Recycling Network System of Waste Electrical and Electronic Equipment Based on GIS in Shanghai. Unpublished PhD.Dissertation, East China Normal University, Shanghai, China.

According to the forecast of main electronic products, service lift and waste percent per year, the forecast of main e-waste can be calculated.

In below table, the number of waste mobile phone is largest whether in 2008 or 2015, which is 166.59 million and 471.20 million respectively. And the fastest speed of increase is the number of waste video camera from 2.58 million to 12.49 million, which is more than 4 times. We can conclude from these data that advanced small electronic item, such as video camera and mobile phone, has a shorter service life and faster rate of replacement. With popularization of small electronic products, the quantity of waste will increase faster and faster. At the same time, the components of these small electronic products have higher value of recycle. For example, the price

of lens of video camera is high and can be reused. Therefore, the e-waste reverse logistics face a huge space of business interest.

Table 2-4: Forecast of Main Electronic Waste in Shanghai

Year	2008	2009	2010	2011	2012	2013	2014	2015
Camera	32.07	35.48	38.66	41.69	45.00	48.71	53.04	57.84
Colour TV set	77.01	90.37	104.49	119.19	135.73	151.80	169.75	187.60
Washing Machine	36.59	40.06	45.54	49.85	51.90	55.80	63.20	70.73
Air-conditioner	57.72	61.88	65.01	72.00	83.60	104.34	131.61	157.97
Video Camera	2.58	3.28	4.21	5.34	6.55	8.08	10.05	12.49
Refrigerator	32.71	35.55	38.56	41.04	43.25	46.42	49.65	52.77
Micro-wave Oven	39.07	43.24	45.35	48.64	54.02	62.03	70.66	77.87
Personal Computer	19.45	22.00	24.19	26.69	29.90	33.48	37.17	41.07
Mobile Phone	166.59	208.99	247.71	293.55	337.96	382.24	426.71	471.20

Union: Million

Source: Wang xi. (2007). Study on the Recycling Network System of Waste Electrical and Electronic Equipment Based on GIS in Shanghai. Unpublished PhD.Dissertation, East China Normal University, Shanghai, China.

From the above analysis, the situation that the electronic waste production is far greater than the capacity of reprocessing manufactures is unable to change in recent decades. The increasing quantity of e-waste requires sound reverse logistics to deal with. And the enough large number of e-waste can ensure this system operate normally and gain the economy scale. Although these data are collected and analyzed in Shanghai, the e-waste situation of whole country can be reflected.

2.2.3 The Maturing Technology

As we all know, the electronic waste is a kind of complex waste. Dealing with the

e-waste requires advanced technology, skill and equipment. After nearly 10 years of continued study, experts gain the breakthrough evolvement in related technology. And some equipments and production process are researched and designed. In Europe, the United States, Japan and other developed countries, some companies have invested in this industry. These relative maturities of the technology and sound equipment provide the necessary technical support to development of e-waste reverse logistics.

2.2.4 The Benign External Conditions

Chinese government energetically supports to develop e-waste reverse logistics. “Regulations on Prevention of Electronic Waste Pollution” has been executed in February 1st, 2008. This regulation applies to prevent and cure the environmental pollution caused by dismantling, using and disposal of electronic waste in territory of China. This regulation’s purpose is to control environmental pollution from e-waste and strengthen the environmental management of e-waste, and this regulation is base on “Regulations on Prevention of Solid Waste Pollution”.

Under publicity of relevant departments and experts, residents accept a clear understanding of environmental awareness and improve their awareness. In the Han Xiaorong’s (2005) paper (From WWW: http://www.dfdaily.com/ReadNews.asp), we can read some exiting data. In her investigation, 60 percent of residents denote that they would return their electronic waste free if government set up special recycle bin. 38 percent of residents support wholly to ban the recycle guerilla, 51.3 percentage support to replace recycle guerilla with certain fee-based recycle. And 10.7 percent of residents express that they understand the government’s difficulties and support free recycle. Residents support the e-waste reverse logistics after realizing the harm

of improper disposition of e-waste.

2.3 Analysis of Current Situation of E-waste Reverse Logistics

With the update on the structure of consumption and faster replacement of electronic products, the number of discarded electronic products from individual families and businesses continuously increase. However, the operation of e-waste is not standardized. I visited a representative second-hand market, Qiujiang Road Marketplace, in Shanghai to understand the situation of e-waste recycles. Qiujiang Road is a famous operation and distribution center of old and used electronic products. Although this market begins to gain scale of operation, I still found the followed main problems.

Firstly, lack of regular recycle channel. All of the old and used electronic products are collected by “recycle guerrilla forces” that make rounds of streets and alley ways to buy the old and used products from residents. The collected old and used electronic products are not tested initially by this way of recycle, which leads to the second problem.

The second problem is that e-waste collected is not classified into different categories and quality level. The e-waste can be divided into used/old and scrapped electronic product. Used or old electronic products are in storage; using and lay idle and maintain part or all of the original value. This kind of e-waste can be sold in second-hand market. And the scrapped electronic products have reached the service life or cannot be used in safe condition before service life. This kind of e-waste cannot entry into second-hand market. However, in Qiujiang Road Marketplace, majority e-wastes are sold in second-hand market for lack of initial testing. The

dealers sell the e-waste without necessary classification through simple repair or re-assemble. In the field investigation, I found that the phenomenon of substituting shoddy goods for good cargo is common. Many e-wastes with new appearance are made up parts that have exceeded the time limitation. And the problem of insulation aging is serious. It is dangerous to sell scrapped electronic products to second-hand customers.

Thirdly, ultimate disposal is dangerous. Dealers take down the e-waste and select reusable parts firstly. They dispose directly some parts that can not be reused without necessary environmental protection measures. Although the advanced technology and equipment have been researched in developed countries, the dealers still use the backward still to treat the e-wastes. Most operations of treatment are completed by family workshops, which use simple physical methods, such as smashing, shear, water scrubbing, and chemical methods, such as burning, acid handling. These undeveloped methods' operation costs are lower. Therefore, primitive process and backward technology filed to achieve large-scale mechanized.

The fourth problem is lack of Effective Information Channel. Currently the information resources of e-waste recycle comes mainly from two aspects. The hawkers who make rounds of streets and alley ways and some small advertisements posed everywhere. In the absence of formal channels of information, the randomness of e-waste recycle is strong.

2.4 Conclusion

With the development of economy and technology, reverse logistics attracted more experts and enterprises attention. Electronic industry development brings increasing number of electronic wastes, which critically requires reverse logistics. Although

Current Situation of E-waste Reverse Logistics, at present, is unsatisfying, e-waste reverse logistics is still feasible in China. We should search a suitable operational mode to deal with the above problems of e-waste reverse logistics in China.

3 Research on Operational Modes of E-waste Reverse Logistics

As above analysis, e-waste reverse logistics is feasible and necessary. But how to operate it effectively in China is still a problem. In this chapter, the three traditional operational modes of e-waste RL will be discussed and the suitable mode will be selected for developing in China.

Firstly, in this paper, analysis focuses on operational modes of reverse logistics in which the manufacturer play a leading role. Because the manufacturers understand the composition of their own products and performance characteristics, which can easily put reusable parts and components disassembled sound into the process of reprocessing and reduce the cost of production and improve the rate of recycle. Besides, manufacturers know how to correctly handle remnants of the harmful ingredients. Therefore, manufacturers play an essential role in e-waste reverse logistics, and all operations are to satisfy the need of manufacturers' production.

Drawing lessons from forward logistics operational modes, there are three operational modes, which are Self-supporting Mode, Outsourcing Mode and Union Mode. These modes have own characteristics, so their scopes of applicable are different. According to the following analysis of operational modes respectively, I will choose the most applicable mode for Chinese e-waste reverse logistics.

3.1 Self-Supporting Mode

3.1.1 Definition of Self-Supporting Mode

Entire Self-Supporting Mode is that manufacturer establishes the independent network of e-waste recycling to achieve the product, components and raw materials reuse according to the regulations and the requirement of development. In this mode, manufacturer depends on own organization to achieve the links of recycling and recovery. Manufacturer has to consider building the network of e-waste reverse logistics that cover the whole sale regions to facilitate the recycle various items and transport them to reclaim and disposal center.

Manufacturer establishes own reverse logistics system, which internalize the external social cost. It is main form of EPR. EPR is Extended Producer Responsibility, which has proved to be effective in field of legislation and practice. EPR system requires manufacturer to take charge the recycle and reuse own products, which solve the problem of solid waste and can achieve sustainable development. Implementation of reverse logistics is not only a strategy of response regulation, but also a new growth of profit. Manufactures can understand the shortcomings of the production, and then improve the quality, increase the loyalty of customers, create a good corporate image and enhance the competitive advantages by using Self-Supporting Mode. In short, manufactures can gain more the first-hand information, such as the demand and suggestion of customers, to improve their reaction speed greatly and put them into the powerful advantage.

3.1.2 Advantages of Self-Supporting Mode

Control effectively all aspects of the supply chain and distribution channels.

Self-Supporting Mode has a stronger ability to let production cooperate with other operational areas closely, fully service in the manufacturer operation management to ensure manufacturer to gain long-term stable profits.

Rationally plan and manage the process. Self-Supporting Mode can reduce cost and improve the efficiency of logistics operation. For companies that are larger scale and single product, Self-Supporting Mode make the material flow, financial flow and information flow integrate more closely, which greatly increase all-around operational efficiency.

Strategic integrate purchasing, distribution and production. Self-Supporting Mode can achieve in-time purchase, increase the number of groups, reduce the batches, control inventory and improve the flow of capital, which help manufacturers to achieve zero inventory, distance and operation cost.

3.1.3 Applicability of Self-Supporting Mode

Although Self-Supporting Mode of e-waste reverse logistics has the above advantages, this mode can be utilized effectively in some enterprises that have some certain applicability.

E-waste product must have a certain scale of recycle. The effect of scale of reverse logistics regardless of collection to disposal is distinct. If the number of e-waste product was low and the scale was limit, the cost of operation would be higher and the degree of specialization would be lower. Some moderate and small manufactures with limited number of products that use Self-Supporting Mode cannot gain scale, and they will be unable to sustain the huge cost, even fill the high day-to-day running

cost. Therefore, Self-Supporting Mode would lead to high logistics cost and less product competitiveness when this mode used under unsuitable condition. On the other hand, the rate of recycle is the important decision factor of e-waste reverse logistics, but this rate in moderate and small manufacturers is low.

Manufacturer holds the necessary logistics capabilities. Enterprises must not only be familiar with the product mix and related processing technology, but also have the equipments used to e-waste processing and related logistics skill of construction of reverse logistics system. In the vast major manufacturers, the logistics sector is only a logistics department, and this department is not strength of the enterprises. Under such circumstances, development of Self-Supporting Mode is forcing the manufacturers to engage an unspecialized business activity. The management staff has to spend more time, energy and resources to do supporting work. As the result, supporting work is arrested and the key business cannot play a central role.

Manufacturer has strong financial strength. The establishment of reverse logistics not only requires a great investment in software and hardware, also the return period is relatively long. For example, investment in warehouse, transportation equipments and human resources increase the enterprise’s financial pressure and weaken the ability to withstand the market’s risks. And this additional investment must influence other important investment, particularly the investment in research and development, which will impact the core competitiveness of the enterprises.

Therefore, Self-Supporting Mode is suitable for some large manufacturers that have larger product and relatively high value of recycle. IBM, DELL, NEC etc. have established their own reverse logistics system and began to implement specific recycling business.

We can conclude from the above analysis that most Chinese electronic product manufacturers have not the conditions of development of Self-Supporting Mode. At present, Chinese electronic product manufacturers are struggling price war, and their profit is very limited. A certain electronic product may throughout the country, so effective tracking of sold products is difficult. Besides, with the development of second-hand electronics market, more and more e-waste that are washed out less of life of products inflow into a large number of secondary cities and rural areas, which bring bigger problem into collection of e-waste product. At the same time, manufacturers are also difficult to response timely for their requirement of e-waste recycle because of separate situation of consumers and secondary consumers. So the rate of recycle is not assured by Self-Supporting Mode of electronic manufacturers. Conclusions, Chinese electronic manufactures still have not enough strength to develop the Self-Supporting Mode of e-waste reverse logistics.

3.2 Outsourcing Mode

3.2.1 Definition of Outsourcing Mode

Outsourcing Mode e-waste reverse logistics refers to manufacturers entrust all of the links of e-waste recycle operation to professional reverse logistics supplier by agreement and paying the related freight. In this mode, the third-party reverse logistics is responsible for the implement of a series of manufacturers' reverse logistics operation. See the below Figure 3-1.

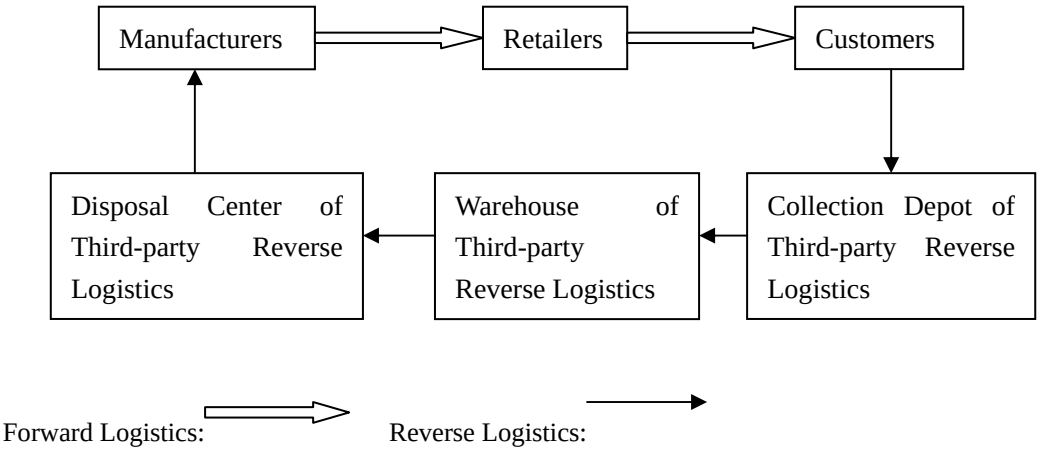

Figure 3-1: Sketch Map of Outsourcing Mode

Outsourcing is a trend of forward logistics development. Is it also a better choose for e-waste reverse logistics in China? Now study the Outsourcing Mode from e-waste reverse logistics view.

3.2.2 Advantages of Outsourcing Mode

There are many advantages of Outsourcing Mode of reverse logistics. Manufacturer can focus on main business, reduce the investment and financial risk, and increase the flexibility of development. Now, its main advantages are listed follow.

Third-party reverse logistics gain economy scale. It is not necessary for enterprises to invest in reverse logistics equipment and human resources, once they consign the reverse logistics operation to TPRL suppliers. TPRL suppliers with permission of service capacity can provide service to a number of enterprises at the same time to gain scale of management and operation. Compare with Self-Supporting Mode, Outsourcing Mode holds obvious advantages of scale. In the Self-Supporting Mode, the human resource, equipments, information system and so on may not be utilized

fully. However, Outsourcing Mode can achieve scale economy and improve the efficiency of related resource through integrating businesses.

Manufacturer can concentrate on the coral businesses. Manufacturer focuses on its core manufacturing business, once they entrust the reverse logistics operation to third-party reverse logistics company. For example, Xerox replace and upgrade thousands of office copiers every month, they commissioned these businesses to professional TPRL. They trained technicians from TPRL in skill of demolition and installation to ensure product to be operated without damages. And then, Xerox can put more attention to research and develop their core businesses by saving resources from reverse logistics operation. Xerox's decision of Outsourcing reverse logistics not only ameliorated customer service quality and customer satisfaction, but also reduced the company's fixed cost and indirect costs. The secondary important businesses are completed by paying commission to TPRL, and the technical staff can play more essential role in company's development.

Manufacturer gain amelioration suggestion from third-party. TPRL would give suggestions about product design, components of raw materials to facilitate their operation recycle and demolition etc. These suggestions help manufacturers to optimize the design of product. And the TPRL brings the feedback information from customers to the production enterpriser. Outsourcing Mode of e-waste reverse logistics has higher efficiency than Self-Supporting Mode.

3.2.3 Disadvantages of Outsourcing Mode

There are also risks in Outsourcing Mode. Firstly, enterprise, according to their own characteristics, always focuses on a particular area or a specialized business to form

their own advantages, which will lead enterprisers to concentrate limited resources on minority competitive businesses selected carefully. To concentrate on their core businesses operation, enterprise has to separate some secondary important businesses from the main businesses and entrusted them to third-party professional company. However, manufacturer must provide some design information, including raw materials product composition and structure design, to TPRL when they select the Outsourcing Mode. It is dangerous for some products of design products and confidentiality technology. There is risk of leakage. Secondly, at present, major reverse logistics suppliers developed from forward logistics by launching reverse logistics business. So the advantages of actual reverse logistics are the traditional transportation, inventory, packaging, and distribution business, not operations of recycle, testing, classification, and disassemble. Last and not least, TRRL easily cause material waste and environmental pollution.

Outsourcing Mode requires higher level of TPRL. To sort reusable parts and raw materials from e-waste products, the reverse logistics suppliers not only have a wide coverage recycling network, logistics equipments, and professional human resources, but also understand the relevant constitute principles and performance characteristics of electronic products and master the knowledge of disassembly. These requirements are not only too high for TPRL suppliers, also related to the confidentiality of production technology. Therefore, it is unrealistic for TPRL suppliers to operate all of activities of the e-waste reverse logistics at this stage.

3.3 Union Mode

According to above analysis, at present stage, the Self-Supporting Mode and Outsourcing Mode of e-waste reverse logistics, I concluded that these two modes are

not feasible for manufacturer to develop the e-waste reverse logistics in China. How to organize e-waste reverse logistics at present? I consider the Union Mode is most feasible.

3.3.1 Description of Union Mode

Union Mode means e-waste reverse logistics operations are completed by the unity of retailers, third-party logistics and manufacture. In this mode, manufacturer requires retailers to recycle electronic wastes from their customers and selects a qualified TPL to complete operation of transportation and inventory management. And there is reclaim and disposal center operated mutually by manufacturer and TPL. In this center, the main responsibility of third-party logistics is inventory management and transportation arrangement, and the manufacturer takes charge of professional technical operation, such as testing, classification, dismantling and so on. The sketch map of Union Mode is shown in figure 3-2.

In Union Mode, all key nodes of e-waste reverse logistics are re-assigned to achieve vertical integration. Retailer, TPL suppliers and manufacturers will be combined together in order to gain more efficiency. In this Union Mode, different reverse logistics missions are entrusted to various nodes in the chain, rather than entrusted all missions to one party. E-waste reverse logistics can be divided into individual tasks. It mainly involves the following steps: collection, elementary testing, transportation, cleaning, demolition, testing, classification and reuse. According to the characteristics of different steps, all of these steps will be entrusted to suitable party. Collection and elementary testing relate to various varieties and cover a wide area. These jobs are entrusted to retailers by contracts or agency. And the TPL is responsible for transportation. Some complex professional tasks, such as cleaning,

disassembly, testing and classification, are done in recycle and disposal center. The reusable parts and raw materials, in this center, are reused not only by original manufacture also by other manufacturers.

Aim to the status quo of development of Chinese logistics industry, Union Mode is brought up. In this mode, different parties cooperate with due division of labour. Union Mode of e-waste reverse logistics is different from the two former modes; this mode is completed by different principle parts.

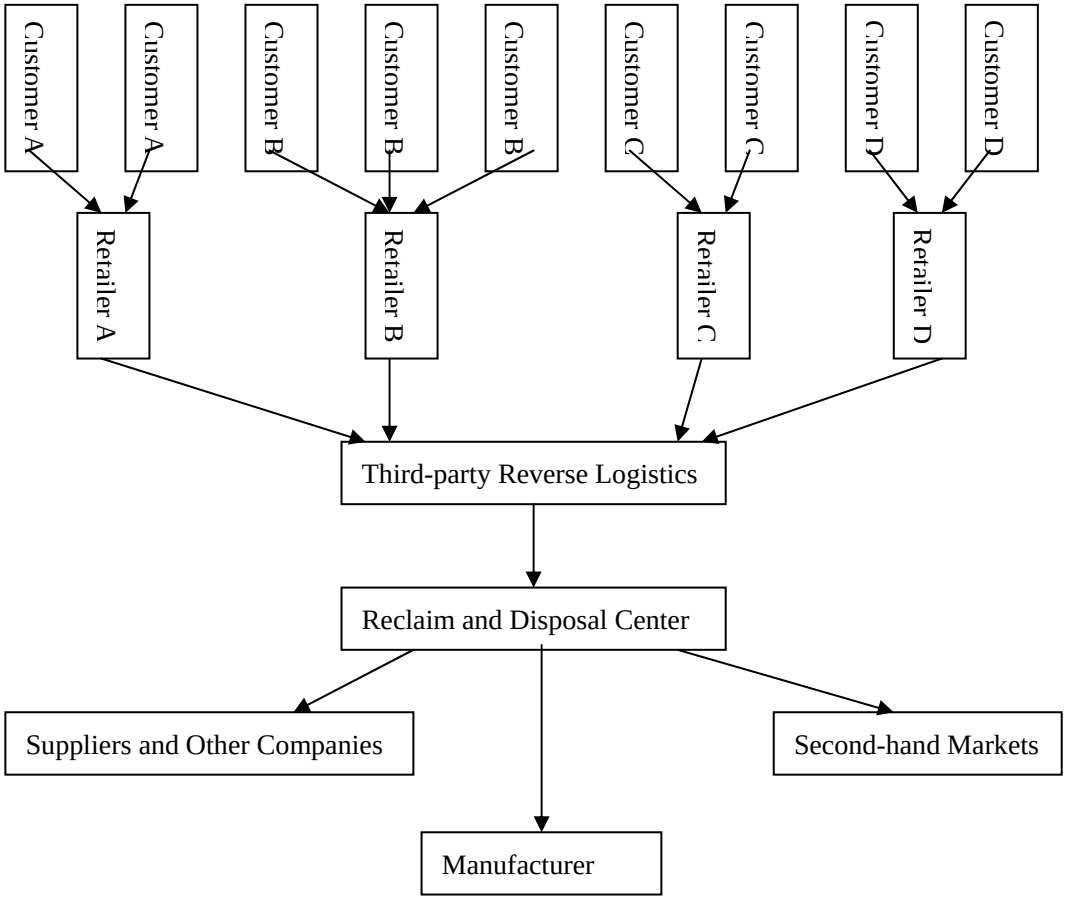

Figure 3-2: Sketch Map of Union Mode

3.3.2 The Functions and Advantages of Union Mode

1. Reorganize and consolidate whole community resources of reverse logistics

In Union Mode, the relative isolation superior resources can be linked to each other through business cooperation, which form a competitive reverse logistics value chain. All aspects of e-waste reverse logistics have taken advantage of existing social resources: the retailers' network for recycle, TPL suppliers' logistics resources for delivery and inventory, manufacturers' technical resources for reprocessing and disposal. Without union, these resources are always isolated and cannot form the overall advantage in the entire value chain.

2. Effectively improve agility of reverse logistics

Agility manifests in two aspects. One aspect is the rate of response. Retailers can give fast response to customers' demand of e-waste recycle. Retailers' locations are close to customers and they have rich experience in customer service, which help retailers to form a natural habit of rapid response. Retailers can satisfy the customers' recycle demand whether home service or retail store recovery. Another aspect is that cooperate with due division of labor effectively maintain the agility of e-waste reverse logistics. In the Union Mode, respective enterprises take charge of their own advantage business and bind each other by cooperation agreement. Enterprises must carry out responsibilities and obligations under the binding contract, and any violators are to be punished according to the agreement. Enterprises can deal with own business faster and keep their vitality, which avoid disputing over trifles and slow response.

3. Reduce the operation cost of e-waste reverse logistics

In this Union Mode, all operational actions are completed by enterprises that are good at their own advantage business, such as TPL are charge of transportation and inventory. Because the enterprises in charge have strong technical resources, professional equipments and trained personnel, the costs of every aspect of operation are lower. And then taking cost saving of investment into account, the entire e-waste reverse logistics cost is lower than the traditional recovery mode.

3.3.3 The Practical Significance of Union Mode

Union Mode of reverse logistics overcomes some practical difficulties. The majority Chinese manufacturers is shortage of capital and weak in technology, so they have no sufficient investment and advanced technical ability to develop reverse logistics themselves. The third-party logistics companies that can provide professional reverse logistics service is very few, which bring manufacturers more difficulties to search the professional third-party reverse logistics suppliers. Therefore, development of Self-Supporting Mode and Outsourcing Mode is still difficult at this stage in China. By cooperation, Union Mode makes full use of existing community logistics resources, and reduces the pressure on the manufacturers' investment. Professional operation of all key links reduces the cost of whole process of recycle, increases the efficiency, and achieves the scientific treatment, which deal with the problem of materials waste and environmental pollution that caused by second-hand traders and small workshops.

In the current situation, Chinese enterprisers' strength of capital and technology and their experience in recycle are limited, cooperation between retailers, TPL and

manufacture help every party to focus on their core businesses. Retailers always spread all over city, so they hold better location to collect electronic waste from customers. At the same time, it is easy for customers to return e-waste to retailers. And TPL can bring their core function to play in this Union Mode. TPL has rich experience in distribution and inventory management. Manufacturers also can reuse reusable raw materials to reduce material cost and establish the environmental friendly image. What the most important is that all of them can pay more attention to operate and develop their own competitive businesses.

Besides, from legislation enacted by government that requires manufacturers to undertake the liability of recycling and reuse the e-waste and some relative cost, we can forecast that e-waste reverse logistics will form a huge market and provide new profitable opportunity to manufactures. Manufacturers accumulate relative experience in e-waste reverse logistics through operating Union Mode, and then create new profit resources. The third-party reverse logistics can gradually expand their scope of business and gain more benefits through close cooperation with manufacturers. And then they will transform into an independent reverse logistics service provides. From the above analysis, we can see that Union Mode bring many benefits to three parts of this mode by jointing enterprisers, which is more suitable for China’s status quo.

3.4 Conclusion

According to research on three operational modes of e-waste reverse logistics, the Union Mode is the best choice to launch the e-waste reverse logistics at current stage in China.

4 Theoretical Analysis and Mathematical Proof of Union Mode

4.1 Value Chain Theory

4.1.1 Introduction of Value Chain

In 1985, Professor Michael Porter put forward the concept of “value chain”. He considered that enterprises’ process that creates value can be segmented into a series of value-added actions that are independent and interrelated. And the sum of the actions constitutes the value chain. Generally, a firm’s value chain can be segmented into primary and support activities. Primary activities include design, production, marketing, distribution and service after the sale. Support activities are the collection of value-added actions, which provide the assistance for the primary activities to take place. Each value-added activity is a part of value chain and they jointly determine the profit of the value chain. (Michael E.Porter, 1990,pp 28-30)

The value chain theory indicates that not all the activity involved in the enterprises’ value chain can create value. The value created by enterprises comes from some special links in value chain. These links that really create value for enterprises are called as “strategic links”. Enterprises can control the whole value chain once they seize these strategic links. At the same time, each link of value chain requires different essential factors of production. So any enterprises can only hold some advantages of certain links and can have not all the advantages.

Value chain theory let the firms to know the parts of their activities that create value and those that do not. Understanding these issues is important because the enterprises can gain above-average profits only when they control the strategic links. Value chain inspects enterprises' activities and their interactions and analyzes the various resources. Through study, value chain allows enterprises to understand how to gain the competitive advantages from cooperation. To gain the competitive advantage, enterprises must control firmly strategic links through weighing every links of value chain. On the other hand, non-strategic activities can be entrusted to the specialized companies. From the perspective of the value chain, enterprises intercept a part of value chain, and other parts completed by other enterprises.

4.1.2 Describe Value Chain of E-waste Reverse Logistics

The basic value activities of e-waste reverse logistics are related to the activities of e-waste recycle and reuse, such as recycling, transport, testing, classification, reprocessing and disposal. Supporting activities support the primary activities through the provision of logistics information, human resources and other relevant functions. The basic structure of value chain of e-waste reverse logistics is shown in the following figure.

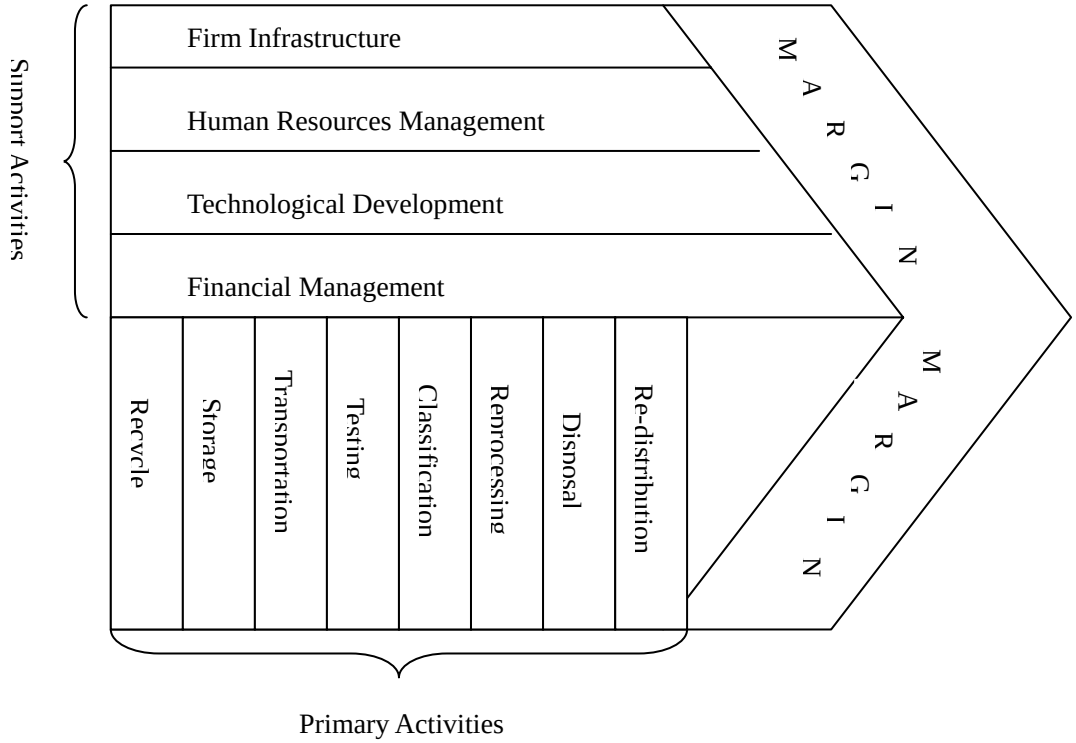

Figure 4-1: Value Chain of E-waste Reverse Logistics

From the composition of value chain of e-waste reverse logistics, there is no difference between reverse logistics and forward logistics. However, e-waste reverse logistics has own characteristics in primary activities. First of all, there is more complex links and structure. Secondly, the degree of specialization is higher and the correlation between them is weaker. Thirdly, the level of specialization of every links is different. Some is higher, such as manufacturing, some is lower, such as transportation.

4.1.3 Analysis of Union Mode Based on Value Chain

The whole value chain of e-waste reverse logistics consists of all activities of e-waste reverse logistics process. To gain the competitive advantage and profits, electronic products manufacturers should try to seize the key links and bring these links'

original advantage into play. It is not necessary for manufacturers to execute all links of value chain. For the constraints of own resources and capacity, manufacturers, TPL supplier and retailers cannot take advantage of all links of value chain respectively. Therefore, the suitable development idea, in China, is that the manufacturers that may gain the great majority profits from e-waste reverse logistics should joint the TPL supplier and retailers to establish complementary cooperation. In this value chain, recycle can be completed by retailers outstandingly. The TPL supplier is good at transporting, warehousing and other logistics activities. The activities of transporting, storage are the TPRL supplier's superior businesses. And the manufacturers master relevant technology of demolition, decomposition and reprocessing. Every link can realize the greatest contribution to value chain and achieve mutually beneficial results together. So manufacturers can gain the competitive advantage in value chain of e-waste reverse logistics through cooperating with retailers, TPL suppliers.

According to the above analysis, the links of e-waste reverse logistics is more, and some links require highly professional operation. The retailers, TPL suppliers and manufacturers have own advantage in value chain respectively, and they have no strength to control whole value chain. Based on this consideration, I point out joint these three parties to develop the Union Mode of e-waste reverse logistics.

It is necessary to emphasize the importance of retailers' function in e-waster reverse logistics. Retailers that are resources of recycle are always ignored in traditional mode of reverse logistics. In Self-Supporting Mode, manufacturers invest in their own recycling outlets, which increase the cost of recycle. Retailers are the manufacturers' point of sale and close to the customers. They understand customers and their psychological characteristics. And they have their own storage capacity. At

the same time, retailers and manufacturers can set a good environmental image and enhance overall competitiveness. Therefore, retailers play an important role in e-waste reverse logistics.

4.2 Transaction Cost Theory

4.2.1 Introduction of Transaction Cost Theory

The concept of transaction cost was pointed out by Ronald Coase in 1937. He described the transaction cost as “operation expense of economic system”. There are at least two contents. The first content is the expense of gaining information. Enterprises have to bear this cost when they search and confirm market information that is related to the objects of transaction and market price. The second content is the expense of negotiation and agreement supervisor. To avoid a conflict, enterprises need negotiate with each other and then confirm the agreement and they have to pay for these. And Oliver Williams (1985) regarded transaction as the friction of economy world. He utilized the Ronald Coase’s concept of transaction cost to analyze the economy organizations. And he divided the transaction cost into beforehand and afterwards transaction cost. The beforehand transaction cost includes expenses used to draft, negotiate and carry out contracts, and the afterwards transaction includes following four shapes. First shape of expense is used to handle change when the transaction deviates from the agreement. Second shape of expense is used to correct the deviation. When deviation activities are resorted to law, the third shape of transaction cost occurs. The fourth shape of transaction cost is a constrain expense that used to match commitments. Thus, the concept of transaction cost becomes a real important analysis tool of the economic organizations.

It could be concluded from above definitions that transaction cost includes all costs

which do not occur in process of material production.

This transaction cost theory is based on two behavior hypotheses which are bounded rationality and opportunism. These are the characteristics of contractual man, which are reasons of transaction cost. And the transaction cost is decided by the three dimensions, which are characteristics of exclusive assets, uncertainty and frequency of transaction. These three characteristics jointly influence the transaction cost of economy system.

4.2.2 Conclusion from Transaction Cost Theory

According to transaction cost theory, Union Mode is a regulation assignment of saving transaction cost.

All kinds of transaction cost that come from the process of transaction increase the total cost of operation in economy system. Union Mode as an effective institutional arrangement was arose. From the entire process of transaction, the Union Mode constructs the cooperation between parties and decreases the related transaction costs. As the regular communication and cooperation, the expense of searching the objects is lower. Mutual trust and commitment built through providing personalized service reduce the risk of default. The conflicts, in course of transaction, can be resolved through consultation because of the general long-term contract, which avoid endless bargaining, or even legal resort.

From the main trading behaviors, the alliance will promote to establish learning mechanism between partners, thereby enhancing the members' awareness of environmental uncertainty and reducing transaction cost caused by bounded

rationality. The long-term cooperation can effectively restrain the opportunism. Because a one-time betrayal and fraud will lead to tit-for-tat retaliation and punishment, and then partners have to face the high cost of adverse selection. Therefore, union can keep the transaction cost to a minimum.

Union Mode is in conformity with the three dimensions of transaction cost research. The three dimensions of transaction promote the enterprises to construct the strategic cooperation. Exclusive assets are the most important aspects. The higher degree of exclusive assets means that the investment brings considerable sunk costs that are included in fixed and variable costs. Establishment of union and common possession of exclusive assets is the effective choice to decrease the level of exclusive assets.

Uncertainty of transaction and volatility of market are closely related to the bounded rationality and opportunism. Each enterprise cannot perceive the minutest details and pre-set items to avoid unexpected events in future. Union Mode takes the place of market transaction, which can obviously reduce the occurrence of unexpected events. The higher frequency of transactions means that the large volume of transaction and ongoing transactions, resulting it a higher transaction costs. Union can provide an institution arrangement through seeking an organizational form to eliminate the negative impact of higher frequency. Because the union is a long-term lease arrangement, the transaction cost beard by unit transaction has a decrease trend. The most valuable part of cooperation for one enterprise is that establishment of cooperation relationship and gain the additional capacity. And then enterprises form a win-win situation.

Reverse logistics has the characteristics of investment risks, complex structures and sites scattered. If the manufacturers exclusive operate the entire reverse logistics

themselves, they would reduce the transaction cost. However, this mode also lead to increase the inventory and transportation cost, slower response to recycle, lower quality of service and lose the competitive advantages finally. Therefore, the Union Mode is a better choice for reverse logistics operation.

Besides, the union partners, in a strategic cooperation, save purely market transaction costs, at the same time, they still maintain their relative independence and high market efficiency. And the competitiveness still exists among partners. In doing so, this Union Mode avoid the organization cost caused by rigidity of integration organization.

4.3 Mathematical Proof of Union Mode

As we all know that the Union Mode unify the retailers, TPL and manufacturer to operate the e-waste reverse logistics. And the first step of Union Mode and the most important step is that retailers recycle the e-waste from final customers. Generally speaking, the manufacturer-oriented e-waste reverse logistics can use the follow three modes to recycle the e-waste from customers: Third-party Take-back (TPT), Retailer Take-back (RT), and Manufacturer Take-back (MT). In the Union Mode, we recall the RT used by the retailers to be responsible recycling operation. Is it the optimal mode for e-waste reverse logistics? Through mathematical models and calculation, I analyze the retail and wholesale prices; recycle rate and profits of these three modes respectively.

New products can be fully produced by raw materials, and also can be produced by recycled components. Support the unit cost of new product that produced fully by raw materials is Cm, and the unit cost of new product that produced by some

recycled components is Cr. "π" represents the saving cost for using the recycled components, π = Cm- Cr. In this mathematical model, I assume that all the products are sold through retailers. Support the wholesale price that manufacturers provide to retailers is"θ", and the sales price is "p". Recycle cost is a function of recycle rate. Recycle cost is made of fixed cost and variable cost. And the recycle rate (ε) is a concave function of fixed cost invested in recycle action, such as publicity poster. If C_f represents fixed cost, $\varepsilon = K_o\sqrt{C_f}$ could be showed as $C_f = K\varepsilon^2$. Variable cost is $S * \varepsilon D(p)$. "S" is the unit cost of recycle and $\varepsilon D(p)$ is the quantity of waste recycled. So the total cost of recycle is a function of " ε ". That is $C(\varepsilon) = C_f + S\varepsilon D(p) = K\varepsilon^2 + S\varepsilon D(p)$. In the modes of TPT and RT, third-party and retailers collect the waste firstly. So manufacturers have to pay for them to gain the waste collected, this price is "t". Support the demand of product is linear, and the demand curve is $D(p) = \phi - \beta p$, "ϕ"and "β" are parameters ($\phi, \beta > 0$), "p" is the product retail price. The $\prod_i^j$ represents profit in which "i" is a participant, " j "is the recycle mode. (Yao Weixin, 2004, p.76-80) According to Yao (2004) mathematical calculation, the optimum formulas of $p^*, \varepsilon^*, \theta^*, \prod_M^*$, $\prod_R^*$,and $\prod_{TP}^*$ under different recycle modes respectively are listed in the following table.

Table 4-1: The Formulas of $p^*, \varepsilon^*, \theta^*, \prod_M^*$, $\prod_R^*$, and $\prod_{TP}^*$

	TPT	MT	RT
p^*	$\frac{3\phi+\beta_{c_m}}{4\beta}-\frac{t(\pi-t)(t-S)}{4[4K-\beta(\pi-t)(t-S)]}$	$\frac{3\phi+\beta_{c_m}}{4\beta}-\frac{(\phi-\beta_{c_m})(\pi-S)^2}{4[8K-\beta(\pi-S)^2]}$	$\frac{3K-\beta(\pi-S)(t-S)\phi+\beta_{C_m}}{\beta[4K-\beta(\pi-S)(t-S)]}$
ε^*	$\frac{(\pi-t)(t-S)}{2[4K-\beta(\pi-t)(t-S)]}$	$\frac{(\phi-\beta_{c_m})(\pi-S)}{8K-\beta(\pi-S)^2}$	$\frac{(\phi-\beta_{c_m})(t-S)}{2[4K-\beta(\pi-S)(t-S)]}$
θ^*	$\frac{\phi+\beta_{c_m}}{2\beta}-\frac{(\phi-\beta_{c_m})(\pi-t)(t-S)}{2[4K-\beta(\pi-t)(t-S)]}$	$\frac{\phi+\beta_{c_m}}{2\beta}-\frac{(\phi-\beta_{c_m})(t-S)^2}{2[8K-\beta(\pi-S)^2]}$	$\frac{\phi+\beta_{c_m}}{2\beta}-\frac{(\phi-\beta_{c_m})(\pi-t)(t-S)}{2[4K-\beta(\pi-S)(t-S)]}$
$\prod_M^*$	$\frac{K(\phi-\beta_{c_m})^2}{2\beta[4K-\beta(\pi-t)(t-S)]}$	$\frac{K(\phi-\beta_{c_m})^2}{\beta[8K-\beta(\pi-S)^2]}$	$\frac{K(\phi-\beta_{c_m})^2}{2\beta[4K-\beta(\pi-S)(t-S)]}$
$\prod_R^*$	$\frac{K^2(\phi-\beta_{c_m})^2}{\beta[4K-\beta(\pi-t)(t-S)]^2}$	$\frac{4K^2(\phi-\beta_{c_m})^2}{\beta[8K-\beta(\pi-S)^2]^2}$	$\frac{K^2(\phi-\beta_{c_m})^2[4K-\beta(t-S)^2}{4\beta[4K-\beta(\pi-t)(t-S)]^2}$
$\prod_{TI}^*$			$\frac{K(\phi-\beta_{c_m})^2(t-S)^2}{4[4K-\beta(\pi-t)(t-S)]^2}$

Source: Yao Weixin.(2004, Februray). Comparison of Different Take-Back Models in Reverse Logistics. *Management Sciences in China*, 17(1), 76-80.

4.3.1 Analysis of Recycle Modes Based on Optimum Formulas

4.3.1.1 Transfer Price

In the mode of TPT, the optimal t is $t^* = \frac{\pi+S}{2}$. In the mode of RT, manufacturers should transfer the saving-cost that caused by using recycle components to retailers, which is transfer price equals to saving cost.

The reason why the third-party to invest on recovery is entirely dependents on transfer price. So manufacturers face the following compromise when they decide the optimal transfer price .If they give a greater value of transfer price, the third-party suppliers would be more enthusiasm. In this circumstance, the recycle rate is higher,

and the manufacturers' net saving-cost is lower, and the differential value between saving cost and transfer price is lower. It could well be proved that while $t^* = \frac{\pi + S}{2}$, transfer price will exert balance for the direct and indirect impact on manufacturers' profits.

However, in the mode of RT, manufacturers prefer giving the saving cost to retailers to sharing it with them. The reason for such strange phenomenon is that manufacturers will gain a higher market share. Manufacturers' decision brings retailers more profit, so they are willing to decrease the retailer price to increase the market demand. When transfer price increases to cost saving, the recycle rate is highest.

4.3.1.2 Recycle Rate

The relationship between these three modes is that the recycle rate of Retailer Take-back is highest and that of Manufacturer is second. From the above formulas, the marginal utility of recycle rate in TPT mode is smaller than that in MT mode. Compared with manufacturers in MT mode, third-party suppliers' investment on recycle is lower. Compare MT and RT, the marginal utility of recycle rate is equal. Retailer has the direct impact on market share, and manufacturer only has indirect impact on retailer through tactfully choosing the wholesale price. Therefore, recycle situation of RT is better than that of MT.

4.3.1.3 Retail Price

The relationship between these three modes is that the retailer price of Retailer Take-back is lowest and, that of Manufacturer Take-back is second and that of Third-party Take-back is highest.

In TPT, third-party supplier can gain the direct profit from investment on recycle. Manufacturer gives a lower wholesale price, which only secondarily impact on the retail price. In MT, manufacturer gives a lower wholesale price to expand the market demand, and save more cost through recycling. In RT, the range of decreasing sale price is the biggest. So retailer can gain more profit through decreasing the sale price.

4.3.1.4 Profit of Manufacturer, Third-party and Retailer

According to above calculation, the manufacturer, third-party and retailers can gain the most profit from the Retailer Take-back Mode; and the Third-party Take-back provides the least profit for manufacturer, third-party and retailer.

From the above analysis, manufacturer, in RT, transfer all saving-cost based on recycle to retailer, thus retailer gain the highest profit and manufacturer also win higher earning by expanding market demand. Retailer and manufacturer, in TPT, obtain lowest benefit. And in Retailer Take-back Mode achieve the highest recycle rate of e-waste, which is important to develop union mode of e-waste reverse logistics.

4.3.2 Empirical Analysis

To explain the above conclusions, I use the following example. Support the unit cost

of a new product is 30, that is $C_m = 30$. And the unit cost of new product that produced by some recycled components is 10, $C_r = 10$. Recycle cost if 10, S=10, the other parameters are K, θ, and β equal to 200, 100 and 2 respectively. Then I can calculate that saving cost is 20. (Yao Weixi, 2004, p76-80)

Table 4-2: Manufacturers' Profit in TPT and Retailers' Profit in RT

t	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
$\prod_M^{TPT}$	102.30	104.17	105.54	106.38	106.67	106.38	105.54	104.17	102.30	100.00	97.32	94.34	91.17	87.72	84.21
$\prod_R^{RT}$	52.47	54.85	57.12	59.26	61.22	62.98	64.46	65.63	66.39	66.67	66.35	65.31	63.37	60.36	56

Source: Yao Weixin.(2004, Februray). Comparison of Different Take-Back Models in Reverse Logistics. *Management Sciences in China*, 17(1), 76-80.

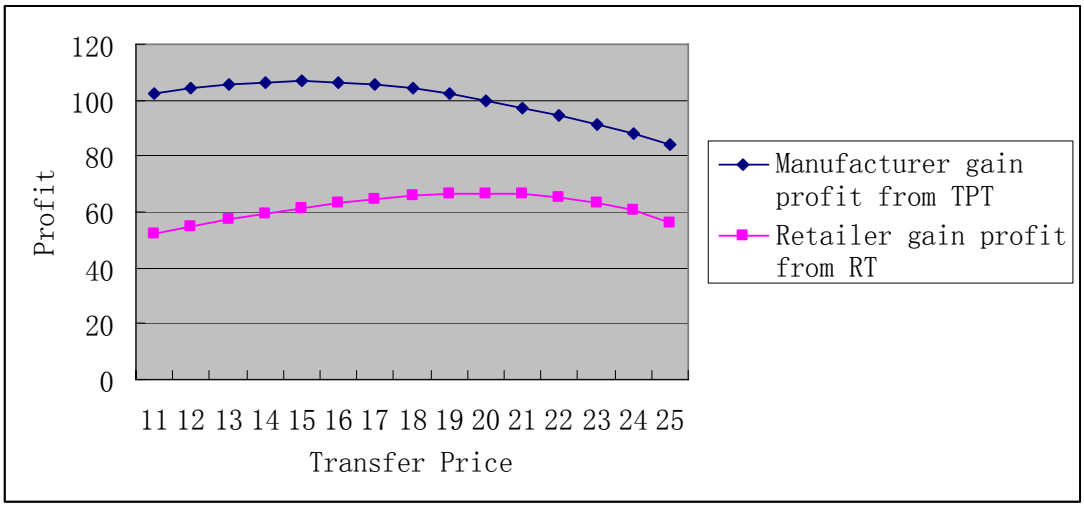

Figure 4-2: Manufactures' Profit Curve in TPT and Retailers' Profit Curve in RT

Source: Yao Weixin.(2004, Februray). Comparison of Different Take-Back Models in Reverse Logistics. *Management Sciences in China*, 17(1), 76-80.

When the transfer price increases from 11 to 25, the calculation results of manufacturer's profit from TPT mode and retailer's profit from RT mode are shown in the table 4-2 and figure 4-2. From the table and figure, in TPT, when transfer price

equals to 15, the profit of manufacturer is 106.67. This profit is highest. From the third line of table 4-2, in RT mode, when transfer price equals to saving cost that is 20, the retailer gain the highest profit 66.67. Figure 4-2 gives a more direct expression. Two curves have sole extreme value respectively, which prove the correctness of above conclusions.

In the mode of MT, manufactures are directly responsible for recycle, so the related formulations are not concerned in the transfer price. And the results of calculation are listed in the third line of the table 4-3. In TPT and RT mode, all of the formulations are connected with transfer price. When choose the optimal transfer price in respective modes, the related results are listed in second and fourth lines of table 4-2.

From the second line of table 4-2, the smallest recycle rate is in TPT mode, the largest recycle rate is in RT mode, and the recycle rate of MT mode lies between the smallest and largest. So the conclusion 4.3.1.2 is correct.

From the third line of table 4-2, the smallest retail price is in RT mode, the largest retail price is in TPT mode, and the retail price of MT lies between the smallest and largest. So the conclusion 4.3.1.3 is correct.

From the fourth and fifth lines of table 4-2, the manufacturers' profit of RT mode is higher than that of the other modes; retailers' profit of RT mode is higher than that of the other modes; and the manufactures' and retailers' profits are the lowest in these three modes. This conclusion is identical to the 4.3.1.4.

Table 4-3: The Related Value with Optimal t in Different Modes

	TPT $(t = \frac{\pi + S}{2})$	MT (not related to t)	RT $(t = \pi)$
Recycle Rate	0.133	0.286	0.333
Retailer Price	43.84	43.33	33.38
Profit of Manufacture	106.67	114.29	133.3
Profit of Retailer	66.67	65.31	56.89

Source: Yao Weixin.(2004, Februray). Comparison of Different Take-Back Models in Reverse Logistics. *Management Sciences in China*, 17(1), 76-79.

Through above mathematical calculation and example of verification, I analyzed three different recycle modes. This contrastive analysis provides a theory to choose a suitable recycle mode. From above analysis, the Retailer Take-back Mode is the most profitable and reasonable mode for e-waste reverse logistics. In this recycle mode, recycle rate is highest and the manufacturer also gains the largest profit. Although, retailers, in RT mode, cannot achieve the maximum profit, manufacturer can award compensation for recycling activity through some regulations. Therefore, recycling operation is completed by retailers in Union Mode, which is benefit to develop e-waste reverse logistics in China.

4.4 Conclusion

From the above theoretical analysis and mathematical calculation of Union Mode, I can conclude that the Union Mode is a suitable operational mode of e-waste logistics in China. This mode accord with the value chain theory, and can effectively reduce the transaction costs. Through calculation, the recycle operation done by retailers is the accurate choice for e-waste reverse logistics.

5 Construction Union Mode of E-waste Reverse Logistics

5.1 The Target and Principle of Construction

The Union Mode of manufacturer, retailer, and third-party logistics supplier is designed according to actual situation. The concrete targets are as follows. Firstly, give customers a rapid response to recycle demand. Secondly, treat e-waste properly. Under the permission of environmental protection, excavate the value of e-waste as much as possible. Thirdly, reduce the investment. Make full use of existing community resources of reverse logistics. Fourthly, cooperate with due division of labour and give full play to respective advantages. Fifthly, reduce environmental pollution caused by the improper treatments.

At the same time, construction of Union Mode should follow some principles that can ensure to achieve the target of construction. For example, the principle of reusing collected e-waste, principle of environmental protection and information sharing.

5.2 Organization Alliance of Union Mode

As above analysis in Chapter 3 and 4, the Union Mode is composed by retailers, TPL and manufacturers. How to organize these enterprises effectively to make fully use of their respective competitive advantages? It is very essential to develop the Union Mode of e-waste reverse logistics. And from the view of value chain and transaction cost theory, enterprises, in Union Mode, have the common interest of e-waste reverse logistics and have distinctive advantages and functions. To save costs, increase

transaction efficiency and gain the long-term profit, enterprises should cooperate in the organization mode of strategic alliance. In this strategic alliance, enterprises trust each other, bear risks and share profits jointly through agreements. Therefore, each enterprise makes fully use of their competitive advantages to operate, which is favorable to develop the e-waste reverse logistics industry.

The construction of organization alliance can be divided into the following four main steps.

1. Confirm the mission of alliance

Object is the base of the alliance operation. According to these value chains, respectively describe enterprises' own core capacities and necessary capacities used to complete the mission is essential. And then confirm the objects and analyze the gaps between existing capacities and required capacities. In doing so, we can decide the feasible mission of alliance that can be gained by potential members.

2. Evaluate and select the alliance members.

Selection of appropriate members is essential factor of successful cooperation. Many experts utilize the AHP to select the partners. This is a common and comparative simple model to select and evaluate the potential partners. At the same time, there are more complex mathematical models. Whatever methods used, there is still some essential policy. Initiative of developing e-waste reverse logistics is the first element that should be considered. Then enterprise should comprehensive consider and judge the following problems.

Are the potential partners' strategic targets matching the enterprise's mission? And do they have the common desire?

Analyze the potential partners' core competitiveness and confirm whether two parties' core competitiveness is mutually complementary.

Accurately evaluate the quantity of resources that partner want to invest.

Study on the enterprise culture and values of partner. Is there a culture conflict between them?

Accurately forecast the possible cooperation relationship in future.

Survey and understand potential partners' problems that occurred in past cooperation.

3. Design the organization alliance

First of all, we should determine the modality of participation. Alliance enterprises select the appropriate form of participation from the non-equity participation, joint-venture construction, equity participation and mergers and reorganization through combining the long-term strategic objectives, preference of risk and other factors. In light of China's current market circumstance and the situation of development, contractual alliance is more appropriate. Although the transaction cost of contractual alliance is higher than that of equity alliance, from a long-term view, the process of development cannot reach the goal in one step.

Obviously, manufacturer is the greatest role in Union Mode of e-waste reverse logistics. However, many problems need coordinate with retailers and TPL to deal with during the specific operation. Therefore, it is necessary to set up a coordination committee to manage and coordinate the whole organization by instructions and agreements. And the most important is that the Coordination Committee should be independent from any partners of alliance. Thus the coordination committee established by manufacturers and partners is responsible for the decision-making and operational management. The basic framework is showed in Figure 5-1

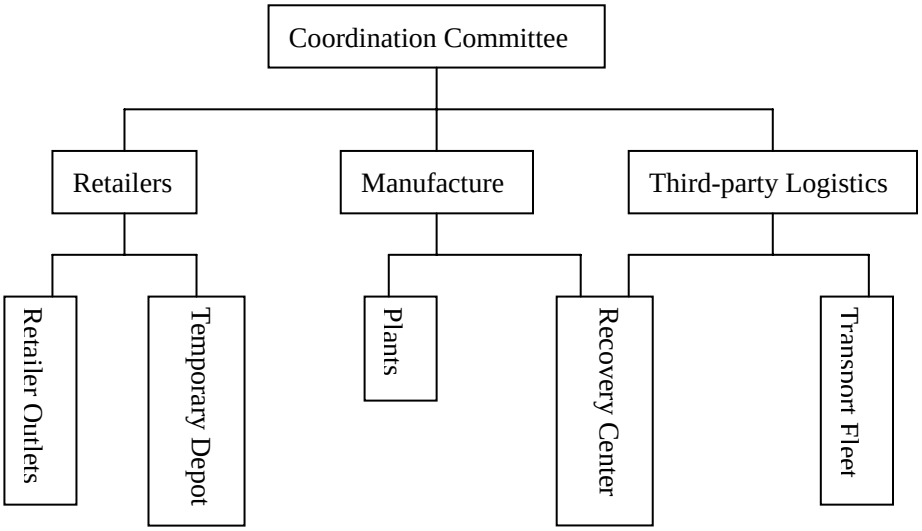

Figure 5-1: Framework of Coordination Committee Organization

From the above figure, both manufacturer and TPL are responsible for the reclaim and disposal center, because the two functions of center are completed by the manufacturer and TPL respectively. These will be discussed in the next paragraph.

At the strategic level, the core enterprise, that is manufacturer in this paper, should communicate and coordinate timely with other partners, retailers and TPL to guarantee the smooth implementation of agreements. At the tactical level, core enterprise should exchange some technical, management, and logistics information with partners promptly to ensure the information sharing.

4. Formal implementation and coordination

It is necessary to evaluate the effectiveness of implementation and solve the existing problems, such as cultural differences. Enterprises not only consider short-term interests but also solve the problems related to alliance implementation and reduce the negative impact of contradiction existing partners by communication and

coordination.

These four steps describe the main process of construction of alliance organization. Alliance is the foundation of Union Mode operation, which provides an effective organization form to integrate each enterprise's competitive advantages.

5.3 Design Flow of Union Mode

5.3.1 The Channel of Union Mode

Retailers, TPL and manufacturers compose the channel of Union Mode of E-waste Reverse Logistics. And the retailers play a role of entrance in this channel. All e-wastes enter into Union Mode through retailers. These e-wastes are properly disposed to reuse in suitable situation.

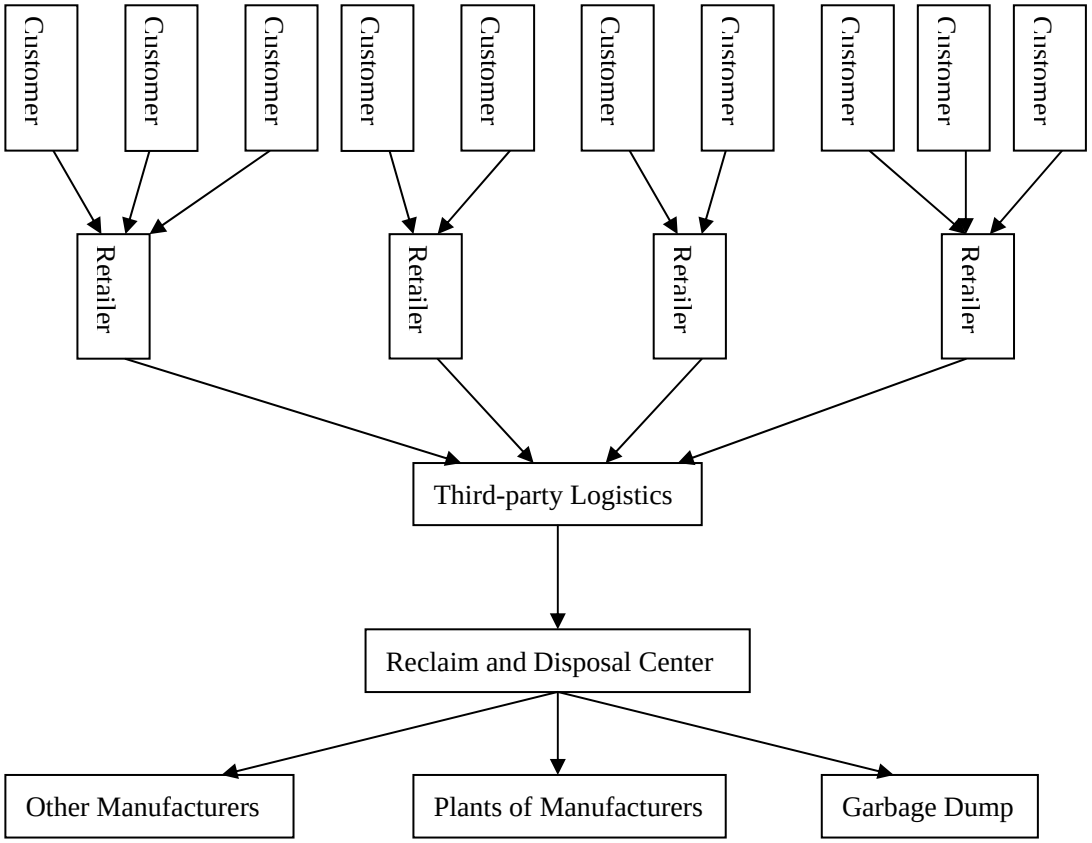

Figure 5-2 Channel of Union Mode

5.3.2 The Whole Flow of Union Mode

Manufacturer, TPL and retailers choose the channel of recycle firstly, and design a reasonable and effective flow of recycle is necessary. In chapter 4, I have analyzed that, in value chain, each enterprise has own resources advantage. Enterprises complete with division of labour to take charge of their own strategic links and achieve the maximum social and economic benefits of Union Mode. The whole flow of Union Mode of e-waste reverse logistics is designed based on consulting flow of forward logistics and combining the characteristics of electronic wastes and reverse logistics.

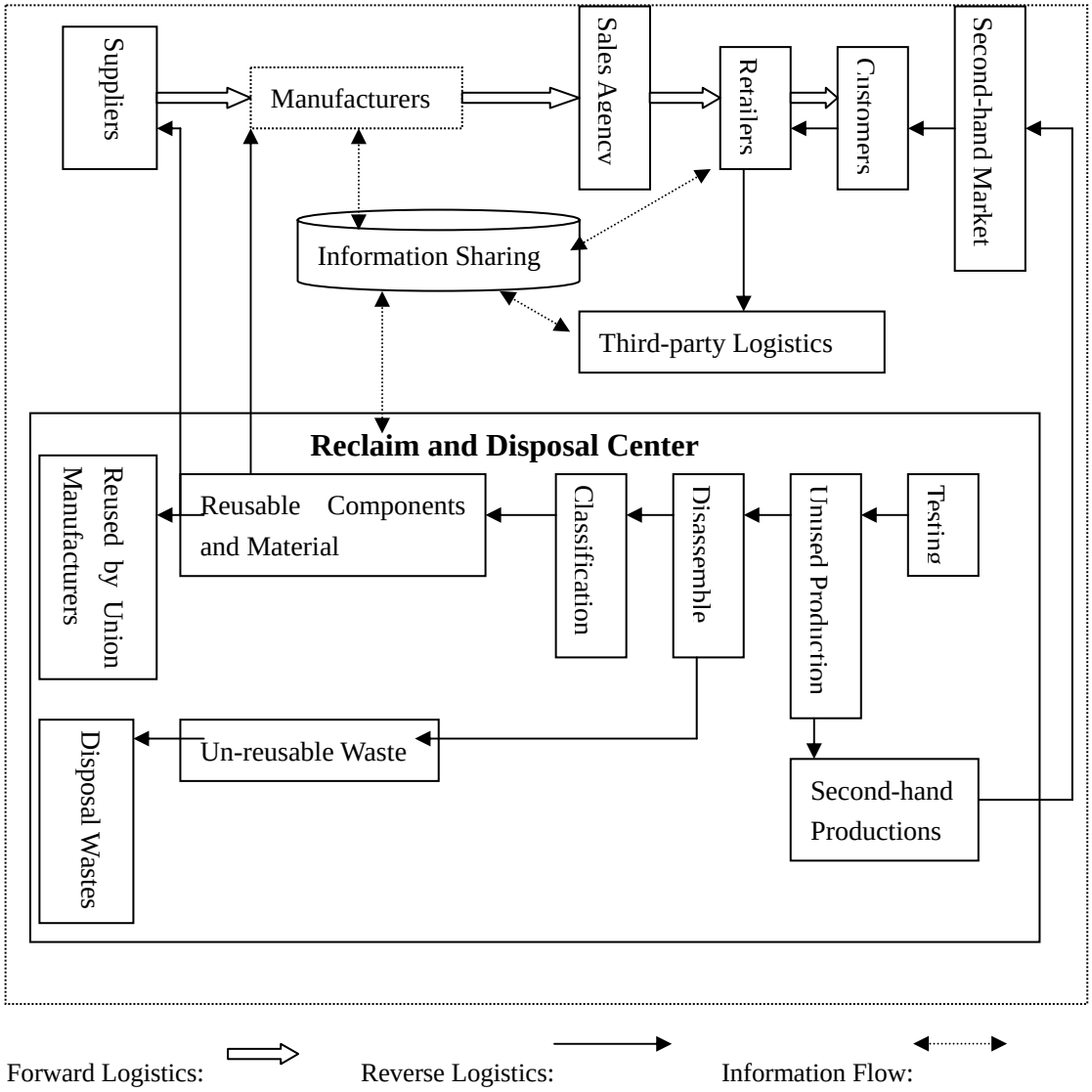

Figure 5-3: Whole Flow of Union Mode

The basic process of recycle: retailer collects the e-waste from customers and tests initially the quality and safety in order to judge whether these electronic products can continue to be used fully without repair or dismantling. Some electronic products that are qualified can directly entry into the local second-hand market. And some e-wastes go to the next step of Union Mode. And then TPL supplier is responsible for transporting remaining e-wastes collected in retailers to its regional reclaim and

disposal center. Un-reusable directly electronic products are dismantled and classified in center. Some components that are reusable will be reused in reprocessing. Reclaim and disposal center delivery timely the reusable parts and materials to manufactures by checking their inventory and purchasing plan. And manufactures reuse these reusable parts and materials based on production plan. Some parts and materials may not suitable for original manufacturers because of updating technology and products. These parts and materials can reused by manufacturer's suppliers and other enterprises through market transactions or exchanging. At last, the valueless e-waste will be treated in refuse disposal plant.

In order to maximize recovery e-waste and protect environment, some parts and materials are sold to suppliers and other manufacturers. These activities are not the main target of Union Mode, so that are no discussed in this paper.

5.3.3 Concrete Flow of Union Mode

5.3.3.1 Recycle Flow of Retailers

Retailers, in Union Mode, are not only the manufacturers' selling-points but also collection depots. The main responsibility of retailers is collection of e-wastes and temporary storage. Retailers are the main locations of selling, and traffic facilities as well. They are familiar with the customers' psychology and habits, product type, classification and quality, which is pretty beneficial to the recycle development. Furthermore, the retailers have their own depots in which the e-wastes collected temporarily are stored. In doing so, it could relieve the third-party logistics and manufacturers' burden of the construction of recycle depots

Firstly, manufactures and retailers must reach a consensus on the method of recycle. In this process, consumers can directly return e-wastes to outlets; retailers also collect e-wastes at customers' home based on collected information through phone call and Internet. Some e-wastes can be collected by trading in the old for the new. Retailers should firstly check whether this e-waste is produced by cooperative manufacture, which require information sharing with manufacturers. The data of production and sales should be available for retailers through Internet. And retailers can check and confirm whether e-waste is in the range of their businesses. If the e-waste is produced by cooperative manufacturer, retailers would collect this e-waste. What's more, retailers must record some related information, such as time, product type, and period of using and so on. Retailers should refuse the e-wastes not produced by cooperative manufacturer, because these are gaps of materials and technology between different electronic products produced by various enterprises. It is difficult for manufacturer to treat these unfamiliar e-wastes in reclaim and disposal center. Retailers can store e-wastes collected in their own temporary depots.

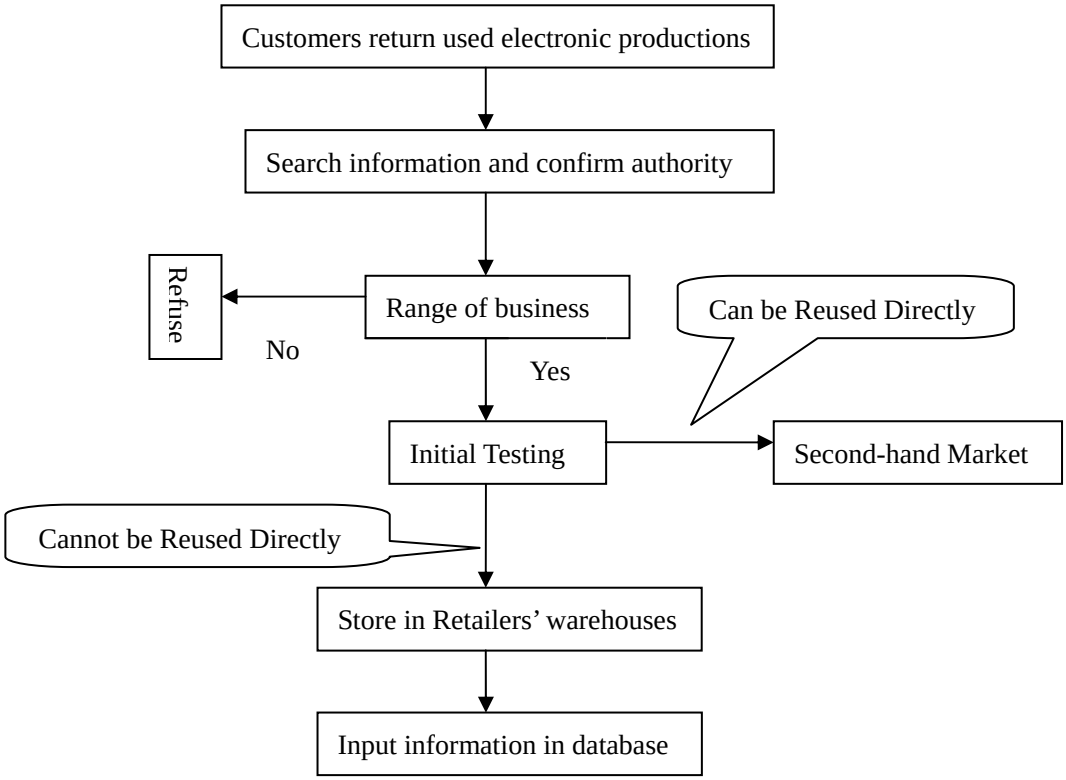

Figure 5-4: Recycle Flow of Retailers

5.3.3.2 Recycle Flow of Third-party Logistics

Third-party logistics mainly takes charge of two jobs based on the cooperative agreement. First of all, TPL should delivery the e-wastes collected and stored in retailers' temporary depots to regional reclaim and disposal center. Retailers' temporary depots are small, which only provide limited space to store the e-wastes. Storage in fixed center also facilitates management and treatment of e-waste. TPL second job is to forecast the inventory and demand of e-waste according to the storage of reclaim and disposal center and the rate of treatment. At the same time, TPL should timely distribute the reusable parts and materials to manufacturers. The two main responsibilities of TPL are discussed respectively as follow.

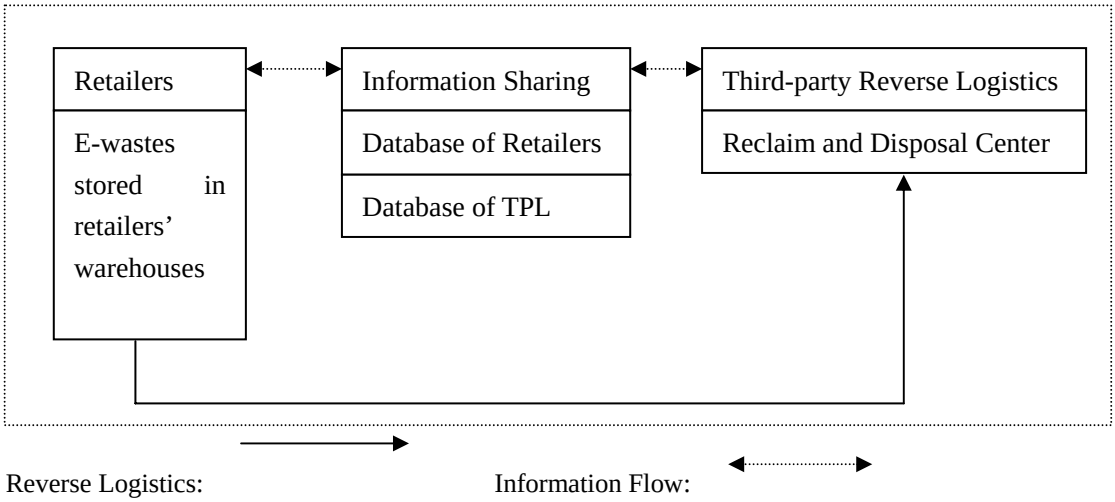

Figure 5-5: Recycle Flow of Third-party Logistics from Retailers

1). TPL collect e-wastes from retailers

This process can be designed from two circumstances. One is that TPL are only responsible for manufacturers' reverse logistics business. Under this circumstance, TPL arrange transportation according to the capacity of retailers' depots and the quantity of the e-waste recycled. On the basis of the fixed route, TPL assign trucks to pickup at first retailer, then to the second, third, and so on and so forth. In doing so, retailers can keep the capacity of depots and increase the efficiency of transportation resources. This flow is showed in the below figure.

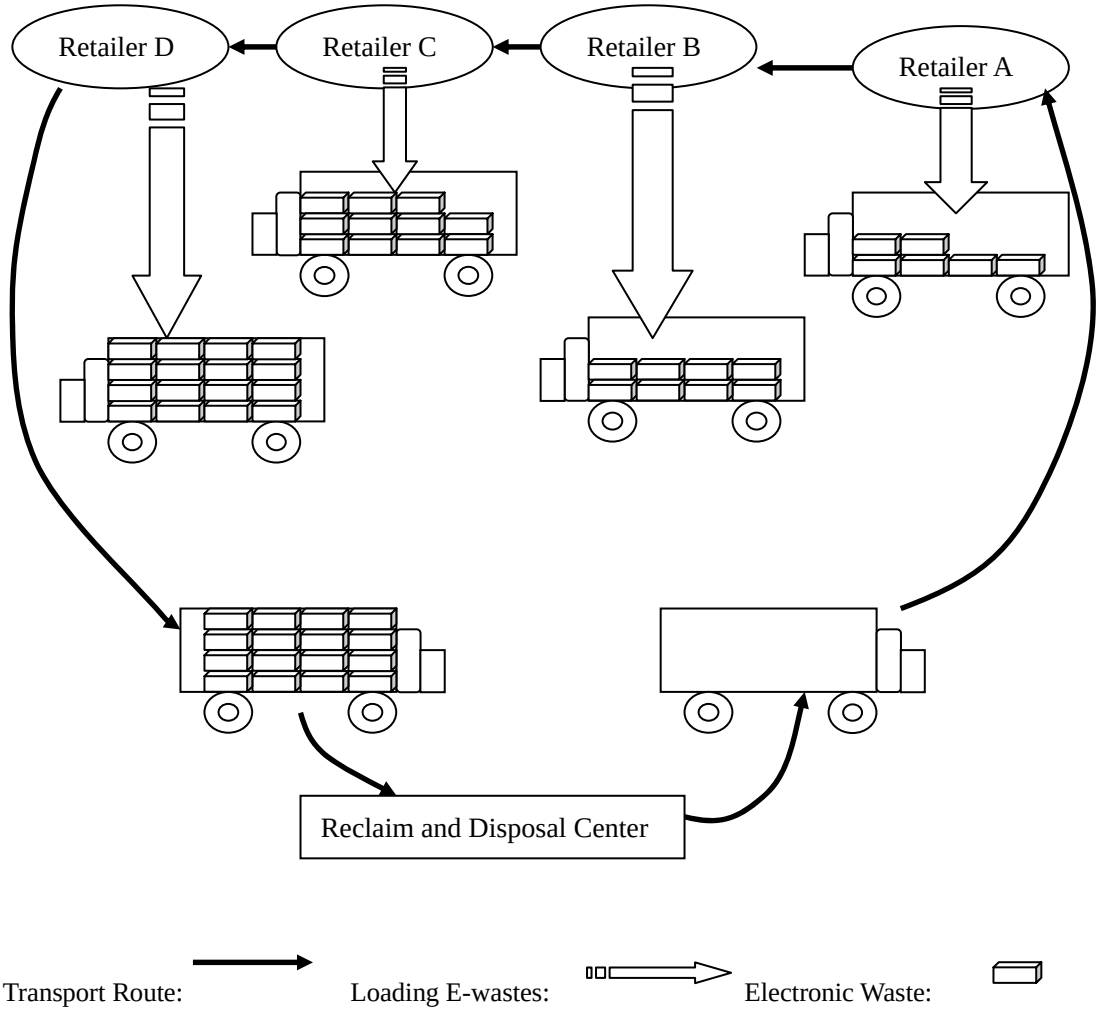

Figure 5-6: The Sketch Map of Recycle from Retailer to Center Ⅰ

The other circumstance is that TPL bear the manufacturers' forward and reverse logistics businesses. In this circumstance, TPL recycle the e-wastes when they deliver goods to retailers. TPL reduce the number of times to recycle e-waste and save the transportation cost. If individual retailers don't order goods in short term, TPL should also assign special truck to collect e-wastes with the above arrangement of first case.

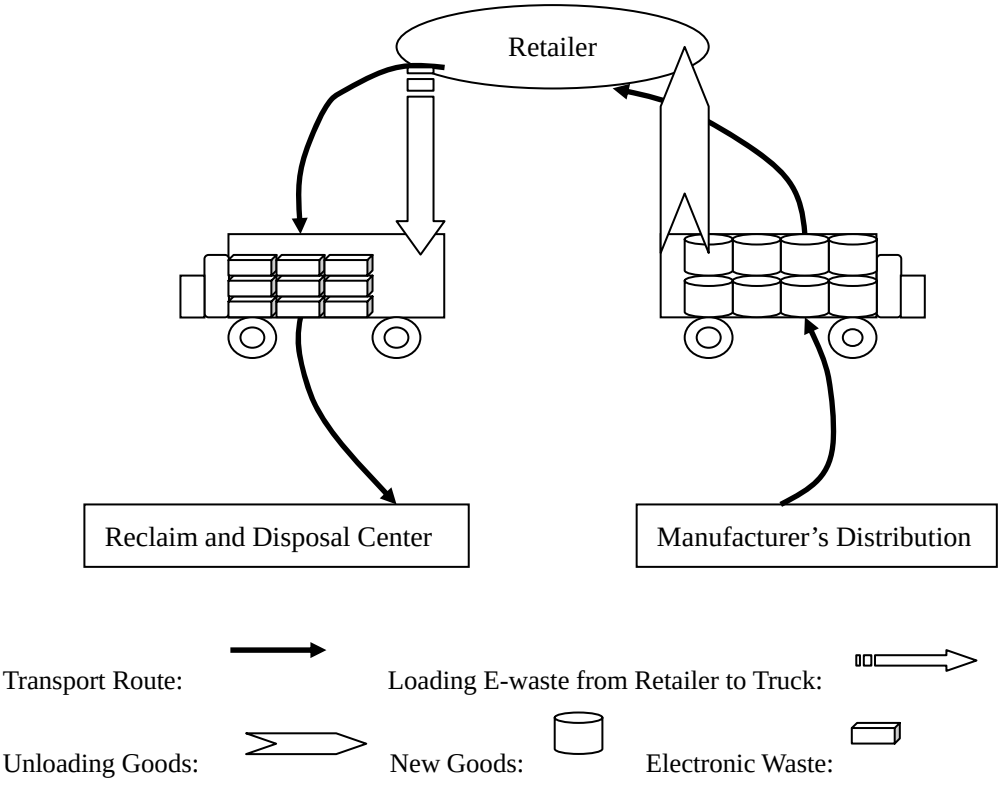

Figure 5-7: The Sketch Map of Recycle from Retailer to Center Ⅱ

2).TPL Transport E-waste from Recovery Center to Manufacturers

In Union Mode, TPL is responsible for the inventory of e-waste. If TPL master the information of e-waste in center and plants, information could be shared with manufacturers. So the reclaim and disposal center can be regarded as supplier for reprocessing. In this center, managerial expertise of TPL is qualified, which concentrate competitive advantages of TPL on dealing with e-wastes. To ensure the consecutive operation of center, TPL must grasp the quantity of e-wastes waiting for treatment and be on the way through sharing information. In accordance with the manufacturers' demand of e-waste and the speed of treatment, TPL assign the transportation schedule and the quantity. The operations of reverse logistics in this process are similar to suppliers' customer management in forward logistics.

5.3.3.3 Internal Operation Flow of Reclaim and Disposal Center

Reclaim and disposal center is a hub of the whole process of Union Mode of e-waste reverse logistics. There are seven main steps of internal flow of reclaim and disposal center. Step one, accept e-waste and input related information to database, such as quantity, type and quality. Step two, identify and examine the condition of e-wastes. Qualified e-waste can go back second-hand market, otherwise prepare to dismantle. Step three, sort the e-wastes. Step four, clean the e-wastes. Step five, dismantle the e-waste according to the design drawing and classify the different parts and materials. Step six, confirm the transportation schedule and quantity of e-wastes to manufactures. This step is base on the manufacturers' materials inventory and purchasing plan. Step seven, sell some parts and materials which are valueless for manufacturers to suppliers or other manufacturers with market price. And transfer electronic garbage to professional dumps. The following figure shows the internal flow of reclaim and disposal center and the relationship with external enterprises.

From the internal flow of reclaim and disposal center, the center has two basic functions. On the one hand, the center bear the traditional logistics functions, such as inventory and distribution, on the other hand, center deal with some professional technology operations, such as inspection, sorting, dismantling and repair. The classification of functions is bases on the various parties in charge. The first part of function is provided by TPL and the second by manufacturers.

1) The function of inventory and distribution

The reclaim and disposal center will accept the e-wastes initially tested by retailers. These e-wastes are stored and/or distributed according to inventory and demand of manufacturers; all of activities are similar to forward logistics. Some reusable

e-wastes that have been cleaned or repaired enter into the second-hand market. And some parts and materials of e-waste are not useful for manufacturers, which can be transacted with other manufacturers or suppliers. At this time TPL should complete this mission of transportation.

2) The function of professional technology

In reclaim and disposal center, professionals from manufacturers examine the e-wastes. Although these e-wastes have been initially checked, manufacturers well know the products designed and produced by themselves. After professional rebuilding, some used electronic products are still valuable. In light of the natural capacity of electronic products, professionals will dismantle, classify and sort some un-reusable e-wastes to bring the parts and materials of e-wastes into play fully.

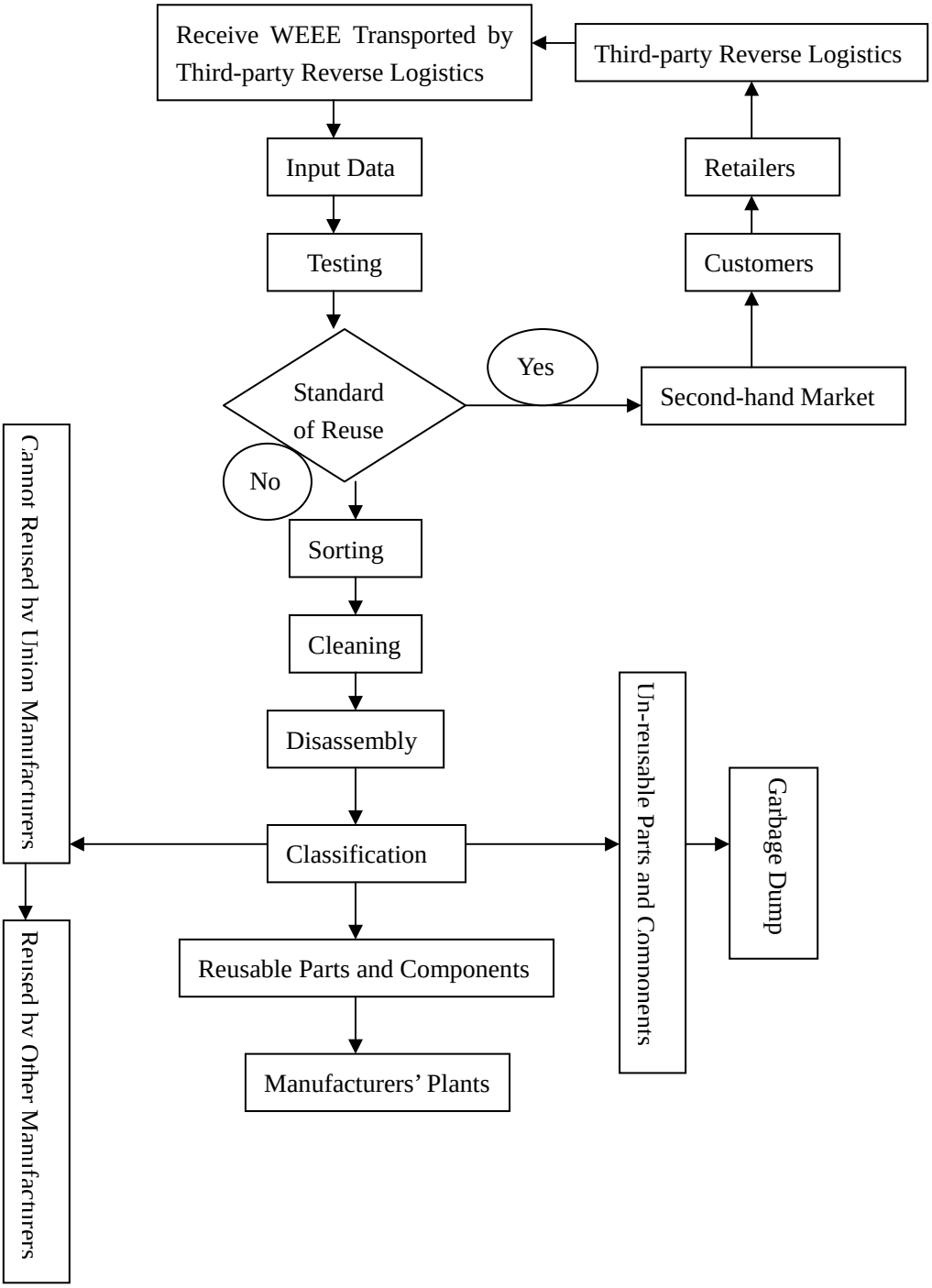

Figure 5-8: The Internal Flow of Recovery Center

5.3.3.4 Distribution from Reclaim and Disposal Center to Manufacturers

This distribution activity correspond to the sixth step of inter flow of reclaim and disposal center. Some reusable parts and materials will be delivered to plants of manufacturers and reused directly in reprocessing. In this link, plants of manufacturers and the center should communicate timely with each other. Manufacturers decide the purchasing plan according on the demand and inventory of materials through information sharing database. If the inventory of plants' warehouses and recovery center cannot satisfy the manufacture demand, manufacturers should order materials from suppliers. Distribution plays an important role in balance the demand and supply of materials. Before arranging the distribution plan from reclaim and disposal center to manufacturers, checking the plant's purchasing plan and inventory is necessary.

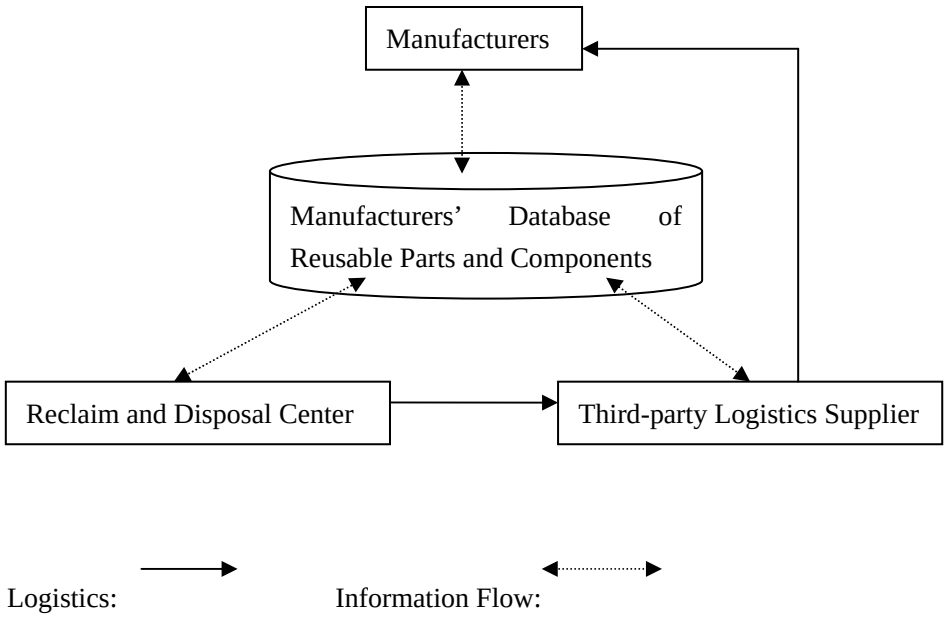

Figure 5-9: Flow from Recovery Center to Manufacturers

There is a great difference between the flow of e-waste reverse logistics and production forward logistics. Because the demand of production is relatively accurate (based on the previous data), and the production and logistics activities are continuous. However, the complicated and distracted reverse logistics has brought about the unfixed time and quantity of recycling. So imbalance circumstances of e-waste reverse logistics always occur. Sometimes the quantity of recycle is very large, and sometimes it is very small. It requires enterprises to pay attention to set up the database of information sharing and communicate timely.

5.4 Conclusion

The main target of this chapter is to discuss how to construct the Union Mode of e-waste reverse logistics. According to the targets and principles of construction, I design the flow of different operation in Union Mode after confirming the organization alliance.

6 Conclusions

Facing unreasonable e-waste recycles and serious environmental pollution, Chinese government accelerates the legislative process and requires manufacturers to take responsibility for e-waste recycle and treatment. However, the vast majority enterprises, in China, are lack of experience in e-waste reverse logistics. In this circumstance, Chinese enterprises have to consider how to resolve the problem of e-waste, that is, how to organize the e-wastes reverse logistics from customers to manufacturers with low cost and high efficiency. From the analysis of developed countries' traditional recycle modes and China's actual situation, I find that Chinese majority enterprises are not appropriate to adopt these traditional modes. Because the economic strength and technological level are not enough, we should establish a suitable recycle mode in China. This dissertation launched based on China's actual situation and the characteristics of e-waste a Union Mode of e-waste reverse logistics. In this mode, some current difficulties of e-waste recycle can be solved through cooperating with due division of labour between retailers, TPL and manufactures. In this dissertation, I proved the scientificness and feasibility of Union Mode through utilizing value chain, transaction cost theory and mathematical calculation. And I also discuss the construction of Union Mode. I also try to construct the Union Mode through discussion of the organization alliance and operation flow.

Any enterprises can not take advantage of all the links of e-waste reverse logistics for their own constrains of resources and capacities. Therefore, retailers, TPL and

manufacturers must develop a Union Mode by complementary cooperation to decrease investment, reduce cost and increase profit. Besides, I prove the important role of retailers in Union Mode by mathematical calculation. To save the transaction cost and keep the enterprise's agility, Union Mode requires strategic alliance organization. In this alliance organization, each partners should operate related activities according to flow in order to make fully use of partners' advantages.

Union Mode effectively conquers problems of low efficiency and serious environmental pollution compare with the recycle mode of small workshop and second-hand traders. And this mode fully uses the existing community resources, saves investment and cost and increase the competitiveness of reverse logistics value chain compare with developed countries' traditional recycle modes. Therefore, Union Mode of e-waste reverse logistics is appropriate for current electronic industry and logistics industry.

The Union Mode of e-waste reverse logistics constructed in this dissertation provides a new train of thought of recycling e-waste. In this mode, manufacturers gain a high efficiency, environmental friendly and economic recycle with a small investment. At the same time, the value of e-waste is tapped fully.

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