Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China

The HEA (household electrical appliances) manufacturers’ perspective

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SUMMARY

Linnaeus University, School of Management and Economics, 5FE02E, Spring 2011

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Background: With economic development, the requirement of public for enterprises and products has become increasingly rational. Price is no longer the only consideration of public, they also pay attention to other factors, such as energy conservation. The manufacturers face enormous challenges because of the late start of products recycling in China. So enterprises start to build their own recycling logistics system in order to have more competitive for themselves.

Purpose: The purpose is to describe the methods of inventory controls in the case HEA manufacturers and the problems of inventory controls, find out what problems exist in the case manufacturers, then analyze what are the origins of these issues for HEA manufacturers as well as propose how these issues can be alleviated, and what methods would be suitable. By solving these research questions, the thesis tries to offer some suggestions about inventory control improvement not only to the cases, but also wider to the whole HEA manufacturers in China.

Method: Multiple-case study as research method has been applied. Specifically, two case companies, Chinese HEA manufacturers, have been selected. Two telephone focused interviews combined with open-ended interviews have been conducted with two related managers. The empirical evidence has been analyzed by using with-in case study and cross-case analysis method, then model analysis is applied.

Results, conclusion: First, the methods are not good enough in the two case companies, a new model is built to help inventory control in the case companies. Second, from external and internal perspective, the origins to cause the problems are a lot, but the main causes are environmental factors, and in busy seasons of these companies. Besides, for doing reverse logistics is a capital costing job, none of the enterprises would like to step in. and reverse logistics is in an uncertainty environment, doing so need to make sure everything clearly and orderly, or costs will be a large amount. The best way of improving inventory control of WEEE reverse logistics in China is that the enterprises standing together to restore the orders.
Limitations and drawbacks: For one thing, there are not enough previous studies references in China, this brought some difficulties of supporting the view points in the thesis. Two empirical cases are not persuasive enough to represent the whole China due to the limitation of the authors’ knowledge and the huge area of China. Nevertheless, the ideal model in model analysis is not that complicated, which means, for more complex problems and processes, the model would be lame.

Keywords: Reverse logistics, inventory control, HEA manufacturer, WEEE, China, inventory model, Haier, Midea.
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1. Introduction

The introduction chapter intends to provide an overview of the subject, motivation, and purpose of this thesis. It opens with a background of reverse logistics of WEEE in China, especially in HEA\(^1\) (household electrical appliances) manufacturers, inventory control in this field is also referred, giving the reader insight to the important role of inventory control in reverse logistics of WEEE. Thereafter, follows problem discussion, research questions and purpose.

1.1 Background

With economic development, the requirement of public for enterprises and products has become increasingly rational. Price is no longer the only consideration of public, they also pay attention to other factors, such as energy conservation. The manufacturers face enormous challenges because of the late start of products recycling in China. So enterprises start to build their own recycling logistics system in order to have more competitive for themselves.

China is one of the world's largest household electrical appliance producers and country of consumption. From the data of State Statistics Bureau, the domestic HEA began to enter the family from 1980s. In 2004, the output of television sets, washing machines, refrigerators, air conditioners, computers is 0.35 billion units, and the maintain social is expected to exceed 10 million units. According to the normal life of HEA which is 10 to 15 years, most of them have been entered or is about to enter retirement period. China will enter the peak of HEA scrapping, which means that the amount of annual retirement of television sets, refrigerators and washing machines

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\(^1\) HEA stands for “household electrical appliances” in this thesis, in the following texts, it won’t be explained.
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will reach 5 million, 4 million and 6 million units, respectively. After adding the amount of air conditioning, mobile phones, computers and so on, there will be a total of 30,000,000 units around of the HEA scrapped. With the application of high technology, the replacement cycle of electronic products is greatly shortened, number of which is very large. With the "Regulations of waste HEA recycling" promulgated formally and the growing awareness of public's environmental protection, it is urgent to establish a scientific, large-scale recycling system of waste HEA. The lack of a perfect logistics system, a professional logistics company and the successful experience of poor reverse logistics results reverse logistics of waste HEA in an uncertain environment and causes great difficulties for the reverse logistics of waste HEA. (Lian, 2006)

Liu and Shang (2005) state that HEA manufacturers as the terminal of recycling phase of used HEA, which occupy a very important part in reverse logistics. Starting from HEA manufacturers on the feasibility of waste HEA controlling is a necessary and important link to achieve the HEA recycling system. Under the guidance of sustainable development strategy, HEA manufacturers need to design logistics processes according to the idea of circular economy, reduce waste generation and promote cyclic utilization of raw materials and energy to achieve the double benefits of economic growth and environmental protection. To achieve the double benefits pursued, HEA manufacturers need to focus on the research management of waste HEA in reverse logistics. Reverse Logistics for circular economy pursuit circulation of materials from raw material, intermediate products waste material to the product in the production process to make the optimal use of resource, energy and investment.

Li (2005) states that the sign which determine that the reverse logistics management is good or bad is how to reduce return product inventory as soon as possible to restore it back to reusable products. The first is to reduce occupied funds of returned product
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inventory. The second is to obtain the value from returned product and create greater profits. Because the returned products are old and damaged products, their statuses are bad. And if these products cannot be handled in time, the situation of products will further worse as time increases. Liu and Shang (2005) argue that reduce the cost of reverse logistics and recover the value of return product inventory to the utmost extent is the main objective and significance of improving the return inventory management. Therefore, how HEA manufacturers to manage return appliance inventory has become a maverick in the competitive strategy, which also become a powerful tool to enhance competitiveness. Good manager of reverse logistics will make their company to win the competition. When most of enterprises are indifferent of reverse logistics, some companies have realized that it is very important even strategic to improve inventory management of reverse logistics. Smart managers can obtain a lot of profits each year by improving inventory management. Effective inventory system of reverse logistics and inventory management process can save costs, increase profits and improve customer service.

In inventory management of reverse logistics, there are many uncertain factors affecting the manager to make a decision about stock options. So making an inventory strategy analysis of HEA in reverse logistics in uncertain environment has its practical significance. (Lian, 2006)

1.2 Problem discussion

There have been a lot of studies and researches which focus on reverse logistics of WEEE, and also inventory in reverse logistics. But studies in China have many limitations, besides, there are some blanks of studying in China.
Reverse logistics of WEEE

Without a formal definition, according to the authors’ knowledge, WEEE (Waste of Electronic and Electrical Equipment), or "waste electrical and electronic products", referred to as "electronic waste", is an industrial electronics, home appliances, communication products, information appliances, entertainment appliances and other waste products, collectively. From the 20th century in the late 90's, China introduced the concept in.

According to Hawks (2006), reverse logistics is: The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics.

In many developed countries and regions, people have been paying attention to reverse logistics of electronic products since earlier, now the system has become more complete, meanwhile, they have many representative theories and methods.

Germany, Canada, Britain and some other countries have carried out extensive research and practice in the field of waste removal technology, recycling technology and other aspects. The concept of reverse logistics has been introduced into these countries dozens years before.

Noller (1992) makes a summary of the design on the recovery of the past 5 years, describes the general principles of HEA and methods of design, material selection,
and the recycling of waste products, treatment strategy. Spicer (1995) holds the idea that the environmental awareness of the design should take into account of all stages of product life cycle, namely, raw materials extraction, product manufacturing, product use, scrap and recycling of products. And makes a comprehensive assessment on the products in each stage might have environmental impacts, takes appropriate coping mechanisms to minimize pollution of the environment. Whitmer et al (1995) propose a model based on environmentally conscious design of the product, discourse the product forms of retirement after four treatments (reuse, remanufacturing, recycling and waste disposal), and the impact the design of product recovery factors (time, materials, energy, cost, modularity, etc.) were considered. Borland and Wallace (2000) ecological impacts from the product life cycle and recycling aspects of economic evaluation and analysis of the two, by giving different levels of under recovery of the ecological impacts of values and the corresponding cost recovery, scrap recycling for products and product re-design of some theoretical basis. Hong Chao Zhang put forward a recovery of a material management decision-making framework model of the system, and the recovery of PCB and plastic products as an example to explain. (Zhang and Ling, 1999) Sodhi and Reimer (2001), respectively, from the waste products of manufacturers, recyclers, and material handling business point of view to establish a recycling economy model and a systematic analysis. Klausner and Hendrickson (2000) studied the EPR system, the companies used in the implementation of product recall, should be how to reduce costs. Germany's power tool product recovery, for example, the cost of processing and recycling from the two aspects of freight improvements, and the use of quantitative analysis tools.

In brief, WEEE reverse logistics in western countries has developed a lot, and many researches materials can be found, which are about plenty of kinds of WEEE reverse logistics aspects.
Reverse logistics of WEEE in China

With the improvement of living standards of our people, combined with continual upgrading of electronic products, appliances large quantities into the homes of ordinary people, while a large number of discarded home appliances are also being eliminated, updated, our 380 million annual household waste generated by household appliances the amount is huge. Compared with advanced countries, China's HEA studies in the waste recovery and utilization are not doing enough.

Discarded appliances in China in recent years, reverse logistics of WEEE has made some progress.

Some of our experts, industry associations and relevant government departments have all WEEE reverse logistics or ongoing research, and some results have been obtained to practical application. One valuable study include: Li (2005) stressed the importance of legislation and proposed recycling State should establish a special subsidy system, the development of relevant management practices, that this is in line with international practices, but also for enterprises to participate in international competition to create a fair environment. Yan (2005) WEEE reverse logistics of building that should learn from foreign experience, combined with China's national conditions, efficient use of special tools + equipment + process route of artificial technology, so that the economy, efficiency, safety, environmental protection, efforts to reduce costs and increase value-added. Zhang (2004) the United States, Japan, the European Union's WEEE reverse logistics system from the laws and regulations, the use of economic instruments, recycling network operation, process technology R & D carried out a brilliant four square analysis. China Household Electric Appliance Research Institute launched in February 2002, "household waste recovery and recycling technology" project, servers, the economic regeneration of the former Ministry of Domestic Trade Research Institute developed a "waste refrigerator,
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freezer box steel recycling process," "motor winding core and magnet wire separation device." In addition, AQSIQ issued in July 2005 for the EU ROHS Directive 6 standard detection methods, respectively, by atomic fluorescence spectrometry, flame atomic absorption spectrometry, diphenyl hydrazine spectrophotometry, x-ray fluorescence spectrometry, HPLC and GC-MS method detected 6 kinds of harmful substances, and will be January 18, 2006 come into operation, also announced a national commitment to electrical and electronic products of 18 hazardous substances in the laboratory detection tasks list. August 2005 China Household Electrical Appliances Association, commissioned by the National Development and Reform Commission jointly Haier, Little Swan, Gree, Panasonic, Sony, Siemens launched six companies (the Chinese home appliance recycling waste disposal charging mechanism "issues, mainly of foreign waste appliances with the closing mechanism and the cost of standard treatment costs; the study of Chinese discarded appliances operating mechanism and management mechanism and pricing mechanism; estimated cost of processing the Chinese home appliance recycling waste; design cost of China's waste recycling standards for household appliances; Finally, the formation of "China's cost of recycling of waste appliances management approach, "draft. (China Household Electrical Appliances Association) These studies have been or will be the same as in the construction of WEEE reverse logistics system to provide a scientific basis and valuable experience.

All in all, these researches show that China has been having a great progress in developing WEEE reverse logistics, and many aspects are referred. Meanwhile, the researches are all based on the literatures of Western countries etc., but not that much about the practical uses in China, some researches would be better or more convictive with empirical cases.
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Inventory control of reverse logistics

Dozens of researches on inventory control of reverse logistics have been made, and many inventory control models have been presented also.

Foreign scholars study of reverse logistics inventory early start, but until the late 90s of last century, research in this area have a more extensive development. Besides, domestic scholars on the issue of reverse logistics inventory less the research literature, and the issue of reverse logistics inventory data for in-depth analysis of the article is not much. Huang (2003) proposed a model to allow return of inventory control. Huang et al. (2004) proposed a reverse logistics EOQ with delay extension order model. And then, many scolars studies inventory control models in reverse logistics, they are all developed in models built, and developed in calculating, but none of the researches are related to empirical findings. Most of the researches are about inventory models, meanwhile, not other inventory methods are applied in management control.

1.3 Research questions

Given considerations above, reverse logistics has been studied for long time in foreign countries, reverse logistics is also start to be studied these year. For WEEE reverse logistics in China, not so many references show that the studies are going further into reality. Considering the inventory control of WEEE reverse logistics in China, there are many models discussed, but the models are kind of too complicated, moreover, they are not useful for the enterprises in reality. Based on the problem discussion, the research questions to be addressed in this thesis are:

*RQI: What methods of controlling inventory in reverse logistics system exists in the case of HEA manufacturers?*
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RQ2: From HEA manufacturers’ perspective, what factors could be the origins of the problems they meet in inventory management of WEEE reverse logistics?

RQ3: How can the identified problems be alleviated?

1.4 Purpose

The purpose is to describe the methods of inventory controls in the case HEA manufacturers and the problems of inventory controls, find out what problems exist in the case manufacturers, then analyze what are the origins of these issues for HEA manufacturers as well as propose how these issues can be alleviated, and what methods would be suitable. By solving these research questions, the thesis tries to offer some suggestions about inventory control improvement not only to the cases, but also wider to the whole HEA manufacturers in China.

1.5 Framework of this thesis

Figure 1.1 shows the framework of this thesis.
2. Methodology

In this chapter the methodology choices for this thesis are described. Multiple case studies is discussed as a research strategy. Furthermore, it is described selection of the empirical cases, and the way of collecting data, directed by the methods. Besides, based on the data, data analysis is also outlined, by comparing the data and materials with model in ideal environment, to make a further analysis. Finally, it is presented how requirements on the scientific credibility will be fulfilled.
2.1 Case study in Deductive research – research strategy

According to Mark et al. (2009), there are many different research strategies could be used for exploratory, descriptive and explanatory research, and some of these clearly belong to the deductive approach, others to the inductive approach. For some research projects you will use the literature to help you to identify theories and ideas that you will test using data. This is known as a deductive approach in which you develop a theoretical or conceptual framework, which you subsequently test using data. For other research projects you will be planning to explore your data and to develop theories from them that you will subsequently relate to the literature. This is known as an inductive approach and, although your research still has a clearly defined purpose with research question(s) and objectives, you do not start with any predetermined theories or conceptual frameworks. (Mark et al, 2009) Recalling the previous problem discussion in the introduction section, researches both in China and abroad, show that many studies has done on reverse logistics, and there are a lot of models for inventory controls, but merely studies about inventories controls in reverse logistics, not even related in empirical cases. So the main purpose of the thesis is to find out ways of improving inventory controls in reverse logistics of China, both in theory and in practice. As referred above, a deductive research is suitable for the thesis, which can be introduced as research approach.

To assist deductive research, case study would be a good choice as research strategy. Yin (1981) claims that the case study does not imply the use of a particular data collection method. What the case study does represent is a research strategy. Yin (1994) claims that the case study is particularly suitable when the research questions are “why” and “how” as opposed to the survey strategies research questions of “who, what, where, how many and how much”. In addition, Yin (1994) concludes that the case study as a research strategy is preferred when we are examining contemporary events. Which has been declared that the purpose of the thesis is to find out how to
improve inventory control? Besides, the research questions are all about “what”. So case study is reasonable for the thesis as research strategy.

2.2 Research Methods
Given the considerations above, research methods in the thesis can be outlined as following, qualitative method and multiple case studies.

Qualitative Methods
Denzin and Lincoln (1994) argue that the word qualitative implies an emphasis on processes and meanings. These processes and meanings are not rigorously examined, or measured, in terms of quantity, amount, intensity, or frequency. Similarly, Alvesson (1996) states that the arguments for qualitative research are based on its increased possibility for broad and rich descriptions and its sensitivity for the ideas and meanings of the individuals concerned. As mentioned above, the thesis is more a deductive research, usually quantitative methods are used in deductive research. On the other hand, qualitative research is generally gaining recognition in logistics (Golicic et al., 2002; Mangan et al., 2004), resulting from the entrance of behavioral approaches in the discipline (Kent and Flint, 1997). Traditionally, quantitative methods were often linked to deductive and qualitative to inductive research approaches (Hyde, 2000; Mentzer and Flint, 1997). However, qualitative research is not inductive per definition; also deductive research can employ qualitative methods (Hyde, 2000). In another word, we can say, it is suitable that logistics researchers employ qualitative method in deductive research.

In this thesis, as mentioned above, there are lack of practical studies on inventory control in reverse logistics of China. So it is important to know the knowledge in this area, it’s about understand, rather than focus on a single entity, to solve the exactly problems in the entity. Qualitative measures serve a useful purpose when one is
attempting to understand the world from the perspective of the potential customer (Calder, 1977; Dougherty and Hardy, 1996). This qualitative method fits the thesis’s purpose very well.

**Quantitative Methods**

Bryman and Bell (2007) define that quantitative research is a distinctive research strategy that emphasizes quantification in the collection and analysis of data. In quantitative research, as the term suggests, data are collected and analysed in numeric form, which tends to emphasize relatively large-scale and representative sets of data, and is often, falsely in our view, presented or perceived as being about the gathering of facts. In studies of inventory controls, it is more convicitive to have quantitative methods as supports, especially with inventory control model, data explains and represent the reality. With changing data, models can assist the inventory control perfectly. So in this thesis, quantitative methods will be applied into analysis part.

**Multiple case studies**

Ellram (1996), claim that a single case is used to “test a well-formulated theory, an extreme or unique case, or a case which represents a previously inaccessible phenomenon”. Multiple cases, on the other hand, “represent replication that allow for development of a rich theoretical framework” (Ellram, 1996). Besides, without spending a significant long period in the entity, there won’t be extremely relevance gained. So to get more knowledge in the area within a limited period, more case studies of less depth is practical than a single case study. And to cover a wider range, comparison of multiple case studies is more convicitive. Furthermore, another reason for why this approach has been used is that the analytic conclusions based on multiple cases will be more powerful than those arising only from one case (Yin, 2003).
2.3 Sample selection

According to Hyde (2000), what is required in qualitative research is to formalize the deductive processes employed. The use of “hold out” samples might be included in formal procedures. Strict deductive procedure requires that the dataset used as the source of theory building is not the same dataset as that used to test that theory. Sample selection is crucial in case study and selection of the cases has been made by applying theoretical sampling as the purpose was to identify cases which can contribute to an existing theory (Eisenhardt, 1989). As the basis above, in order to describe inventory problems in WEEE reverse logistics of China from the manufacturers perspective, two HEA manufacturers have been selected for purpose of collecting empirical evidences. For the reason that in China, there are not so many enterprises have the authorities of handling WEEE, and do the series of reverse logistics activities. Besides, not every enterprise has its own warehouses, the outsourcing strategies are not discussed in this thesis. To cover the whole area of China, two enterprises are chosen: Haier, which located in Northern part of China, and Media, which located in Southern part of China. Besides, both Haier and Media have their own warehouse, and the two enterprises are authorized by the government to manage WEEE recycles. Nevertheless, quantitative methods require enough data for the analysis, since the two cases have been doing WEEE recycling for years, the database would be better in this thesis, and the two enterprises have developed their own inventory theories or control methods, this reduce the uncertainties, which means the analysis can go deeper of the problems rather than discuss only problems may caused by many uncertainties. The two enterprises, have similar scale in size and in ROI, which will describe in empirical findings, the two cases are easier comparable.

2.4 Case study protocol

Large field studies require careful monitoring throughout their conduct. Protocols need to be determined and laid out in advance. Theories related to inventory control
were studies to develop a theoretical framework to design the inquiry form for data collection, and also, the theories were studies to be able to generalize the results of the case study. Analytical generalization has been applied as the previously developed theoretical framework served as a template with which the empirical results have been compared (Yin, 2003). A preliminary case study protocol based on previous research and existing literature has been laid out. The protocol comprises of two parts; case study plan and interview guide. Case study plan includes procedures that need to be followed during conducting of case study. It comprise consist of research question, statement of the purpose of the thesis, unit of analysis, methodology, sample selection, basic outline of overall case study report, collecting evidence, data analysis and time table (Ellram, 1996) (see Appendix I). Interview guide has been developed based on the presented theoretical framework related to the subject of inventory control in WEEE reverse logistic.

2.5 Data collection

It is a common way by using interviews and assisted by materials collecting for data collection as the source of empirical evidence.

According to Keegan (2009), materials collection could be researching accessible data sources, such as newspapers, magazines, social networking or other internet sites, or reading existing qualitative reports. Creative forums in which participants, chosen for their creative abilities, work together on problem definition, idea generation and evaluation. Keegan’s ways will are more or less followed in this thesis, but focus on collecting texts and words from internet, books, newspaper, annual reports of the organizations, some other materials from organizations. The materials will be collected first, then sifted, the left which are about organizations’ environment, inventory control, background, etc. will be translated into English, attached in appendix.
Interviews would be telephone interviews, which are half-opened, for the knowledge limitation and study level of the thesis, the interview questions comprise of two main parts, questions with options and questions with open-up answers. Each interview lasts approximately 1 hour, and manager of logistics department, general manager of the organization will be interviewed.

### 2.6 Data analysis methods

In the thesis, based on the data collected, and in order to analyze the evidence collected from interviews and materials, firstly, with-in case analysis will be applied, external factors and internal factors are divided to analysis the origins of the problems that the two case companies met. And then by comparing the data they presented and the analysis of with-in case analysis, a cross case analysis is made to double confirm the origins are reasonable and convictive, based on the analysis, model analysis is made to solve the problems that the companies met, which is based on the theory work process, then calculation will be done, with the results from the model, some conclusions about the model will also be made. A table has been developed that comprise of the manufacturers (listed horizontally) and of data categories within the research questions (listed vertically). (Ellram, 1996)

### 2.7 Scientific credibility

Scientific credibility has been defined as the extent to which science in general is recognized as a source of reliable information about the world. (Bocking, 2004) According to Yin (2003), as a research design is expected to represent a logical set of statements, the quality of a given design can be judge according to four logical tests based on notions about trustworthiness, credibility, confirmability, and data dependability. There are four tests to be used in order to establish of any empirical
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social research. As case study as a research method is included in the social research the four tests were relevant for such research method. Specifically, good research design needs to fulfill requirements regarding external validity, reliability, construct validity and internal validity. The requirement on internal validity is only relevant for explanatory case studies. (Ellram, 1996)

**Internal validity**

Saunders et al. (2009) defines internal validity as the extent to which findings can be attributed to interventions instead of any flaws in the research design. The problem of internal validity for case study research is making inferences. Therefore, within-case study-an analytic technique for case study data by building an explanation about the case (Yin, 2008), will be used to deal with this problem. Rival explanations among the two companies of different locations chosen in this thesis are revised and managed to fit into each other in order to achieve internal validity. Moreover, both interview and documentary evidence are collected to enhance the correctness of inference.

**External Validity**

In order to be able to generalize results beyond the selected case study samples (unit of analysis) it is crucial to achieve external validity. In other words, how precisely the results represent the phenomenon that is studied is related to generalizability of results. (Ellram, 1996) Multiple case study approach in this thesis supports invalidity, besides, the analysis follows theoretical framework, and inventory model is used in analysis part to assist the case study analysis. But as the sample selection mentioned, the multiple case study approach can give references to other researches, and can also contribute to the whole area, at least parts of the area.

**Reliability**

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Reliability concerns the repeatability of the study, which means that if another researcher would conduct the same study the findings would be the same. (Maylor and Blackmoon, 2005) According to Ellram (1996), in case study method, there are two ways how to achieve reliability; case study protocol and development of case study data base. In this thesis, case study protocol is developed consisting of all the procedures followed during conducting the case study, nevertheless, by collecting materials and interviews by telephone, case study database will be developed.

**Construct Validity**

Pennington (2003) States that construct validity refers to whether a scale measures or correlates with the theorized psychological scientific construct that it purports to measure. In other words, it is the extent to which what was to be measured was actually measured. It is related to the theoretical ideas behind the trait under consideration. According to Ellram (1996), the establishment of construct validity is associated with the following three elements; multiple source of evidence, establishing a chain of events and review the case study research made by key informants.

Multiple source of evidence in the thesis refers to a chain of evidence, both by material collecting and interviews. Establishing a chain of events allows reader to follow the case study data from the first beginning of defining the research questions to the very end of getting the conclusion, and the whole case study report is examined by two reviewers (tutor and examiner), from the research question, to case study plan, to analysis. Reviewing the case study research made by key informants refers to the informants who are interviewees and organizations in the thesis, the draft will be sent back to them when the interviews recording is finished, to review the interview, then the case study report will sent to them also when it is finished.
2.7 Summary of methodological choices

The following *Figure 2.1* a summary of methodological choices relevant for this thesis is presented.

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*Figure 2.1:* Summary of methodological choices relevant for this thesis

3. Theoretical framework

In this chapter, reverse logistics is applied first, by showing reverse logistics’ workflow, and features, a general acknowledge of reverse logistics is shown.
Then according PEST analysis, a WEEE reverse logistics in China is showed, the workflow is also showed, and what problems in WEEE reverse logistics in China, which means the problems caused by environmental factors, and what the origins problems are, then give some theories which might solve these problems. Then inventory theories are applied, the workflow of WEEE reverse logistics in China is illustrated, key elements and features of inventory are also showed in this part. After these base theories, advanced inventory theories are applied in the following 2 parts, one is theories about inventory models, and the other one is theories about inventory methods.

Figure 3.0 Relations between research questions and theoretical framework. (Own design)

Figure 3.0 simply illustrates the relations between research questions and theoretical framework, part 3.1 and part 3.2 are related to research question 2, which mainly show external factors theories of the origins, part 3.3.1 and part 3.3.2 are related to research question 2 as well, which mainly show internal factors theories of the origins, part 3.3.3 is related to part of research question 3, part 3.3.4 is related both research question 1 and research question 3, part 3.4 is related to research question 3.
3.1 Reverse Logistics

Although the definition of reverse logistics is defined for many statements, but there is no uniform concept in the end. Council of American Logistics Management (CLM) (1998) makes the definition of reverse logistics, it is described as follow: it is in the opposite direction with traditional supply chain, for restoring value or reasonable disposal, to make the effective planning, management and control process for raw material, intermediate stocks, final products and related information from the consumption site to starting point.

Two points must be described and added for the definition above: First, the purpose of reverse logistics is not just to restore value and reasonable disposal, it also should include to reduce costs, improve customer satisfaction, set up competitive advantage and achieve sustainable development at the community level and enterprise level. Second, consumption site and starting point should be the two generalized concepts, they can be located at the any point between the terminal point of consumption and raw material supply point, that means reverse logistics can start or end at any point between consumption point and raw material supply point. For example, recycled computer chips do not have to return to the status of raw materials, but can be converted into new products. (Klausner and Hendrickson, 2000)

Song (2007) claim that reverse logistics can use all or part of channels of forward logistics, or use different channels of forward logistics. The direction between forward logistics and reverse logistics is opposite, in a sense, reverse logistics is a inverse process of forward logistics.

Reverse logistics is a very broad concept. Generalized speaking, reverse logistics represent all related operations about products and raw materials recycling. The management of these operations is related to recovery management, involving reprocessing production, re-grinding and other activities. Reverse logistics is not just
re-use of packaging containers and recycling of packaging materials, it also includes re-designed packaging to reduce raw materials use, transportation, energy use of other important activities and pollution and so on. Reverse logistics also involves dealing with returned purchase due to damage, seasonal inventory and excess inventory, etc. And recycling programs, hazardous materials programs, the disposal of obsolete equipment and resources recycling is involved in reverse logistics as well. (Song, 2007)

3.1.1 The workflow of Reverse Logistics in Supply Chain

Zeng and Sun (2003) claims that reverse logistics consists of the following links:

**Recycling**

The product which is held by customers is returned to sellers by way of paid or unpaid. The seller we said may be any node in the supply chain, such as products from the customer may be returned to the upstream suppliers and manufacturers, or may be returned to downstream distributors and retailers.

**Testing and treatment decisions**

According to figure 3.1, this process is related to testing and treatment section. To test and analyze the function of recycled products, and according to the structure and characteristics of products and performance of the various components to determine
the possible treatment proposals, including direct re-sale, the sale after reprocessing, the re-use of components after spin-off and the scrap processing of products or components. Then, to make the cost-benefit analysis for projects in order to determine the optimum treatment project.

**Disassemble and re-processing**

According to the structure and characteristics of products to split the product into components, processing the recycled products or components after splitting to restore its value. This can be related in figure 3.1, disassembly section.

**Scrap processing**

For those recycled products or components which harm the environment seriously or without any economic value, they will be destroyed by mechanical treatment, landfill or incineration, etc.

### 3.1.2 Characteristics of Reverse Logistics

Liu *et al* (2004) have identified four mainly characteristics of reverse logistics compared with forward logistics as follows:

**Disperstiveness of reverse logistics**

Flow of waste and old materials that may arise in the areas of production, circulation or consumption, involved in any area, any department, any individual, it occurs in the day and night in every corner of society. So this diversity is one which makes reverse logistics to be dispersive.

**The mixed nature of reverse logistics**

When recovery products get into the reverse logistics system, it is difficult to be divided into products. Because different types of waste materials and different
conditions of waste materials are often mixed together. When recovery products have been checked and sorted, the mixed nature of reverse logistics gradually decline with the generation of waste materials.

**Uncertainty of reverse logistics**

Since the disperstiveness of reverse logistics and consumer abuse on freedom recovery policy, the time, place and quantity of generation of reverse logistics is difficult to foresee, which make difficult for enterprises to control the recovery time and space of products. This leads uncertainty of reverse logistics.

**The slow nature of reverse logistics**

It is not difficult to find the generation of waste materials is not often to meet certain needs immediately, they need to through processing, restructuring and other sectors, even only as a raw material to be recycled, time of this series of processes is longer. At the same time, collection and arrangement of waste materials is also a more complex process. All of above determine the slow nature of waste materials flow.

3.2 Reverse Logistics of WEEE in China

3.2.1 Environmental theories in Reverse Logistics of WEEE

In analyzing the macro-environment, it is important to identify the factors that might in turn affect a number of vital variables that are likely to influence the organization’s supply and demand levels and its costs (Kotter and Schlesinger, 1991; Johnson and Scholes, 1993).

**Chaotic market of reverse logistics of WEEE**

Chinese government has not formulated relevant laws and regulations to regulate the WEEE recycling market, so that in China, a large part of the WEEE flows into two
channels. One is an informal collection channel where hawkers, peddlers and individual vendors repair, refurbish and then resell the WEEE. In the other, WEEE is recycled for components and raw material after being taken apart mostly in small handcraft workshops. These ways of disposal produce a high level of waste of valuable resources and pollution of the environment. (Anonymous, 2007)

At present, the problem of WEEE recycling has not been resolved. 80% of WEEE are not treated and used effectively, which resulting wasting of resources. However, if some WEEE with six kinds of toxic substances are disposed improperly, in addition to making water, air, soil and plant pollution, it will also form a pollution chain to harm human health and safety, which result the incalculable damage to human survival environment.

**High cost of Reverse Logistics of WEEE**

The cost of reverse logistics of Chinese enterprises in the proportion of GDP output of whole country is quite amazing. According to National Bureau of Statistics figure, it shows that GDP of China is 1.1558 trillion US dollars (ranks No.3 in the world), the cost of reverse logistics reached 72.2 billion US dollars (lower than average level of developed countries), of which electronic products accounted for more than 30%. (Song, 2007) Therefore, how to make reverse logistics of WEEE has great significance for cost reduction of logistics of Chinese enterprises.

Byars(1991) claims that a number of checklists have been developed as ways of cataloguing the vast number of possible issues that might affect an industry. A PEST analysis is one of them that are merely a framework that categorizes environmental influences as political, economic, social and technological forces. Sometimes two additional factors, environmental and legal, will be added to make a PESTEL analysis, but these themes can easily be subsumed in the others.
PEST analysis perspective is a useful strategic tool for understanding market growth or decline, business position, potential and direction for operations. The headings of PEST are a framework for reviewing a situation, and can in addition to SWOT and Porter’s Five Forces models, be applied by companies to review a strategic directions, including marketing proposition. (Kotler, 1998)

**Political perspective**

Political environment include a country’s social system, the nature of ruling party, the Government’s guidelines, policies, laws and so on. Different countries have different social nature, different social system has different restrictions and requirements for organization activities.

With increased environmental consciousness, reverse logistics has been paid more and more attentions in practice operational field and management research field. For the increasing threats of exhaustion of resources and deficiencies in waste disposal capacity, waste materials control has become a focus of attention problem in many industrialized countries. China also pays more and more attention to disposal problem of waste materials. There are many domestic legislation to be established, some of them are related to reverse logistics, such as “Solid Waste Pollution Prevention Law” and so on. (Jiang and Chen, 2010) But some kinds of HEA like TV sets, air conditioners and computers has not yet appeared in the “Waste Electrical and Electronic Equipment Recycling Management Regulations”, the recycling of these types of WEEE is still in a chaotic state. So the recycling market of WEEE need more standardized management, and WEEE recycling still has a long way to go in China.
Economic Forces

Economic conditions affect how easy or how difficult it is to be successful and profitable at any time because they affect both capital availability and cost, and demand (Thompson, 2002).

The macroeconomic changes do not affect overall development of manufacturing industry, will only bring structural adjustment of the industry. In order to alleviate the adverse effects of decline in exports for Chinese economy caused by the financial crisis, the state has adopted a series of economic stimulus measures and carried out a moderate relaxation of fiscal policy and monetary policy, thereby to promote the acceleration of infrastructure and make a significant impact on the downstream industry and logistics industry. (Yao, 2003) Facing to the economic environment above, opportunities and challenges of reverse logistics exist at the same time. Life cycle of products is becoming shorter and shorter, which have become very obvious in many industries, the shortened life cycle of products increase the waste materials and management costs if entering into reverse logistics. Because of this increasingly powerful consumer groups, many companies will take reverse logistics as an important factor to enhance competitiveness. Through the recycling and reuse of waste materials, on the one hand, enterprises can reduce the production cost and consumption of materials, tap the residual value of waste materials to increase economic efficiency directly. On the other hand, enterprises can enhance business “green” image and improve the relationship between businesses and consumers in the fierce competitive environment, and increase the economic efficiency indirectly. (You, 2005)
Social Forces

The socio-cultural environment encapsulates demand and tastes, which vary with fashion, disposable income, and general changes, can again provide both opportunities and threats for particular companies (Thompson, 2002; Pearce and Robinson, 2005).

At present, the ability of conquer nature and nature remaking of human being has enhanced greatly by strong promotion of the technology. However, the conquer nature and nature remaking led to environmental pollution, resource depletion, energy crisis, ecological destruction and global climate anomalies and a series of serious crises. The emergence of reverse logistics compensate the defect of one-way operation mode of forward logistics, it is propitious to reduce environmental pollution caused by inappropriate logistics and also reduce the cost of products disposal, improve business performance to result enormous ecological and economic benefits. (Jiang and Chen, 2010)

Technological Forces

Technology is widely recognised by various literature on strategic management (Capron and Glazer, 1987), as part of the organization and the industry part of the model as it is used for the creation of competitive advantage. New technology could provide a useful input, in both manufacturing and service industries, but in turn its purchase will require funding and possibly employee training before it can be used.

Technological environment provide a guarantee of implementing reverse logistics of WEEE for enterprises. Centralized recycling centers which to be the first node of handling recycling materials have a strong classification, processing and inventory adjustment function. Recycling centers, in accordance with the requirements of
enterprises, divide recycling materials into re-sale goods, re-sale goods after repairing and unrenewable goods, and then make different disposition decisions. (Jiang and Chen, 2010)

3.2.2 Recycling process of WEEE

Currently, about treatment strategy of recycling products in reverse logistics, the view of Thierry (1995) is widely used. He considered that re-use ways of products is divided into four patterns:

First, direct re-use. Do not need repairing and other operations and directly put into use. Such as glass bottles, containers and packaging containers.

Second, repairing. To make the damaged products into a usable state by repairing, but the quality may be decreased, such as industrial machinery, electrical equipment.

Third, reproducing. That is, making the product into a “new” state through demolition, replacement, etc. For example, in mechanical assembly, you can replace the old parts and this method does not change the original structure of products.

Fourth, regeneration. It is just to achieve the material resources recycling reuse, no longer to maintain any structure of recycling products, such as the recycled metal from scrap, paper regeneration.

Jiang and Chen (2010) list a process of WEEE recycling flow based on the literature reviews, which could be seen in figure 3.2.
Initial sorting
HEAs are circulated to consumers from HEA manufacturers by distributors. For the WEEE that is used by consumers, some of them return back to HEA manufacturers through distributors, most of WEEE are returned to recycled goods inventory uniformly by recycling process of recyclers. After the initial sorting of recycled goods inventory by means of the basic test to determine whether there are WEEE available in the recycled goods inventory, and then determine the available WEEE back to HEA manufacturers, through repairing, remanufacturing process, inspection and classification, subsuming them to the finished goods inventory and re-circulate to the hands of consumers. (Jiang and Chen, 2010)
Second sorting
Some WEEE which can not be used determined in the initial sorting are split, to make a second sorting about the capability and availability of the treated parts. The mainly reason for making a second sorting is to determine whether there are some spare parts recycled. We can put the spare parts can be recycled into available parts inventory, after treatment, the spare parts can be re-entered to the manufacturing process, then put the finished products into inventory of finished goods. (Jiang and Chen, 2010)

Third sorting
The parts that are not available to use in the second sorting are putted into scraps inventory to make the third sorting. The mainly point is to determine whether there is a part can be used. If there is, to put these parts into raw materials inventory to re-enter the manufacturing process. Some parts that can not be used in the third sorting need to be destroyed. (Jiang and Chen, 2010)

3.3 Inventory theories
In this part, the workflow of WEEE reverse logistics in China is illustrated, besides, key elements and features of inventory are showed, after these base theories, theories of inventory control, both inventory control models and inventory control methods are considered.

3.3.1 Inventory workflow of WEEE reverse logistics in China
As an essential part of reverse logistics, inventory is aimed to minimum the overall costs, ensure services and supplies by controlling inbound, outbound, and activities in the warehouse. In view of above, the environmental factors have crucial impacts on WEEE reverse logistics in China, inventory workflow of WEEE reverse logistics in China has its own features and emphasis. With the help of Qiu et.al, (2009)’s inventory management information system workflow, on the basis of WEEE reverse
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China
--The HEA (household electrical appliances) manufacturers’ perspective

logistics in China, and inventory, figure 3.3 shows the inventory workflow of inbound-inventory-outbound.

**Figure 3.3.** Inventory control workflow of WEEE reverse logistics in China. (Own Design & adopted from Qiu et.al, 2009)

**Sorting I:** WEEE are recycled from different channels, most of these channels have their own ways to sort different kind of appliances. This sorting I is a brief and simple sorting.
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China

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**Analysis by inventory models:** Before inbound, specialists do the analysis based on the inventory system database, with suitable models, in this process, inventory models are chosen by specialists, based on the experiences and the database.

**Choose inventory methods:** After the analysis, a inventory method is chosen to manage inventory.

**Inbound:** When the preparations are done, WEEE will be inbound, in specific ways which has decided in previous process.

**Check:** When WEEE are inbound, they are checked and recorded, the records are sent to inventory system database. After check, it will happen in two different directions. Some stocks keep as it came before, some will be sorted again.

**Inventory control I:** As the stocks keep constant, inventory control follows the inventory methods chose before.

**Sorting II:** Some stocks need to be checked and sorted, to make sure some components can still in use or different parts of different materials would be kept in a more suitable way. This sorting II refers re-treatment of WEEE, and this sorting II works in more detailed and more precisely ways. After this, inventory methods need to be decided again.

**Inventory control II~V:** These inventory controls are based on the inventory methods decisions,

**Outbound:** This process refers reuse, re-manufacturing, destroy etc. ways. when stocks are outbound, there should be records into inventory system database.

**Calculating the costs:** After the whole inventory process, calculation is needed. The results are recorded into inventory system database for next inventory process. (Qiu et.al, 2009)
All in all, inventory control of WEEE reverse logistics in China is aimed to arrange the returned appliances rationally, and to make full use of these appliances, make the inventory efficiently, besides, costs of inventory should be controlled.

3.3.2 Key elements and features of inventory

In this part, key elements of inventory and features of WEEE inventory are laid out.

**Key elements of inventory**

According to Chopra and Meindl(2003), Where there is inflow, outflow and storage of goods, is called inventory system. Inventory system is a major component of demand, supply, constraints and cost, besides, stocktaking mode is also contained in this system:

**Demand.**

Wang(2007) states that when the external demand occurs for inventory, goods in warehouse will be shipped. Therefore, the demand is output of inventory system. The time-varying characteristics of demand largely determine inventory control method. Although the majority of products at different stages in the life cycle have ups and downs needs, but sales periods of many products are very long, from the perspective of planning, it is enough to be considered for an indefinite period, the demand for such products be regarded as a continuing of demand. On the other hand, the demands for some products show strong one-time or seasonal or peak-like features, such as construction equipment or indoor air conditioning. Demand for some products can be expected to terminate at a future time, such as plans to amend the textbooks, military aircraft spare parts, medicines with period of validity, and such demand is named termination needs.
Demand can also follow the quantity required, demand rate and demand patterns into deterministic demand and non-deterministic demand two broad categories. For deterministic demand, the demand is often seen as a constant; non-deterministic demand is unstable or a random value in quantitative terms, it is easily interfered by various external factors than deterministic demand.

**Supply.**

According to Wei(2005),Hu, et,al.(2005), for reduction of the external demand, inventory must be added to meet demands, inventory replenishment is the input process of inventory system. It can be ordered through the suppliers, can also be produced by their own organization. External demand is out of control, but the replenishment and input can be controlled. Wang and Zhang (1987) state that the supply of inventory is a process that takes time, the time from the ordered goods to its inventory by adding the actual duration called delayed time. In another perspective, in order to replenish stocks at a time, the orders must be made in advance, then this time can also be called the lead time.

**Constraints.**

Hu(2005) states that Constraints is restraint to the inventory system. Limited storage capacity and funding constraints may bound the number of stocks; there are also some strategies that not allowing out of inventory for some certain items; In addition, the administrative decision-making can also restrain the strategy of inventory system.

**Cost.**

According to Chopra and Meinl(2003), according to the most economical operation of one of inventory management’s main tasks is to use the lowest cost at the right time and right place to get an appropriate amount of raw materials, consumables, or the final product. The most direct standard to measure the merits of inventory strategy is
to calculate the average cost. The key elements of inventory system are inventory holding costs, ordering costs, production costs and shortage costs. The objective function used to determine the optimal storage strategy generally contains: an average cost optimal, the optimal profits and discount fees; strategy chosen to achieve the minimum costs or maximum benefits.

Stocktaking modes.
Gu and Zhu (1987) State that stocktaking models can be divided into a continuous counting and cycle counting. In the case of continuous counting model, inventory levels are known at any time; in the cycle count model, counting is made per cycle. Different counting models affect decision-making of inventory.

Features of WEEE inventory
Reverse logistics management aims to reduce inventory of returned product as soon as possible, returned products in stock will be restored back into the product that can be used again, this is to reduce inventory costs in reverse logistics and maximize recovery value of returned products in stock, this can not only reduce occupied capitals of returned products, but also to obtain the product value and create greater profits from the returned products as soon as possible. The dispersivity, hybridity and variability features make the inventory in reverse logistics more complex. In specific, reverse logistics inventory stresses two main characteristics which are: two supply sources and random uncertainty.

Two supply sources
Based on Yang (2004)’ s states, compared with traditional inventory systems, the most important feature of reverse logistics inventory is more complex because of the returned products, the inventory in stock, including not only general manufacturing process of new products, but also returned product, which means there can be two
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China
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complementary supply sources of inventory, in addition to the traditional order / production replenishment of new products stocks, the returned products can also be added as inventory source, which further led to the inventory control complex, the complexity is primarily showed in the following three aspects: First, the choice of supply source needs to be determined on the basis of problems in determining inventory check cycle, determining the order quantity, determining when to order. Second, in addition to traditional inventory ordering costs, inventory holding costs and stock costs, there is a reverse logistics cost in inventory costs contain return product transportation, storage, repair, resale and other cost components.

**Random uncertainty**

According to Bao(2004), The collection of recovery is a supply-driven material flow, rather than the market demand-driven material flow in forward logistics. The supply-driven material flow exceeds the direct control of the enterprise, resulting in a high degree of uncertainty in the quantity, time and quality conditions of returned products. This also led to a distinct random uncertainty of inventory in reverse logistics, for example, WEEE cannot be ordered in advance, it can only passively accepted from the consumers, which led to random uncertainty of the returned products in quantity and return time; components’ recovery rate of WEEE is random, this brings high degree of uncertainty to logistics material recycling planning; relationship between the incoming and demand is uncertainty ; high degree of uncertainty in re-use products and re-use products markets makes it is difficult to predict product demand, which lead to the unstable balance of supply and demand.
3.3.3 Inventory control models

A lot of inventories models studies have been done for recent years. In this part, the literature reviews both the worldwide and in China are listed, then with the studies, some theories about inventory control models are applied systematically.

To make this part clear, figure 3.4 shows the logic of the inventory control models.

![Figure 3.4 Framework of inventory control models. (Sources: Own Design)](image)

Research current situation of reverse logistics inventory control

Foreign scholars study of reverse logistics inventory early start, but until the late 90s of last century, research in this area have a more extensive development. The first model of reverse logistics inventory of researchers is Sschrady (1967), his study is a deterministic EOQ inventory model for reverse logistics, assuming that the demand for finished products, the recovery rate of waste products, new products, product recovery and recycling are determined in advance of the known, while ordering the
product is assumed to be fixed start-up costs, the model of recycling / repair cycle and the production / procurement cycle more than once, and he calculated the optimal order quantity model. Nahmias and Rivera (1979) is for a limited circulation / repair rate in the model was extended to this research. Mabini et al. (1998) taking into account a variety of products, and based on these models were further extended. Teunterls (1998) gives a product that can be recovered only part of the re-use the model, that decision-makers determine whether the recovery rate of known materials recovered for reuse. He made the following assumptions: because the recovery is lower than the manufacturing cost of goods re-manufacturing costs, so the product's inventory holding cost coefficient is higher than the re-manufactured products.

In addition, Rainer (2002), who considered the recovery of one or several products produced by decomposition of a variety of parts after the demolition, and they have their own situations for different purposes. They assume a single-stage product recovery inventory system, in the analysis, they noted that the case of a product recall, the use of recycled products manufactured to meet the needs of another than to manufacture new products to meet the needs of more cost advantage. Dobos and Richterlv] (2004) gives the model it is assumed that only one cycle and a production process, and the aim is to calculate the marginal cost of using the minimum speed and recovery speed. They analyzed two models: one is the lowest cost EOQ model, the other is related to reducing and non-EOQ related costs. The study concluded that: either the production of new products, or all of the returning goods recycling is the best choice.

Domestic scholars on the issue of reverse logistics inventory less the research literature, and the issue of reverse logistics inventory data for in-depth analysis of the article is not much. Huang (2003) proposed a model to allow return of inventory control, the model allows customers to return to set vendors, recycling products that
have been treated can still sell the original price. In this condition, the proposed model and an optimal ordering algorithm and numerical examples and discussions of the different return rates, inventory costs and stock losses to the vendors and the expected return of optimal order quantity of. Huang and Da (2003), Huang et.al.(2004) proposed a reverse logistics EOQ with delay extension order model. They considered the returned product repair and restoration lag costs, assuming that vendors in the purchasing cycle, T, allows consumers to return, simply return the item after a fixed time L treatment (such as cleaning, replacement packaging etc.) can still be and the "new products "as sold, but returned after the TL products were directly obtained by expansion of a vendor EOQ order model, and discussed the return rate on business income and sales Order Strategies. Xu and Xu (2006) proposed a variety on a regular basis to allow return of the order model and presents a heuristic algorithm. The so-called variety that a joint order order order policy varieties of materials, looking for the joint ordering cost of the province of all varieties of order cycle and order volume. Finally, an example that the joint order packet ordering scheme than the low-cost single-cycle. Yi(2003) According to the returning characters and different materials handling, the Reverse Logistics Inventory is divided into autonomous recovery and management of inventory issues two types of recovery, and inventory control are given a model and example analysis. Bao(2004) states that customer retention and customer does not retain the order of reverse logistics inventory model orders were made by research, and keep the customer orders into the multi-period inventory model for further research environment, the last of the single-cycle and multi- cycle inventory model under the case studies are made. Yang (2006) introduced in the traditional inventory model for reverse logistics factors in the development of a series of new inventory control model. Hao(2006) introduced the return of several commonly used forecasting model products, and inventory control of an existing model, based on its improvement, proposed a new model is more realistic.
Based on these well-developed researches, theories of inventory control are systematically applied as below:

**Single-period inventory model**

Single-period inventory model studies problems of single-cycle or seasonal goods. The decision-making are involved only a demand cycle. In the traditional inventory model, such problems are often attributed to the classical newsboy problem to deal with, in the reverse logistics model, based on the number of stock points, single-period inventory model will be divided into single stock point model and multi-stock point model.

**Single Stock Point Model.**

This type of models usually assumes that the system has only one stock point, return goods is either considered to be as products, or of no consideration.

Vlachos et al (2003) make a detailed research on single-cycle, single point of storage inventory problem by virtue of the classical newsboy problem. The model assumptions: the ordered goods have arrived from the start point; demand is a continuous random variable; the return is a linear function of demand; items have a constant interval from sold to return; re-processing will pay for processing fees. This paper proposes several solutions for dealing with reverse logistics, which are as follows: (1) all return products are sold in the second-hand market; (2) pick out the ones in good condition from the return products to directly meet customer needs; (3) select part of the return product for re-processing and then used to meet customer needs, the rest are sold to second-hand market; (4) all return products can be re-processed and then re-used to meet the needs of customers. The authors subdivide
the latter two strategies according to there is fixed cost in re-processed, these six different treatment strategies to the authors establish a newsboy problem model with maximize profits as the objective function, obtain ordering strategy for each of the 6 different conditions. Webster and Weng (2000), Guider and Srivastava (1998) study disposal strategy of perishables from the retailer to return to the manufacturer in the perspective of retailers, to maximize the profit of the retailer as the objective function, the authors set appropriate retail price, but the two researches consider more about the whole supply chain collaboration, rather than simply the optimal order strategy.

**Multi-stock point model.**

Multi-point problem that is using different stocks of inventory to store returned goods and supply products, then integrate these stocks to develop a strategy for the optimal inventory control.

Kleber et al (2002) consider the problem of a multi-point stock, based on that the demand and return are random. For in a period, the return of the goods might exceed demand in quantity. A question is required answering: the return products more than needs is safe disposal, or stored for the next phase of re-processing and to meet new needs? In this paper the following assumptions are: (1) one stock for return products, and services of different types of products to be placed in different stocks; (2) all return products have the same quality; (3) different demand classes are divided by products quality and consumer market for the same kind of products; (4) the production and reproduction of the time were negligible; (5) does not allow out of stock. In this cycle need to determine the quantities of products, quantities of safe disposal and re-processing quantities for each demand level. Costs of the system are covered by the safe disposal fees, storage fees of each inventory point, re-processing
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products cost. The authors transferred for the Hamilton function, in the system to minimize the total cost of a mathematical model by transforming the solution.

Multi-period inventory model

The vast majority of reverse logistics inventory models are multi-cycle issues. This type of inventory model is similar to the traditional multi-period inventory, in model the length of the program is divided into multiple cycles, while many of the research literature based on the traditional (s, S), (s, Q) inventory control and other strategies. In these models, we first point under the stock number will be divided into more than a single stock point and the point of two major categories of stocks in each category and yet another way based on inventory stock were divided into periodic inventory methods and two types of continuous inventory method.

Single Stock point model.

Usually this type of inventory model with a single stock point for the inventory of return products and supplies products, as the demand related to multiple cycles, inventory control adopts cycle count model and continuous inventory model.

1). Cycle Count Model

Cohen et al (1980) build a single stock point model with cycle count way to control the inventory, which are according to that some items can be returned directly to meet new customer needs. Model assumption: (1) at a certain stage, sold products are returned with a constant rate after a fixed time interval; (2) order has no fixed cost; (3) replenishment order time is zero. By comparing the cost of inventory holding costs and stock losses costs, the inventory replenishment decision can be made. And the
authors point out that if does not take the cost of ordering and additional orders of the time into account, and then it is the optimal way of producing followed the order. Kelle et al (1989) expands on this basis, they assume a fixed cost for ordering and the return time of sold products is a random variable, a method of using dynamic quantities were studied. Yuan et al (1998) study reverse logistics based on the traditional (s, S) policy, the model assumes that demand follows Poisson distribution, the time intervals of products from sold out to return in the market follow exponential distribution. To minimize the long-term costs, the authors establish a cost model, and give the calculation method. Fleischmann, Kuik (2003) also adopted a (s, S) strategy, and had an analysis of the reverse inventory model with one stock point. Model assumptions: (1) all returned products are recycled without any further processing to access into supply production of production inventory. (2) demand and returns are independent and random variables; (3) ordering has a fixed cost; (4) Ordering additional time is negligible; (5) out of stock will cause a loss. The authors build up a objective function to minimize the unit cost, meanwhile the inventory levels of each cycle is divided into inventory levels with the traditional (s, S) inventory model and single product inventory levels, and give return goods a higher priority. Through the decomposition of the actual inventory levels, which will convert (s, S) model which contains the reverse logistics into a traditional (s, S) model. In addition, the use of Markov theory of optimal solution obtained, the authors point that from a mathematical point of view, random return flow does not make the inventory control models have become much more complicated.

2). Continuous inventory model.

Inventory of these issues by way of a continuous count, is similar to the traditional inventory model, most of the research literature has established a minimum cost per unit time inventory control model parameters in calculation.
Muckstadt et al (1981) studied the return items inventory model of a single kind of product. Model assumptions: product demand and return follow the Poisson distribution, and both independent of each other; ordering has fixed costs; additional orders have a fixed lead time; return goods also need a fixed time for further processing. Authors control the inventory by using the traditional (s, Q) inventory model, through solving the distribution of net inventory levels, and then get the optimal strategy. Van der Laan et al (1996) gives another solution in addition to the above model, and considered safe disposal of return items. Fleischmann et al (2002) have a more thorough analysis on a single species single stock point issue, the authors build (s, Q) inventory model by minimize the average cost of long-term, based on the traditional (s, Q) inventory model, through a way of solving the mean and the variance of demand and inventory level. The model has the following assumptions: (1) product demand and return follow Poisson distribution, and both independent of each other; (2) ordering has a fixed lead time; (3) there is a loss of out of stock; (4) return items are back into storage immediately to meet customer needs. The authors break the inventory level containing return flow down into two parts, namely, independent return new products inventory, and independent return goods inventory with the model parameters. And assumes that these two stocks have the same cost, by applying the traditional (s, Q) strategy in new stock, but the priority using of return products to meet customer needs. Finally, the text gives the proof of existence on the reverse logistics model (s, Q) strategy, besides getting the conclusion through different numerical experiment with different return rates that: it is not appropriate that using net inventory as average stock in the case of stochastic returns.
Multi-stock point model

1) Cycle Count Model

The earliest model of this type of research should be Simpson (1978), with a single product of the recovery model as an example, he uses two inventory points to solve the inventory problem in reverse logistics. Model assumes that: order lead time and repair time of return products are negligible; demand and returns are random and the two are independent. The author solves the problem by weighing the cost savings of return products re-use and inventory costs for return products inventory. Since then, Indefurth (1997) extends the model on the basis of the Simpson’s model, he considers that the product orders have fixed lead time and repairs for the return products have a fixed lead time. Through analysis, the authors note that in this case Simpson’s model is still applicable, and the difference between the ordering lead time and repair for return product is the decisive factor that whether the system is complex or not. Although the literature build a mathematical model in theory, but did not give an effective algorithm to solve problems and the specific steps to control parameters. Kiesmuler, Scherer (2003) give a concrete algorithm steps based on the above model. The paper first studies a single stock point model, pointed out that both demands and returns are dynamic, it is time-consuming if we want the result of precise calculation, so the authors use a similar two methods to solve this: One way is to replace one of the value function in original model, another method is to introduce safety stock to build up a random decision model, to make the calculation greatly simplified. Finally, two stocks were studied on the approximation algorithm, and with eight specific examples it is demonstrated the effectiveness of the algorithm.

2) Continuous inventory model

In the case of multiple stock point inventory using a continuous way, the usual practice way is to simultaneously detect multiple stock points, considering the entire
inventory system, making the decisions according to the actual situation of each inventory point.

Dobos (2003) studied reverse logistics model of HMMS type. Model assumptions: demand is a known continuously differentiable function; items has a constant interval from sold to the return; the return of goods is a linear function of the previous stage demand. The cost of the entire system of inventory held by inventory costs, processing costs, reprocessing costs and costs of safe disposal of the composition of the two inventories. With the use of control theory, the system is studied by using the state space method, a mathematical model is established to minimize the total cycle cost as the objective function. By constructing a Hamilton function and the Lagrange function, the author converts conditional extremal problem of functional constraints into unconditional constraints for the extremum of function in problem solving, and gives some of the features of the model and its proof. From the perspective of the entire supply chain, Minner (2001) considers the recycling situation of supply chain nodes and external products, finished products, semi-finished products and raw materials of their respective points of safety stock inventory issues are discussed. The author hypothesizes that: (1) All items returned are subject to normal distribution; (2) The correlation of the return between different items is negligible; (3) all returns and external products are immediately re-used, and are processed into finished products and stored. The author establishes a mathematical model to minimize inventory holding cost of safety on the whole supply chain as the objective function to. On raw materials - semi - finished products of this process flow and customer demand for the finished product - the required semi-finished products - raw materials, semi-finished products corresponding to the study of the reverse flow of the derived additional orders for each stock node in advance, then calculated based on a certain level of service their own safety stock. Ruud et al.(2002) analyze the reverse logistics inventory models by using the discounted cash flow method and average cost. In the
study of Ruud et al.(2000), a continuous counting, random demand, random return of goods, manufacturing and remanufacturing with fixed lead times inventory model is given. Five methods used to determine the holding cost rates, and for each method, the authors have established two models DCF and AC. By comparing these results obtained in the reverse logistics, each specific model has the best solution. Ruud et al.(2002), who establish another inventory model with return items. The model assumes: all return items are only re-manufacturing (remanufacturing) processed; manufacturing and re-manufactured products of the time can be ignored; waste has a fixed rate of return: after re-manufacture of recycled materials used to meet future customer needs, When the inventory is zero, then the manufacture of new products is made. By DCF and AC compare the results of two methods, the authors conclude: In the traditional inventory model, with the average cost method to analyze relatively simple, the common express is "use of funds discount rate × Item holding cost + shortage ", but in the reverse logistics contained model, because we don’t know the occupation of abandoned funds for the specific items, which will not be able to know exactly the cost of ownership either. In this case, AC approach is clearly no longer applicable, it isn’t approximate as using the DCF method for the results.

According to Yang (2004), reverse logistics inventory model has two major differences compared to the traditional inventory model, one is reverse material flow and two supply sources to meet customer need. Although the content of the above literature are very different, but their common feature is based on the improvement of the traditional inventory model, the researchers try to maximize the integration of reverse logistics to the traditional inventory model. In addition, the models are mostly considered a single species of inventory problems.
3.3.4 Inventory control methods

Most managers don’t like inventories because they are like money placed in a drawer, assets tied up in investments that are not producing any return and, in fact, incurring a borrowing cost. Some methods of inventory control can be applied into the thesis, which are as below:

**ABC Analysis**

ABC analysis is a business term used to define an inventory categorization technique often used in materials management. According to EIPM (2004), ABC analysis, Pareto’s law or “80/20 rule” are all-synonymous of the same tool which basically states that 20% of a given population represents 80% of a specific characteristic. In purchasing, the basic ABC analysis is used to identify which segments represent most of the spend in a given category or portfolio. Most of the time, few segments in a portfolio constitute the largest part of the total spend. Usually, the A segments represent approximately 80% of the total spend within a category; the B segments represent the following 15% of the total spend within a category; the C segments are the remaining (most of the time several segments) which represents the final 5% of the total spend.

The ABC tool is used to identify the “vital few” from the “trivial many”, according to a defined set of criteria (e.g. annual expenditure, number of orders, number of claims, occupied space in the inventory, etc.). Different decisions may be taken from the result of the ABC analysis. The basic utilization of the ABC analysis for a buyer is to use it with the spend as a criterion. It helps the buyer to identify the few A segments which will require special attention due to the “large amount of money” they represent. A small “mistake” in managing the few A segments may cost a lot to your
company. The C segments will require a different approach to simplify the administrative burden to handle them. (EIPM, 2004)

Based on the theories of EIPM (2004), the following 6 steps are used to perform an ABC analysis:

Step 1 – Identify the objective and the analysis criterion
Step 2 – Collect data about the analyzed population
Step 3 – Sort out the list by decreasing impact
Step 4 – Calculate the accumulated impact and the percentage
Step 5 – Identify the classes
Step 6 – Analyze the classes and take appropriate decisions

Vendor-Managed Inventory (VMI)

Vendor-managed inventory (VMI) is one of the most widely discussed partnering initiatives for improving multi-firm supply chain efficiency. Chopra and Meindl (2004) define VMI as a continuous replenishment program where the supplier is given the responsible for all decisions regarding the replenishment of the customer’s inventory.

Waller et al. (1999) state that in a VMI partnership, the supplier, usually the manufacturer but sometimes a reseller or distributor, makes the main inventory replenishment decisions for the consuming organization. This means that the vendor monitors the buyer’s inventory levels (physically or via electronic messaging) and makes periodic resupply decisions regarding order quantities, shipping, and timing. Transactions customarily initiated by the buyer (such as purchase orders) are initiated by the supplier. Indeed, the purchase order acknowledgement from the vendor may be the first indication that a transaction is taking place: an advance shipping notice
cludes the buyer of materials in transit. In this relationship, buyers relinquish control of key resupply decisions and sometimes even transfer financial responsibility for the inventory to the supplier (whether by letter or spirit of their agreement). The arrangement transfers the burden of asset management from the consuming organization to the vendor, who may be obliged to meet a specific customer service goal (usually some kind of stock target).

Within a VMI system, the supplier can better decide when to replenish the customer’s inventory due to better information about inventory status and demand. This makes it possible for the supplier to better plan its production. Moreover, when the supplier has scarce production capacity, VMI supports the supplier to choose which deliveries that can be delayed without causing lost sales for the customer. (Kaipia et al., 2002) Other benefits in a VMI partnership are improved customer service due to better coordination of replenishment orders and reduced inventory stockouts by increasing inventory visibility (Angulo et al., 2004). Waller, et al. (1999) imply that a reduction in inventory is to be expected from an implementation of VMI. This can be attributed to the more frequent inventory reviews and order intervals (Ibid).

Successful implementation of VMI often depends on computer platforms, communications technology, and product identification and tracking systems. In many cases, these systems are already in place at both the retailer and supplier. Software systems are the most likely areas of deficiency and are important because they facilitate such discussions as replenishment quantity and timing; safety stock levels, transportation routing and inter facility transshipments. (Waller et al., 1999) According to Chopra and Meindl (2004), a VMI system also requires that the customer constantly provide its VMI suppliers with accurate information to allow them to take inventory replenishment decisions.
Joint-Managed Inventory (JMI)

According to Ronald (2004), Joint-Managed Inventory (JMI) is based on logistics co-ordination center inventory management. It can effectively improve supply chain bullwhip effect phenomenon appears to reduce unnecessary inventory, improve supply chain synchronization level, thereby optimizing the overall operation of the supply chain performance. JMI emphasis on supply-chain companies to participate in each node to develop inventory management programs, each node in a common enterprise under the framework agreement from their co-ordination among the considerations to keep the supply chain between nodes on demand is expected to be consistent, thereby eliminating the phenomenon of demand variability amplification. Any business needs to determine the adjacent nodes are the result of both supply and demand coordination. (Zhang, 2004)

Gao and Li (2010) state that The implementation of JMI is not a simple process, it requires all nodes in the supply chain enterprise of mutual cooperation, we need advanced information technology support. Each node in the supply chain built on the common interests of companies on the basis of mutual trust is the basis for the successful implementation of JMI, good communication is JMI guarantee of success. In order to ensure the supply chain of enterprises of all good communication nodes, each node in the supply chain JMI Enterprises should establish a framework agreement in consultation, in order to protect the supply chain information flow of effective communication, each node in the supply chain to achieve business-to-market demand information in forecasting, production, Transportation plans and competitive strategies of the common design and control. In addition, JMI is the key to achieve the status of the user inventory transparency, supply chain companies can each node of the inventory at any time follow-up survey, resulting in fast response to market demand information, the supply capacity of the enterprise to make rapid adjustments.
Thus, JMI implementation must rely on advanced information technology. (Liang, 2005)

Zhou (2005) applied 3 concrete steps to implement the JMI, which are: Establish a sound mechanism for coordination and management; the establishment of an integrated information system; consideration of the role played by third-party logistics.

Apart from these theories above, another method of inventory management, Outsourcing Inventory Management (OIM) can also be applied as inventory control method. Other than the theories of inventory control methods, OIM is not exactly a methods in inventory control, but a method of inventory management, the inventory control are handled by a third party that is focus on inventory profession, OIM is applied widely for the reason that it can improve inventory control by professionals, besides, the HEA manufactures can focus more on other core business.

3.4 Hybrid Manufacturing System

Based on Yang (2004)’s theory, the main supplementary sources formed by processed return products are as following: the corresponding post-treatment of return products by collection, detection and classification; destruction for those products, parts and components which cannot be re-used for economic or technical reasons; recycling or reprocessing products to re-obtain the value of a stock of reusable components can be complementary sources of supplies and re-enter the circulation. The process of re-treatment products based on the quality status of reflux can be divided into cleaning, parts replacement and repair of simple re-packaging, handling of more complex products and to take recovery measures, the transformation of old products for return, repair and other value-added activities involved more detailed and complex
techniques and technological re-manufacturing processes. Due to the need of the information of the product structure and high processing techniques, usually remanufacturing process are afforded by the manufacturers themselves. This creates a combined traditional manufacturing process and re-manufacturing process-- hybrid manufacturing system. Figure 3.5 shows the simplified workflow of hybrid manufacturing system.

Figure 3.5 structure of hybrid manufacturing system (Sources: Yang(2004) & Own Design)

4. Empirical findings

This chapter starts with presentation of the two case companies followed by description of empirical evidence. The empirical evidence is shown in the structures as following: general profiles of the company and the inventory department, then the workflow of the inventory control, methods of inventory control, and inventory costs, nevertheless, problems in inventory control management are also listed in this part.
Figure 4.0 Relations between research questions and empirical findings

Figure 4.0 simply illustrates the relation between research questions and empirical findings. Inventory control of WEEE reverse logistics in the two case companies answer research question 1, the problems in the two case companies are related to research question 2, not a solution to question 2, but basis of solving question 2.


General profiles

Founded in 1984, the Haier Group has been dedicated to innovation and creating a world famous brand over the past 26 years. Originally a small collective plant on the verge of bankruptcy, it has now grown into an international group which has more than 70,000 employees around the globe and realizes a turnover of 135.7 billion yuan in 2010. Haier has risen to be the world's No.1 brand of consumer appliances. In addition, it was selected as one of the world's Top 10 innovative companies issued by USA Newsweek's website. Haier is a successful provider of integrated home appliances, meeting the needs of global consumers through continuous innovation. Haier's businesses include the following six units: **White Goods, Brown Goods (digital and personal product), Client Solution Business, Equipment Components Manufacturing Group, Retailing (own home appliance sales channels)** and **Finance** (finance and real estate). As of this year, Haier as established 61 trading companies (19 outside of China), 8 design centers (5 outside of China), 29
Haier is achieving its goal of building a global brand using the "Three-in-One" localization strategy. (http://www.haier.com/index.asp. 2011-02)

Haier sets up a Logistics Promotion Headquarters that has three divisions: Purchasing Division, Distribution Division and Transportation Division. They are responsible for the raw material procurement, production and distribution, product transfer and distribution to the sales center in the first half of the logistics chain. Distribution logistics such as location policy of sales interim library, inventory levels set and distribution operation and so on, is responsible by commodity-circulate department. Haier sets up 36 regional distribution centers and spends huge sums to establish a modern international logistics center in Qingdao. (http://www.360doc.com/content/10/0904/21/547456_51230772.shtml)

3PL is the direction of development on social division of labor and modern logistics. 3PL in European countries has been the subject of modern logistics industry. In china, Haier group was first aware of this development trend of modern logistics, and established Haier Logistics Co., Ltd.

Haier Logistics Co., Ltd., since its establishment in 1999, relying on advanced management concepts of the Haier Group, a powerful network of resources has built the core competitiveness in logistics. By virtue of advanced management concepts and logistics technology application, it proactively develops socialized business whilst satisfying the internal logistics service requirement. We have set a successful model in the transformation from enterprise logistics to logistics enterprise. At present, foreign revenue has accounted for 20% of total revenue, our three-year goal is to achieve both internally and externally business income of 50%, to create a globally competitive platform for third-party logistics.
Haier Logistics focus on the whole process optimization and synchronization of entire supply chain, eliminate the repetitive and invalid work of internal and external aspects in company, so that make resources value-added flowing in each process and make logistics business to support customers achieving the goal of fast orders acquirement and orders meet.

Haier Logistics by use of advanced management concepts and logistics technology was awarded “The First China’s Logistics Demonstration Base” and “The National Science and Technology Progress Award” by China Federation of Logistics & Purchasing, meanwhile has won the “China Logistics Hundred Enterprises”, “Top 50 Logistics Enterprises in China”, “Top 100 Enterprises of Logistics Comprehensive strength in China” and “Best Home Appliance Logistics Enterprises”, etc.

The information of the following part is conducted according to the interview with Zhan Ning who is the manager (Huabei area) in Haier logistics co., ltd.

4.1.1 Inventory Control of WEEE reverse logistics in Haier Logistics

In 2008, Haier proposed “Green Design, Green Manufacturing, Green recycling, Green Business” 4G strategy. So Haier logistics put more attention on reverse logistics. Meanwhile inventory control caused a lot of attention of Haier logistics. Haier logistics adopted JIT distribution management system to improve the efficiency of delivery of raw materials, through the establishment of two modern intelligent and automated warehouses and automatic logistics center to control the inventory by means of ERP logistics information management, so that achieve JIT delivery mode. From the unitization, standardization and universal of logistics container to the mechanization of materials carrying, to the “Kanban” management system of workshop material distribution, set-management system, material consumption monitoring and replenishment system, Haier logistics carried out a comprehensive
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-- The HEA (household electrical appliances) manufacturers’ perspective reform and achieved logistics management objectives called “elimination of space by time”.

Inventory control Workflow

![Workflow Diagram]

Figure 4.1 Workflow of WEEE reverse logistics in Haier (Own drawn, information sources: Zhan ning, Haier Logistics)
In China, household electrical appliances are obsolete very fast, some consumers choose to throw or sell them to the recycler, and others will deal with them to the retailer by replace or refund. In Haier, the customer service department is responsible for uniform recycling of waste electrical appliances. As you can see in the figure above, there are many steps for recycling. In sorting I, the products from recyclers and customer service are sorted by types of products. Haier logistics arrange the sorted products and delivery them to different transfer warehouses for inventory control. The data of products is recorded by HLES system. After that, in sorting II, the products will be checked in quality. Some of them which can not be reused will be delivered to the qualified environment processing enterprises Haier appointed, they are responsible for disassembling of these products. In this step, after disassemble, some of components can be reused will be delivered to Haier, the other can not be used will be threw and treated. Others can be reused will be transfer to the goods warehouse, inbound and check again, Haier logistics is responsible for the inventory control of products by using HLES system. The products can be used directly will be outbound when Haier need them for remanufacturing or repair, others can not be used directly will be outbound and disassembled to useful components and delivered to Haier with other components from qualified environment processing enterprises, then HLES will record the data into database.

**Methods of Inventory Control**

**VMI-HUB**: It is a transit hub of raw materials established by Haier logistics to manage supplier inventory centralized. Suppliers in large quantities and less batch storage, the demand side in small-volume and multi-frequency purchase order for delivery of cargo from storage, centralized logistics and distribution both to reduce delivery cost of suppliers and improve delivery rate of timely, reducing the warehouse area of demand side and increase its production flexibility.
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**VMI-HUB System**: It is based on SAP system, jointly developed a set of information system of independent intellectual property, the transparency of the inventory management and (min-max) early warning of safety inventory not only reduce costs for suppliers, but also improve the response speed of entire supply chain.

**4PL**: On the other hand, when Haier continues to expand 3PL business, at the same time Haier started to provide 4PL services. Compared with 3PL, more service content in 4PL and more area covered, even develop new service field and improve more value-added services. It helps client planning, implement and enforcement of supply chain programmer, and provides value-added services for the companies in manufacturing and aviation industry and so on. And for now logistics business has been a new economic growth point in Haier.

**Product Distribution Center Setting**: For solving that product inventory level of production ends remains high, storage resources appear “bottleneck”, the task of finished-parts storage and in-bound and out-bound storage concentrated and complex in the boom season, Haier set several product distribution centers strategic in the country, effective decompose sorting job functions of Qingdao warehouse to make transport mass in order to have a advantage of transport scale, move the supply of products into the end of supply chain, enhance the logistics support capability and reduce logistics costs.

**SAP LES**: Haier logistics use SAP LES for global logistics management.

Resource management: resource unified management and deployment, reduce logistics costs

Order management: order information synchronization sharing, improve order response time

Transportation management: distribution and transportation system monitoring, in-transit inventory monitoring
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Warehouse management: inventory information sharing, real-time queries and stock alarm

KPI analysis: automatic fetching of logistics nodes KPI, improve efficiency

HLES: Haier logistics use HLES (Haier Logistics Executive System) to carry on management of FIFO product, Falsifying Goods and extended inventory, through the combination of human code, object code and machine code to achieve single product tracking through, the system control of FIFO and transparent tracking of supply chain through the whole process.

Costs of Inventory Control

From the company, the authors get a list of material data, which can be summed up as costs of Inventory control, in the thesis, the details of hairdryer are showed as below, for the reason that both the manufacturing process of hairdryer and inventory level in China are similar, and besides, the retailers, purchasing suppliers of the two cases are basically the same.

In table 4.1, the numbers are slightly revised by the authors with the permission of Zhan Ning for business secrets and easier to calculate in analysis part. The amount of each number are slightly simplified.
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China

--The HEA (household electrical appliances) manufacturers’ perspective
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Table 4.1 Rough estimated details of hairdryer manufacturing and re-manufacturing in Haier of year 2010 (Sources: Zhan Ning)
Based on table 4.1 above, some details are illustrated as below:

Figure 4.2 Demands curve in Haier of year 2010 (Sources: Own Design)

From figure 4.2 above, we can see there are large fluctuations in different periods of the whole year. From the middle of February to April, the demands of hairdryer have plummeted, which means this period is the off-season. After this, inversely, there is a steep rise of demands, it rises to a high level in a short time. These are boom seasons at May, August and October. People have strong purchasing power to stimulate demand because of the national statutory holidays at that period. There is another off-season which is form middle of October to middle of December in a year. The demand reaches highest point in October.
According to figure 4.3, at the beginning of year (from January to February) the ordering costs show us a straight line, indicating no changes of new products ordering. But from figure 4.2 we can see the demand rises at that time, so ordering costs must increase from another products-returned products, we can confirm that from figure 4.4 below. Ordering costs reach acme at May because of boom season that we can see from figure of demands.

In figure 4.4, it is a similar curve trend with figure 4.2, the ordering costs for returned products is low at April and November, meanwhile it is high at February, May, August and October.
From the figure 4.5, there is a plummet from the middle of February to the middle of April, according to figure 4.2 and 4.3, we find the demand and ordering cost both decrease, so stocking costs for new products corresponding reduce. All in all, it is very similar with figure 4.2. But, we can see some big undulatory motion, such as there is a steeper rise from July to August more than the same period in figure 4.2, the stocking costs for new products reach highest point at August, that means Haier can not manage the inventory and control the cost well.
In figure 4.6, the curve trend from January to February is different with figure 4.2 and figure 4.4, it indicates that more returned products is used for remanufacturing to be finished goods as we mentioned above, so the stocking costs for returned products maintain a stable level, which is different from the curve of demands and ordering costs of returned products. Another difference is the curve trend from the middle of February to April. In this period the stocking costs for returned products have a steep rise in figure 4.6 while they are the plummet in figure 4.2 and 4.4, for a lot of recycled products are returned to Haier, so that the stocking costs for returned products are high in this period. The curve trend is similar with figure 4.2 and 4.4 except for these differences.

According to the figures above, the trend of new products follow with demands’, stocking cost for new products increase when the demands are high. Sometimes, the trend of returned products has a little difference with demands’ because of uncertainty of reverse logistics.

4.1.2 Problems Met in Inventory Control of Haier Logistics

There are some problems Haier Logistics meets in the inventory control of WEEE reverse logistics.

1) Haier promote “Zero Inventory” policy, but the quantity and time of recycling products are uncertain, it is not in accord with “Zero Inventory” policy, causing a random inventory costs at the same time.

2) How to control inventory cost in a low level is a hard problem Haier logistics have to face, and it still not be handled well.

3) The rate of recycling of components is random, it causes a high degree uncertainty of material plan in reverse logistics.

4) In sorting II, Some of products which can not be reused will be delivered to the
qualified environment processing enterprises Haier appointed, it causes additional costs.

4.2 Case company B: Midea Group- Annto Logistics Co., Ltd.

*General profiles*

Founded in 1968, Midea is renowned as a sizeable conglomerate that specializes in the manufacturing of household appliances and sets foot in relevant fields of real estates and logistics. It is now one of the largest white household appliance production bases and export bases in China. While strengthening the industry of household appliances, Midea is also taking initiatives in expanding new domains. By acquisitions, mergers, and cooperation on a trans-regional and trans-sectoral basis, the group is now marching to a diversified business operation in a well-grounded way. In addition to the domain of household appliances, Midea is also engaged and developing rapidly in the industries of real estate, automobiles, logistics, information technique, finance, and so on. With the acquisition of the industries of refrigerators and washing machines in 2004, Midea's products group of white appliances has been completed, with its overall competitiveness enhanced. (http://www.midea.com.cn. 2011-03-29)

As is mentioned above, Midea group owns its own sub-company doing logistics business, which is named Annto Logistics Co., Ltd..

Annto Logistics was founded in January 2000, a subsidiary of Midea Group. Annto is one of the major players in domestic 3PL services in mainland China. Annto provides integrated logistics management services which including cold chain service. After a decade of rapid development, Annto has reached the top ranks in China logistics and particular in 3PL services. Annto manages a total storage area of approx 4 million m2; annual transportation volume is over 5 billion ton-km; annual delivery of about 1.2 million orders. Annto has 8 regional offices in managing nearly 200 logistics
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platforms throughout China. Annto not only provides customer with high efficiency storage, and on-time delivery, but also provides value-added service such as bar-code management, replenishment, re-packaging, inventory analysis etc. All these services are to ensure our customers to reduce their total logistics costs and have better management on their shipment flow. Annto also provides professional advice to assist customer in explore business opportunities with substantial result. (http://www.annto.com/en/, 2011-03-29)

Annto has about 4million sqm of storage space nationwide in most of China’s key provincial and tier-2 and tier-3 cities. Annto continues to invest in hardware and software to ensure highly efficient internal warehousing operations processes. These include storage systems, management software, identification system such as barcode and RFID, pick-pack systems and warehouse customization to meet increasingly high velocity business logistics needs. Annto well positioned and extensive network, coupled with our integrated management capabilities and 7X24 operations, provide our clients exclusive and comprehensive logistics services throughout China. Annto’s solution based processes such as VMI, Integrated Hub and Spoke, and Spare Parts Logistics solutions provide new possibilities and create additional values for its clients. Annto’s extensive business services include general and specialized cargo storage; collateral management, spare parts logistics, bar-code management, reverse logistics, shelf life management, etc. (http://www.annto.com/en/, 2011-03-30)

The following information is based on interview (by telephone) conducted 2011-03-27 (Sunday) with Liu Shan, Operation Dept. manager of Annto Logistics.

4.2.1 Inventory Control of WEEE reverse logistics in Annto Logistics

Annto has its own national integrated inventory system: there are 4 inventory centers which are in Shunde, Hangzhou, Zhengzhou and Wuhu, these inventory centers are all
reached by information system management, with the management mode of “covered through by a single invoice”. Company has 10 logistics centers all over China and 110 points in the business network. In 2006-2008 development planning, Annto has set “Green Logistics” as key emphasis in work. And in 2009-2011 development planning, Annto put more efforts on doing better on reverse logistics for Midea Group. Annto has been doing a lot on inventory management in WEEE reverse logistics.

*Inventory control Workflow*

According to information from Liu Shan, based on the materials of interview, a workflow of WEEE reverse logistics in Midea is illustrated as below (the workflow has been verified by Liu Shan), this workflow places extra emphasis on inventory part, the reason that we illustrate the whole process is to make it easier to see WEEE in inventory from inbound to outbound:
Customers have several ways to deal with WEEEs of Midea, some are sold to recyclers or thrown away then collected by recyclers, and some are refunded or
replaced to retailers. In sorting I, different kinds of products are sorted (which are following Midea’s recycling policy). Different returned products are decided to transferred to arranged sites, the site selection is not simply following proximity principle, but also following the functions of the warehouses, and should arranged by Annto logistics. After site selection, clean I is done, in this section, products are simply cleaned such as dedusting, etc., then the sorted WEEEs are transferred into different warehouses, check is done in the same time when the WEEEs are inbound, and should be recorded into ALIS 2.0 database. Inventory control should follow Annto’s inventory methods for the different kinds of products. Sorting II is done to apart the products, some components which cannot be reused are outbound, and these components are stocked outside of the warehouses, somewhere with low inventory costs, wait to be recycled or treated; some components can be reused are transferred into other warehouses or other areas, inbound and check again, record the data into database, they are stocked in inventory methods of Annto, when Midea needs these components for maintenance or remanufacturing, the components are outbound and recorded into database.

Methods of Inventory Control

Annto has several methods in inventory control, which help Annto reduced 30% inventory costs of Midea in the past few years, and help Midea make the whole reverse logistics to run smoothly.

4PL company- Guangzhou Annto Supply Chain Technique Co. Ltd. In inventory control management, it is far not enough to use the traditional methods of inventory control. To deal with problems in inventory control, Annto builds up a 4PL company, in perspective of the whole supply chain, offer solutions for the problems. Also in reverse logistics, the 4PL company helps set up the workflow of WEEE reverse logistics in Midea, and offer solutions for decreasing inventory costs.
ALIS 2.0. (Annto Logistics Information System 2.0). Annto develops an advanced logistics information system—ALIS 2.0, which covers a whole supply chain. The inventory module, which is the first developed, helps Annto achieve the management mode mentioned above—“covered through by a single invoice”. Besides, the system can also observe the condition of warehouses, and connect Annto with both Midea and retailers.

VMI. As mentioned in theoretical framework, VMI is a popular methods in inventory control. Annto uses VMI method by letting retailers manage the inventory, which means that the retailers control their own stock amount, Annto keep the stocks for the retailers temporarily. Midea is not in charge of the inventory anymore. In reverse logistics, the returned products are first kept by retailers or recyclers for a while, this is a way to decrease stock amounts in a time.

ABC. Which is also referred in theoretical part, Annto uses ABC method to differentiate high-value returned products and low-value ones.

Other Methods. In inventory control of WEEE reverse logistics, some other inventory control methods are used as well. FIFO (first-in, first-out) and batch management methods are used to make stocks in order and easy to transfer. Safety stock and continuous replenishment methods make remanufacturing and maintenance run well-balanced.

Costs of Inventory Control

Same as in the case of Haier, Midea has hairdryer production as well, as explained in previous texts, table 2 shows the details of manufacturing and re-manufacturing costs of hairdryer in Midea.
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Table 2 is slightly revised based on the real data in company as well, with the permission of Liu Shan, the authors simplified the data to protect business secrets and also with the simplified data calculation will be much easier in analysis, besides, the data before and after revision are more or less the same.
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China
--The HEA (household electrical appliances) manufacturers’ perspective
<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
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</thead>
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<td>7500</td>
<td>5200</td>
<td>2200</td>
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<td>5400</td>
<td>8400</td>
<td>7500</td>
<td>8600</td>
<td>2000</td>
<td>4700</td>
</tr>
<tr>
<td>Stocking costs for products (RMB)</td>
<td>19856000</td>
<td>22058400</td>
<td>14084000</td>
<td>6224000</td>
<td>25412000</td>
<td>18980000</td>
<td>13968000</td>
<td>26828000</td>
<td>22600000</td>
<td>25212000</td>
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<td>Stocking costs for returned products (RMB)</td>
<td>3723000</td>
<td>4106250</td>
<td>2847000</td>
<td>1004500</td>
<td>4908500</td>
<td>3558750</td>
<td>2756500</td>
<td>9398000</td>
<td>4106250</td>
<td>4868500</td>
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<td>2573250</td>
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<td>Ordering costs for products (RMB)</td>
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<td>5694000</td>
<td>2409000</td>
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<td>82125000</td>
<td>94170000</td>
<td>2190000</td>
<td>5146500</td>
</tr>
<tr>
<td>Ordering costs for returned products (RMB)</td>
<td>11203000</td>
<td>12356250</td>
<td>8567000</td>
<td>3624500</td>
<td>14168500</td>
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<td>13839000</td>
<td>12356250</td>
<td>14368500</td>
<td>3095000</td>
<td>7743250</td>
</tr>
</tbody>
</table>

Table 4.2 Rough estimated details of hairdryer manufacturing and re-manufacturing in Midea of year 2010 (Sources: Liu Shan)
From the data given above, Figure 4.8 to Figure 4.12 is made to illustrate the changing numbers.

In figure 4.8, April and November are slack sales seasons, February, May, August, September and October are busy seasons, for in these seasons, there are national holidays, people go shopping more frequently than in other months.
In figure 4.9, stocking costs of products are low in April and November, high in February, May, August, September and October, similar trend with figure 4.8, but in August, stocking costs go up sharper rather than in demands in figure 4.8, for in August, sales volume reaches the highest point, meanwhile, Midea have no enough ability to manage inventory well. Every year, when sales volume reaches high, Midea always meets the same problem.

Same as in figure 4.8, in figure 4.10, stocking costs of return products are low in April and November, high in February, May, August, September and October. However, in August, stocking costs go up sharper rather than in demands in figure 4.8, even much sharper than in figure 4.9. As mentioned above, in August, Midea meets inventory problems, they do transfer some return products to some warehouses of low usage rates, and save the spaces for selling products, which leads to a much higher holding costs of return products for the transportation and improper inventory controls. Besides, in July, August and September, the holding costs of return products rates are higher than rates in figure 4.8 and in figure 4.9, for these 3 months are in summer, when in summer, inventory costs go higher to pay for relieving summer heat, decrease the dusts, fireproof, etc. return products are different from products for sale, products
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for sales usually are kept within a short period, and well packaged which can decrease the crises, the movements of products for sale are made by modern advanced equipments, meanwhile return products are not the same, so the costs in these three months are high. Never the less, in busy seasons, return products are collected back much more than other months, according to Liu Shan.

In figure 4.11, the curve trend follows demands curve in figure 4.8 more or less, ordering costs of return products are low in April and November, high in February, May, August, September and October. In another words, in the re-manufacturing process, there are no significant problems, which can reflect that the re-manufacturing rate in Midea is high.
In figure 4.12, the curve trend is more or less the same with demands curve in figure 4.8, ordering costs of new made products are low in April and November, high in February, May, August, September and October.

Based on figure 4.8 to figure 4.12, basically, the return products volume follows the demands’ trend, when demands are high, the return products are getting more, and inventory control of WEEE reverse logistics is getting more difficult, for the reason of limited spaces, weather aspect, potential crises and workers in warehouse get no passion at work, etc. and there are no significant problems of re-manufacturing process in Midea for the return products.

### 4.2.2 Problems Met in Annto’s Inventory Control

In inventory control of WEEE reverse logistics, Annto meets several problems which are hard to deal with.

1) WEEE products are usually inbound in small lots, which make it hard to check and difficult to manage.

2) Inventory costs are too high, Annto has no ways to decrease the costs, has even no clue where to start.
3) WEEE products take too much space, and not turnover in short time, what is worse is, the WEEE products stocks are getting much more in busy season, which means that, the normal products need a lot of space as well.

4) After the second sorting process, the wasted components are accumulated outside of the warehouse, these components still take space, and hard to find a balance that can make less inventory costs and less transportation costs.

5) To fit the needs of remanufacturing, the components in stocks are outbound irregularly, which make the amount of components in stocks is high sometimes. Besides, the irregularly amount of components in stocks leads to a difficulty that hard to order components from suppliers regularly.

6) It is common that some warehouses are full used, some are not, and the balance between inventory costs and transportation costs is difficult to control.

5. Analysis

In this chapter analysis of the empirical evidence collected from 2 case companies will be conducted. First of all, a with-in case analysis will be made, then a cross case analysis, based on the analysis, a new model for the two companies will be built which can partly help the companies improve inventory control, and low inventory costs.
Figure 5.0 simply illustrates the relation between analysis and research questions, with-in case study and cross case study answer research question 2, while model analysis answers research question 3.

5.1 With-in Case Analysis

In this part, with-in case analysis of Haier and Midea will be made. From both external and internal perspective, origins of the problems are outlined. The external factors are based on theoretical framework part 1 and part 2, the internal factors are mainly based on theoretical framework part 3 and from empirical findings.

External factors. By recalling 3.1 and 3.2.1, the workflow of reverse logistics and some factors in the environment of China are listed in the parts, by comparing the theories and empirical findings, some external factors are list as following: politics, economics, society, technique, strategy of doing reverse logistics, these factors are described in details in the following analysis to prove their validity.

Internal factors. By recalling 3.1.2 and 3.3.2, the features of reverse logistics and inventory control give some clues to get the internal factor which could be the origins. Then following the clues, by looking workflow of these two case companies, so some internal factors are proposed as following: Scale of the company, process of doing reverse logistics, process of doing inventory control, inventory control method, sites and scales of the warehouses, remanufacturing rate, level of IT application. Then there are descriptions in detailed following the factors to prove their validity.

5.1.1 Analysis of case 1-Haier Group

In this part, we will analyze the situation of hairdryer in Haier Group by using the data and figures from demands, stocking costs of new products and returned products, ordering costs of new products and returned products point of view, respectively.
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Figure 5.1-5.5 below are illustrated the changing of them. We can see clearly the trend of each factor and differences of trend between factors. After the data analysis, discussion of problem origins will be made follow.

As we mentioned above at empirical part, we recognized some problems of Haier on inventory control of reverse logistics through interviewing with Zhan Ning. In this part, we try to figure out and find the origins of these problems through analyzing the external factors and internal factors which impact Haier Group and also related to the model we mentioned above. External factors relate to politics, economy, techniques, social factors and the strategy of doing reverse logistics, etc. Internal factors relate to scale of the company, workflow of doing reverse logistics, workflow of inventory control, inventory control methods, sites and scales of the warehouses, remanufacturing rates, level of IT application, etc.

External factors

Politics. China pays more and more attention to disposal problem of waste materials. The government support manufacturers to develop reverse logistics. In 2008, Haier proposed “Green Design, Green Manufacturing, Green recycling, Green Business” 4G strategy. So Haier logistics put more attention on reverse logistics. Besides, the government has set Qingdao as the first city to do reverse logistics of WEEE, which is the locations of Haier’s main manufacturing factories, Haier takes much more pressure on this.

Economy. With the economy development of China, lives of people get better and better. People have more extra money to buy HEA they need, which results the speed of replacement of HEA becomes faster, and a lot of WEEE need to be deal with. So the manufacturer of HEA has to find a way to return these products well, such as Haier can add the recycle costs into prices of products for sale or pay some money
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back to consumers to recycle WEEE. But according to China reality, it still has a long way to go.

**Society.** In the whole environment of China, many people do not realized the importance of recycling products, some of them just throw it when HEA was broken. It caused a lot of pollution problems for environment. Haier has been doing publicities about doing green cycle of the HEAs, which means Haier is trying to persuade people recycling the WEEEs orderly. This costs Haier a lot.

**Technique.** Although many manufacturers of HEA realized the importance of reverse logistics, and make some effort on recycling their products, they don’t have advanced technology to ensure doing it well. Haier that is the earlier one to do reverse logistics introduce a lot of modern systems and methods to apply for reverse logistics. Haier should utilize more advanced equipments, but it costs a lot. In 2011, Haier is planning to introduce some advanced techniques from Germany, this will probably accomplish before year 2012.

**Strategy of doing reverse logistics.** In china, Haier group was first aware of this development trend of modern logistics, and established Haier Logistics Co.,Ltd. The business on reverse logistics of Haier Group is taken by Haier logistics, it is a good way for Haier managing the business of reverse logistics. And Haier logistics also do some business from other companies as 3PL.

**Internal factors**

**Scale of the company.** Haier is the biggest manufacturer of HEA in China. Haier sets up 36 regional distribution centers and spends huge sums to establish a modern international logistics center in Qingdao. But this increases the inventory cost, and it is difficult to manage.

**Process of doing reverse logistics.** Haier use the customer service of company as recycler to recycle the WEEE. It is easy for consumers to return waste products.
Process of doing inventory control. Haier logistics is responsible for inventory of reverse logistics, and they also sent WEEE to some qualified environment processing enterprises.

Inventory control methods. Haier introduce VMI-HUB system, SAP LES and HLES(Haier Logistics Executive System), using Product Distribution Center Setting. Haier continues to expand 3PL business, at the same time Haier started to provide 4PL services

Sites and scales of the warehouses. As we mentioned in empirical findings, Haier sets up 36 regional distribution centers, Haier logistics arrange the sorted products and first delivery them to different transfer warehouses which are in different sites for inventory control, then making second sorting to control the stock, there is a heavy workload in boom season, some warehouses may be not have much more spaces for returned products.

Remanufacturing rates. According to the data and figure above, the remanufacturing rates are high.

Level of IT application. The level of IT application in Haier logistics is high, it need to be applied better in practice.

Origins of the problems that Haier meets

According to some analysis above, we find the origins of problems as follows:

1) Problem: Haier promote “Zero Inventory” policy, but the quantity and time of recycling products are uncertain, it is not in accord with “Zero Inventory” policy, causing a random inventory costs at the same time.
   
   Origins: this is related to consumers who determine the quantity of recycling products, the manufacturer do not know how many WEEEs the consumers have. This is a highly uncertain factor. Normally, the peak of recycling products is in boom season, but sometimes it is not steady.

2) Problem: How to control inventory cost in a low level is a hard problem Haier logistics have to face and it still not be handled well.
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*Origins:* Haier logistics need more advanced equipments and technology to diminish inventory cost, on the other hand they need to find a better way to carry on “Zero Inventory” policy to decrease inventory cost. By checking the workflow of WEEE reverse logistics, we find there is a additional cost on reverse logistics, which is caused by transferring WEEE to qualified enterprises to deal. This is also a reason of high inventory costs.

3) *Problem:* The rate of recycling of components is random, it causes a high degree uncertainty of material plan in reverse logistics.

*Origins:* This relates to the system on reverse logistics. Haier logistics need a more efficient recovery and management system.

4) *Problem:* In sorting II, Some of products which can not be reused will be delivered to the qualified environment processing enterprises Haier appointed, it causes additional costs.

*Origins:* This relates to public policy, the government suggest manufacturer find a qualified enterprises to do this kind of work. Besides, it may relates to the recycler who can choose to delivery WEEEs to these kind of enterprises directly.

5.1.2 Analysis of Case 2- Midea Group

In this part, empirical evidence from Midea group will be analyzed, first of all, analysis of the data shown above, then the origins of the problems Midea met in reality,

As mentioned above, Liu Shan listed a number of problems in work. In this part, the authors try to dig out the origins of these problems by using theories above and get some clues from the model, which in another word is trying to find the origins by analyzing external and internal factors. External factors relate to politics, economy, techniques, social factors and the strategy of doing reverse logistics, etc. Internal factors relate to scale of the company, workflow of doing reverse logistics, workflow of inventory control, inventory control methods, sites and scales of the warehouses, remanufacturing rates, level of IT application, etc.
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External factors

Politics. As mentioned in theoretical part, the Chinese government has been paying more and more attention to WEEE reverse logistics. In 2008, a policy was published to claim manufacturing enterprises dealing with WEEEs, Midea is one among the enterprises, which means Midea has to recycle the WEEEs of its brand, or penalty will be made.

Economy. Recalling the texts above, with a booming development of Chinese economy, Chinese people can afford more expensive goods, which means Midea can add the recycle costs into prices of products for sale. Meanwhile, more and more HEA manufacturing enterprises are raising with the growth of Chinese economy, which means if Midea rise the products prices, customers will turn their back to Midea. Nevertheless, the salaries of low educated workers haven’t increased a lot. Which leads to a low passion at work for the workers.

Society. People are getting more education in the past 30 years, and they start to realize that WEEE should be dealt with in a proper way for the protection of environment, but still there are a large amount of people haven’t realized this yet, they throw the WEEEs away, which brings difficulties for recyclers.

Technique. With modern advanced techniques, Midea can do a more completely treatment of WEEEs, and also, IT are used in the reverse logistics process, make everything much easier. However, the technical equipments and knowledge cost a lot. And some part in the process cannot apply advanced techniques.

Strategy of doing reverse logistics. Annto logistics is a subsidiary company of Midea Group, in this thesis, Midea manufacturing factories consider Annto logistics as a 3rd party, they outsourcing the reverse logistics to Annto logistics. This makes the management of reverse logistics process more professional, but Midea loses some power to control the whole thing, besides the connection between them two need to be further strengthened.
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Internal factors

Scale of the company. Midea group is a large manufacturing enterprise, who covers its business all over the Mainland of China, it has several factories but this make it difficult to deal with inventory control of return products. Return products are stocked in warehouses which might not in the same place of manufacturing factories. This increases inventory costs.

Process of doing reverse logistics. The whole process of WEEE reverse logistics in Midea is accessible, but the recycling part need to be further developed, for the recyclers sometimes are not well trained or organized, different kinds of WEEEs are returned to warehouses disorderly, which bring more recycling costs and inventory costs for Midea.

Process of doing inventory control. The process of doing inventory control is well done in Midea.

Inventory control methods. By introducing 4PL company into management, using ALIS2.0 system, VMI, ABC and other methods, Midea has been doing well in inventory control of reverse logistics.

Sites and scales of the warehouses. As mentioned in empirical findings, Midea has many sites of warehouses, but the scales of some ones are not that proper for the sales or for the WEEEs, sometimes the stocks have to be transferred from one warehouse to another one, it cost a lot, especially in busy seasons, when products need enough inventory spaces, warehouses for WEEEs have to be prepared for the products for sales, in this case, inventory controls are usually not done as well as other seasons.

Remanufacturing rates. According to the figures above, the remanufacturing rates are high and with no significant problems.

Level of IT application. High level of IT application is a significant advantage of Annto, but still some further improvement need to be made.
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Origins of the problems that Midea meets

As analyzed above, the origins of following problems can be concluded, which are simply stated as below.

1) **Problem:** WEEE products are usually inbound in small lots, which make it hard to check and difficult to manage.
   
   **Origins:** This can relate to recyclers, who didn’t manage the WEEEes well.

2) **Problem:** Inventory costs are too high, Annto has no ways to decrease the costs, has even no clue where to start.
   
   **Origins:** Policies make Midea has to deal with WEEEes in proper ways, but customers won’t pay for it for now. Besides, technique level is also a limitation to decrease the costs.

3) **Problem:** WEEE products take too much space, and not turnover in short time, what is worse is, the WEEE products stocks are getting much more in busy season, which means that, the normal products need a lot of space as well.
   
   **Origins:** Recycler should be related, before well managed of the WEEEes, they are transferred to Midea’s warehouses, inventory control methods are related as well, Midea need a better way to deal with WEEE inventory especially in busy seasons.

4) **Problem:** After the second sorting process, the wasted components are accumulated outside of the warehouse, these components still take space, and hard to find a balance that can make less inventory costs and less transportation costs.
   
   **Origins:** inventory control problems should be proposed.

5) **Problem:** To fit the needs of remanufacturing, the components in stocks are outbound irregularly, which make the amount of components in stocks is high sometimes. Besides, the irregularly amount of components in stocks leads to a difficulty that hard to order components from suppliers regularly.
   
   **Origins:** This relates to inventory control and IT application in Midea.

6) **Problem:** It is common that some warehouses are full used, some are not, and the balance between inventory costs and transportation costs is difficult to control.
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China

--The HEA (household electrical appliances) manufacturers’ perspective

*Origins:* This relates to the sites and scales of warehouses in Midea, besides, inventory control and IT application in Midea are related as well.

### 5.1.3 Summary of within case analysis

To combine the two cases, a table could be a best way to describe. Table 5.1 shows the different details of the two cases. With the different details, origins of the problems in the enterprises can be easily identified, moreover, in the table, it is much easier to tell what kinds of problems can be revised, what kinds cannot be revised but can be avoided as possible as they can in other ways, what kinds cannot be either revised or avoided. These can be a reference for suggestions in the following texts.
## Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in parts of China

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**The HEA (household electrical appliances) manufacturers’ perspective**

### Case Factors

<table>
<thead>
<tr>
<th>External Factors</th>
<th>Haier</th>
<th>Midea</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Politics</strong></td>
<td>Have policies of doing reverse logistics; take much more pressure;</td>
<td>Have policies of doing reverse logistics;</td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td>Pay for the recycling fees itself;</td>
<td>Pay for the recycling fees itself;</td>
</tr>
<tr>
<td><strong>Society</strong></td>
<td>Many people do not realized the importance of recycling products; but Haier is putting more efforts to persuade people know the importance; Still need to find a effective way to do WEEE recycling;</td>
<td>Many people have no sense of WEEEs recycling themselves; People claim more about WEEE recycling which make the manufacture have to deal with the WEEEs;</td>
</tr>
<tr>
<td><strong>Technique</strong></td>
<td>Introduce a lot of modern systems and methods; Need more advanced equipments; has a plan to introduce advanced equipments before year 2012;</td>
<td>More modern advanced techniques; Far not enough to low the inventory control costs;</td>
</tr>
<tr>
<td><strong>Strategy of doing reverse logistics</strong></td>
<td>By outsourcing the reverse logistics process to 3PL and some qualified enterprises; Following the government’s policies;</td>
<td>By outsourcing the reverse logistics process to 3PL; Following the government’s policies;</td>
</tr>
</tbody>
</table>

### Internal Factors

<table>
<thead>
<tr>
<th>Scale of the company</th>
<th>Haier</th>
<th>Midea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large scale;</td>
<td></td>
<td>Large scale;</td>
</tr>
<tr>
<td>All kinds of HEA products</td>
<td></td>
<td>All kinds of HEA products</td>
</tr>
<tr>
<td>Business area: Whole Mainland of China and overseas;</td>
<td></td>
<td>Business area: Whole Mainland of China;</td>
</tr>
<tr>
<td>Several factories all over China and overseas;</td>
<td></td>
<td>Several factories all over China;</td>
</tr>
<tr>
<td>Workflow of doing reverse logistics</td>
<td>Caused additional cost on reverse logistics;</td>
<td>Well designed;</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Workflow of inventory control</td>
<td>Well designed;</td>
<td>Well designed;</td>
</tr>
<tr>
<td></td>
<td>Well performed;</td>
<td>Well performed;</td>
</tr>
<tr>
<td>Inventory control methods</td>
<td>VMI;</td>
<td>4PL;</td>
</tr>
<tr>
<td></td>
<td>SAP LES;</td>
<td>VMI;</td>
</tr>
<tr>
<td></td>
<td>HLES;</td>
<td>ALIS 2.0;</td>
</tr>
<tr>
<td></td>
<td>Product Distribution Center Setting;</td>
<td>ABC;</td>
</tr>
<tr>
<td></td>
<td>4PL;</td>
<td>Other methods;</td>
</tr>
<tr>
<td>Sites and scales of the warehouses</td>
<td>36 regional distribution centers;</td>
<td>110 net points, all over China;</td>
</tr>
<tr>
<td></td>
<td>Not well designed, for not enough market</td>
<td>The scales of warehouse are not in a same standard;</td>
</tr>
<tr>
<td></td>
<td>investigation or limitation of capital or</td>
<td>Not well designed, for not enough market investigation or limitation of capital or limitation of government policies;</td>
</tr>
<tr>
<td></td>
<td>limitation of government policies;</td>
<td></td>
</tr>
<tr>
<td>Remanufacturing rates</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Level of IT application</td>
<td>High;</td>
<td>High;</td>
</tr>
<tr>
<td></td>
<td>It need to be applied better in practice;</td>
<td>Some parts are still not well connected;</td>
</tr>
<tr>
<td>Passion of employees</td>
<td>High;</td>
<td>Medium;</td>
</tr>
<tr>
<td></td>
<td>In bad environments, such as extremely hot or cold, high;</td>
<td>In busy season, low;</td>
</tr>
<tr>
<td></td>
<td>In bad environments, such as extremely hot or cold, low;</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1 Summary of External factors and Internal factors of Inventory in reverse logistics of Haier and Midea (Sources: Own design)
5.2 Cross Case Analysis- Haier and Midea

In this part, a cross analysis between Haier and Midea will be made. Recalling the empirical findings, we can see the average demands in the two enterprises are approximately the same, which is 2000. Besides, in reality, the situations and business area, company scales, interests, etc. are similar. Recalling with-in case analysis, the external factors and internal factors of these two companies are partly similar. A cross case analysis can be made in the two cases based on the data of hairdryer details in year 2010. To find out the differences of the two companies and see how similar the factors are, some solutions of the problems can be proposed based on the cross case analysis and with-in analysis above.

5.2.1 Comparison based on the with-in case analysis

As presented in 5.1, there are some problems in the two cases, especially in 5.1.3, the exactly differences are listed in a table, which can be easily compared. In this part, the cross analysis will be divided into external factors and internal factors, show the differences and similarities of the two cases.

External factors

Politics. The politics factor is similar in the two cases, which are determined by the government, however, in Haier, they have greater pressure, for the government have a policy that making Qingdao as the first city to do reverse logistics, which means Haier has to make a great effort to keep away from penalty.

Economy. The development of China affects these two cases, which makes the economy factors are the same in the two cases.
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**Society.** For the two cases have the same customers, which means that the society factors are similar, but Haier has started to persuade people know the importance of doing recycling of the WEEE.

**Technique.** The average development of HEA manufacturers in China is the same, the technique factor is similar in the two cases.

**Internal factors**

**Scale of the company.** Both of the two cases are of large scale. They cover their products all over China. It is also the reason that the authors choose them, for they can be compared.

**Workflow of doing reverse logistics.** Haier has an extra process in the workflow, which could increase the costs of inventory, but considering the policies from the government, Haier cannot erase this process. While workflow in Midea is well designed, for they have no such strict policies from government.

**Workflow of inventory control.** All well designed in the two cases, which means 3PL are doing well in reverse logistics, especially in doing inventory control.

**Inventory control methods.** There are many similarities in the two cases, such as IT systems, advanced inventory control methods, and other methods. They all reflect that 3PL are doing a good job in inventory control methods, and it can also reflect that if calculating the inventory cycle and inventory inbound and outbound correctly, inventory costs could be decreased.

**Sites and scales of the warehouses.** Neither of the two cases have good management of the warehouses, even they have so many sites of warehouses.
**Remanufacturing rates.** As in empirical findings, the remanufacturing rates are both high in the two cases, which means that inventory control are well done, besides, it also reflects that if the inventory control are well calculated, the costs of inventory can be decreased.

**Level of IT application.** High level of IT application in the two cases, the case enterprises have realized that it must be high level of IT application to make sure the inventory control can work smoothly in the whole area of China. They know the importance of coordinating.

Passion of employees. There are some differences between the two cases, which could cause a lot of problems. Haier has good incentive system, to make sure the employees keep high motivation to work in bad environment. But Midea has no such system, they don’t really understand why high salary employees finally be as lazy as low salary workers.

### 5.2.2 Comparison based on the data analysis

Figure 5.1 to 5.5 show the comparison of the two cases based on the data in empirical findings.
In figure 5.1, the two curves are almost overlapped, which means Haier and Midea share the market almost with the same percentage in HEA area of China.

In figure 5.2, there are some differences in July, August, September and October, which are in busy seasons. The curve of Haier, as analyzed above, has similar trend with demands trend, but curve of Midea, has a different slope of raising and down. This means that in busy seasons, Haier does better job than Midea does, this related to inventory control and the sites and scales of warehouses. Besides, the treatment of workers in the two companies are not exactly the same, Haier has a slightly higher welfare system than Midea does, which can also be a origin of causing this difference.
Figure 5.3 Stocking cost of return products curve in year 2010 (Sources: Own Design)

In figure 5.3, there are some differences in March and August, which has already explained above, these two different curves show the uncertainty of reverse logistics, it is hard to control the recycling volume unless managing the recycling process or re-organizing the recycling process, but to achieve the goal, a huge amount money is needed which no enterprises would like to offer themselves.

The big differences could have some origins, we use 5WHY analysis.
Why are there big differences in February, March and August? As in the description above, they cannot control the inventory costs very well in Midea.
Why Midea cannot control inventory costs very well? For in February and August the warehouses are short of usage, besides, the management of inventory control are out of order.
Why the warehouses are short of usage? For in February and August are busy season, when are the holidays in China. Customers are much more than usual, the refund, repair, and drop of HEA are more as well. The warehouses are easily short of usage.
Why the management of inventory control are out of order? As it is easily seen in 5.1.3, the inventory control level is high in Midea, the reason for the question should be lack of passion for the employees. In February and August, the weathers are not that good, usually in warehouses, the environments are not good enough, the passion of employees should be motivated.
So the reason for the differences is mostly that lack of passion for the employees.

In figure 5.4, the curves are overlapped, which means the manufacturing process are almost the same in the two enterprises, and suppliers are the same, this can be found in empirical findings. And also, the remanufacturing process should be similar by the reflection of the two curves.
In figure 5.5, there is difference in May, for in March, Haier have not many return products, meanwhile May is a busy season, products are consuming faster. However, in August, September and October, the ordering costs remain the same as the demands trend, which reflect that there are some problems in Midea, could be inventory control problem, sites and scales of warehouses or the welfare systems of the company.

5.2.3 Highlight of the similarities and differences of the two cases

According to the with-in case study and cross case study, some similarities and differences of the two cases would be highlight as below.

**Similarities:** both of the two cases have busy season, almost at the same time; the two cases have similar demands in 2010, and the inventory are more or less similar, which means that the two cases have similar company scale and production capacity, besides, they have large warehouse to hold the inventory. To the inventory control, as within case study show, they have similar techniques and similar external environmental factors.

**Differences:** The inventory level of return products are not exactly the same, welfares of the two cases are different, besides, the costs of reverse logistics in the two cases are different.

By doing cross case analysis, the origins of the problems that the companies met in reality are double confirmed.

As recalling all analysis above, there is a need for a simple but accurate method for determining ordering/remanufacturing policies, which can be a inventory model.
5.3 Model analysis

Considering the empirical findings and analysis above, there are some problems in the two case companies, and after analyzing the origins of the problems, inventory methods need to be applied, but first of all, inventory models need to be introduced into inventory control. However, as mentioned in theoretical framework, the models are tend to be too complex to implement in practice, hence in this thesis, a new model based on previous theories, empirical findings and case analysis above, is built to help the companies find out the optimal inventory costs and find out what are exactly the key elements in inventory control to reduce the costs.

5.3.1 Ideal Model

Reverse logistics of WEEE have uncertainty, which includes the uncertainty of product demand and uncertainty of WEEE in quantity, quality and supply time; In the performance of stock control, it shows the uncertainty of network inventory point of reverse logistics and uncertainty of the recycling number. WEEE reverse logistics in China is under an uncertain environment, in this thesis, considering the theoretical framework and empirical findings, a model is built which can stand for part of the reality, but simplified some situations, it is an ideal model for the case manufacturers’ inventory control of reverse logistics.

Hypothesis

1. One part of inventory of marketable products are replenished by remanufacturing with returned products as raw materials, the others are added from new products.

   Vlachos et al (2003), Fleischmann, Kuik (2003) state this in their study which can be recalled in theoretical part.

2. The market demand is stable. In both empirical findings and cross analysis, the demands show that the market demand is stable.

3. Production rate is \( p \), \( d>p \). which means in this model, there are no inventory for dead stock, all products are sold out.
4. Assuming there is no waste of recycling WEEE, all of them for remanufacturing of new products. Vlachos et al (2003), Fleischmann, Kuik (2003) in theoretical part made the same assumption. Which are much easier to calculate and can make the problems less complicated.

5. Remanufacturing cost of per unit product is less than discard processing costs of per unit recycling product which is not used to remanufacture and penalty costs caused from recycling product which is not used for further manufacture. Dobos (2003) has a similar assumption in his study, which has the same meaning of this assumption;

6. Do not consider the lead time of the production of new products and remanufactured products, that means stock is zero, finished goods inventory added immediately. Cohen et al (1980), Fleischmann, Kuik (2003) in theoretical part made the same assumption in their study, this assumption makes the calculation much easier.

7. The inventory capacity large enough to meet the stock quantity of the uncertain reverse logistics. Fleischmann et al (2002) have this assumption in their study as well.

8. In connection with the model which have Multi-stock point, the number of stock point is K which is a positive integer with random uncertainty (K does not affect the cost of inventory control in the model). Kleber et al (2002) have the same assumption in their study, as showed in theoretical part, multi-stock point model can simulate the reality better. In empirical findings, both Haier and Midea have multi-stock point which can be recalled in company descriptions.

9. The set-up cost is ignored in this model. Dobos (2003) stated in his research that in the linear model set-up cost is ignored.

**Symbols**

The description of symbols in inventory model as follows:

1. Demand rate of finished products is \( d \).

2. The recycling process of WEEE subject to Poisson distribution with parameter \( \lambda \).
$\lambda > 0$. Muckstadt et al (1981) studied this, and have a conclusion which can be recalled in theoretical part.

3. Remanufacturing rate is $r$.
4. Inventory holding cost of per unit of finished goods in per unit of time is $h_p$.
5. Inventory holding cost of per unit of recycling products in per unit of time is $h_r$.
6. Ordering cost of per unit of finished goods is $C_p$.
7. Ordering cost of per unit of remanufactured products is $C_r$.
8. The production capacity of each batch is $Q_p$.
9. Remanufacturing capacity of each batch is $Q_r$, which also is the number of recycled products in remanufacturing period.
10. Production cycle is $T_p$.
11. Remanufacturing cycle is $T_r$.

**Model description**

Based on the assumptions above, we illustrate the timeline and inventory amount line in a cycle as below, which is shown in figure 5.6.

![Timeline and inventory amount line in a cycle](Source: Own design)
All the data that the symbols stand for can be found in the materials which the case companies offer, or can be calculated from the materials. Figure 5.6 shows the timeline and inventory level which are described as below:

According to the description of theoretical part, in a cycle, in $T_1$, using remanufacturing rate ($r$) to complete remanufactured expectations $E(Q_r)$, $T_1 = \frac{Q_r}{r}$, finished goods inventory during the $T_1$ to grow as the rate of $r - d$, the stock reached $(r-d) T_1$ after the $T_1$, then the rate of $d$ reduced to $0$, $T_2 = \left(\frac{1}{d} - \frac{1}{r}\right) Q_r$, the time of remanufacturing $T_r = T_1 + T_2 = \frac{Q_r}{d}$.

In the period $T_3$ to complete the production capacity $Q_p$ with productivity $p$, get $T_3 = \frac{Q_p}{p}$, new product inventory during the period $T_3$ to grow in the rate of $p - d$, the stock reached $(p-d) T_3$ after production, since the rate of $d$ dropped to $0$, $T_4 = \left(\frac{1}{d} - \frac{1}{p}\right) Q_p$.

In a cycle period, $E(Q_r)/d = \lambda E(T)$, and the total cost can be divided into four parts, the cost of each part as follows:

1) The cost of finished goods inventory $C_1$:

   The expected value of finished goods inventory $Ap - E(Ap) = \frac{1}{2} (r - d) E(T1)$ $E(T_s) + \frac{1}{2} (p - d) T_p = \frac{1}{2} (\frac{1}{d} - \frac{1}{r}) Q_r^2 + \frac{p - d}{2pd} Q_p^2$

   $E(C_1) = h_p E(Ap) = \left[\frac{r-d}{2rd} Q_r^2 + \frac{p-d}{2pd} Q_p^2\right] h_p$

2) The inventory cost of recycled products $C_2$: 

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\[ h_r \frac{1}{2} Q_r E(T) = \frac{1}{2d\lambda} h_r Q_r^2 \]

3) The remanufacturing cost \( C_3 \):

\[ E(C_3) = C_p Q_r \]

4) Production-manufacturing cost \( C_4 \):

\[ E(C_4) = C_p Q_p \]

Therefore, the average expected total cost in the whole cycle is:

\[ E(C) = \frac{1}{T} \left[ \frac{h_r}{2} Q_r^2 \left( \frac{1}{d} - \frac{1}{r} \right) + \frac{p - d}{2pd} Q_p^2 + \frac{1}{2d\lambda} h_r Q_r^2 + C_r Q_r + C_p Q_p \right] \]

\[ = \frac{1}{dT_r + Q_p} \left[ \frac{h_r}{2} Q_r^2 \left( \frac{1}{d} - \frac{1}{r} \right) + \frac{p - d}{2pd} Q_p^2 + \frac{1}{2d\lambda} h_r Q_r^2 + C_r Q_r + C_p Q_p \right] \]

Decision variables is \( Q_p, T_r, E(C) \) is a typical constrained optimization problem (which can be proved through the Hessian matrix), this planning is convex programming, and the function is convex function, the Kuhn-Tucker conditions are the necessary and sufficient conditions of the most advantage of memory.

As \( \frac{E(Q_R)}{d} = \lambda E(T) \), then \( E(Q_R) = \lambda dE(C) = \lambda (Q_r + Q_p) \).

To \( \frac{h_r}{2} Q_r^2 \left( \frac{1}{d} - \frac{1}{r} \right) + \frac{p - d}{2pd} Q_p^2 + \frac{1}{2d\lambda} h_r Q_r^2 + C_r Q_r + C_p Q_p \), find the derivative of \( Q_p \),

\[ \frac{pdC_p}{d - p} \]

so that \( A = \frac{pdC_p}{d - p} \)

To \( \frac{h_r}{2} Q_r^2 \left( \frac{1}{d} - \frac{1}{r} \right) + \frac{p - d}{2pd} Q_p^2 + \frac{1}{2d\lambda} h_r Q_r^2 + C_r Q_r + C_p Q_p \), find the derivative of \( T_r \),

\[ \frac{rdC_r}{(d - r)h_p + (\lambda - r)d} \]

so that \( B = \frac{rdC_r}{(d - r)h_p + (\lambda - r)d} \)
When \( \frac{2E(C)}{2Q_p} = 0 \) and \( \frac{2E(C)}{2T_r} = 0 \), \((Q_p^*, T_r^*)\) by solving is the obtained optimal solution of the smallest average cost in the planning period.

\[
\begin{align*}
\frac{d-p}{2pd}Q_p^2 + \frac{p-d}{p}Q_p^* T_r + \left( C_p - dC_p \right) T_r^* + \frac{1}{2} \left( \frac{1}{d} + \frac{1}{r} \right) T_r^* = 0 & \quad \text{Formula 1} \\
\frac{p-d}{2pd}Q_p^2 - \frac{1}{d} \left( h_p \lambda^2 \frac{1}{d} + \frac{1}{r} \right) Q_p^* T_r^* + \left( C_p - dC_p \right) Q_p^* T_r^* + \frac{1}{2} \left( \frac{1}{d} + \frac{1}{r} \right) T_r^* = 0 & \quad \text{Formula 2}
\end{align*}
\]

Formula 1 + Formula 2 will be:

\[
\frac{p-d}{p} \left( h_p \lambda^2 \frac{1}{d} + \frac{1}{r} \right) Q_p^* T_r + \left( C_p - dC_p \right) Q_p^* T_r^* + \left( C_p - dC_p \right) T_r^* = 0 \quad \text{Formula 3}
\]

The relationship between \( Q_p^* \) and \( T_r^* \) can be obtained from formula 3, suppose

\[
A= \frac{p-d}{p} \left( h_p \lambda^2 \frac{1}{d} + \frac{1}{r} \right) , \quad B= C_p \frac{C_p}{d} , \quad C= C_p \lambda - dC_p ,
\]

so \( AQ_p^* T_r + BQ_r^* + CT_r^* = 0 \), \( Q_p^* = \frac{-CT_r^*}{AT_r^* + B^*} \), put \( Q_p^* \) expressed by \( T_r^* \) into formula 2 to get equation on \( T_r^* \)

\[
\frac{p-d}{2pd} \left( AT_r^* + B^* \right)^2 + \frac{1}{d} \left( \frac{p-d}{p} - A \right) \frac{CT_r^*}{AT_r^* + B} - \frac{BCT_r^*}{AT_r^* + B} - \frac{1}{2} \left( \frac{p-d}{p} - A \right) T_r^* = 0 \quad \text{Formula 4},
\]

Denote the left of the formula 4 as \( f(T^*) \), \( f(T^*)=\frac{p-d}{2pd} \left( AT_r^* + B^* \right)^2 + \frac{1}{d} \left( \frac{p-d}{p} - A \right) \frac{CT_r^*}{AT_r^* + B} - \frac{BCT_r^*}{AT_r^* + B} - \frac{1}{2} \left( \frac{p-d}{p} - A \right) T_r^* \), because function of \( T^* \) is a monotonic function, you can use one-dimensional search method to solve formula 4 and get optimal \( T^* \), the Newton algorithm is given here.

Step 1: given the initial point \( T_0^* \), allowing the deviation \( \varepsilon > 0 \), set \( k=0 \).

Step 2: check \( |f(T_k^*)|<\varepsilon \)? Yes, output \( T_k^* \) and stop the calculation, calculate \( Q^* \) by using \( T_k^* \); otherwise transfer to step 3.

Step 3: calculate point \( T_{k+1}^* = T_k^* - f(T_k^*) | f(T_k^*) |^{-1} \), set \( k=k+1 \), turn to step 2.
5.3.2 Calculation

As mentioned in empirical findings, the data showed in the thesis is slightly revised. However, the calculation and results can be merely affected. For in quantitative analysis, the data comparisons are all based on the data show in empirical findings, so the numbers are still available.

Assumption addition:
The reverse logistics process of hair dryer follows Possion distribution, in which \( \lambda = 5 \);

There are no data for the production rates \( p \) and remanufacturing rates \( r \), so in this thesis, we assume \( p = r \), and \( p + r = d \).

Calculation of case 1- Haier Group

\[
d = \frac{(7000+7400+5100+2200+8400+6600+5600+8300+7400+8600+2000+4800)}{365} \approx 200 \text{ (units/day)}
\]

\[
p = r = \frac{d}{2} = 100 \text{ (units/day)}
\]

\[
h_p = \left(\frac{(20440000+21708000+14892000+24728000+19072000+16352000+26236000+19608000+25112000+5840000+14016000)}{7000+7400+5100+2200+8400+6600+5600+8300+7400+8600+2000+4800}\right) / 365 \approx 8 \text{ (RMB/day)}.
\]

\[
h_r = \left(\frac{(3822500+3851500+5484500+1004500+4899000+3823500+3066000+4744250+4051500+4708500+995000+2528000)}{7000+7400+5100+2200+8400+6600+5600+8300+7400+8600+2000+4800}\right) / 365 \approx 3 \text{ (RMB/day)}
\]
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\[ C_r = \left\{ \left( \frac{74460000 + 82125000 + 56940000 + 24090000 + 94170000 + 71175000 + 59130000 + 91980000 + 82125000 + 94170000 + 21900000 + 51465000}{7000 + 7400 + 5100 + 2200 + 8400 + 6600 + 5600 + 8300 + 7400 + 8600 + 2000 + 4800} \right) / 2 \right\} / 365 \approx 60 \text{(RMB/unit)} \]

\[ C_p = \left\{ \left( \frac{115325000 + 121915000 + 840225000 + 276780000 + 108735000 + 92260000 + 136742500 + 121915000 + 14168500 + 32950000 + 79080000}{7000 + 7400 + 5100 + 2200 + 8400 + 6600 + 5600 + 8300 + 7400 + 8600 + 2000 + 4800} \right) / 2 \right\} / 365 \approx 90 \text{(RMB/unit)} \]

Assume the precision \( \varepsilon = 0.00005 \), based on the model given above, \( Q_r^* = \frac{-C_r^*}{ATr^2 + B} \),

\[ A = \frac{3751}{1000}, \quad B = \frac{177}{2}, \quad C = -17700, \]

then

\[ f(T^*) = -\frac{100}{4000} \frac{17700^2 T^*}{1000} + \frac{1}{200} \left( \frac{-1 - \frac{3751}{1000}}{3751} \frac{-17700 T^*}{1000} + \frac{177}{2} \frac{3751 T^*}{1000} + \frac{177}{2} \frac{3751 T^*}{1000} + \frac{177}{2} \frac{3751 T^*}{1000} + \frac{177}{2} \frac{3751 T^*}{1000} \right) \]

\[ T^* \text{ is integer, initial point is } T_0^* = 1, \quad T_{k+1}^* = T_k^* - f(T_k^*) \left[ f(T_k^*) \right]^{-1}, \]

by using software lingo, to run the formula, the codes are as following:

**model:**

**sets:**

quarters/1..100/:k;

**endsets**

**min**=@abs(t);

\[ f = -100/4000*((17700^2)*(t^2))/((3751/1000*t+177/2)^2)+1/200*(-1-(3751/1000)))*(-17700*(t^2))/((3751/1000*t+(177/2)))-(17700*177/2*t)/(3751/1000*t+177/2)-1/2*(-1-3751/1000)*(t^2);

@Table: \( t = t - f * (@abs(f))^(-1) \);
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in China
--The HEA (household electrical appliances) manufacturers’ perspective

\[ t > 1; \]
\[ @bin(t); \]
\[ @for(quarters:@bin(k)); \]
\[ @free(f); \]
end

by running the software, we can get the result as below:

<table>
<thead>
<tr>
<th>Linearization components added:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraints: 4</td>
</tr>
<tr>
<td>Variables: 4</td>
</tr>
<tr>
<td>Integers: 1</td>
</tr>
</tbody>
</table>

Global optimal solution found at iteration: 0
Objective value: 1512.977

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Reduced Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>1.000000</td>
<td>1525.992</td>
</tr>
<tr>
<td>F</td>
<td>-1512.977</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Row</th>
<th>Slack or Surplus</th>
<th>Dual Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000</td>
<td>1.000000</td>
</tr>
<tr>
<td>2</td>
<td>1512.977</td>
<td>-1.000000</td>
</tr>
<tr>
<td>3</td>
<td>0.000000</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

Which means when T*=1, T* get the optimize value. \( Q^* \approx 190 \). Further more, the optimize inventory cost is approximately 900.

By using the model with data from case 1, we can see when the remanufacturing process period is single, inventory cost of products and return products can be optimal. In reflection, the inventory control of WEEE reverse logistics in Haier is under a uncertainty environment, which means that the reverse logistics process is hard to calculate in regular way, for there are no regular cycle in the process.

**Calculation of case 2-Midea Group**

\[ d = \frac{(6800+7500+5200+2200+8600+6500+5400+8400+7500+8600+2000+4700)}{365} \]
=200(units/day)

\[ p = \frac{d}{2} = 100 \text{(units/day)} \]

\[ h_p = \]
\[ \frac{(19856000+22058400+25412000+18980000+13968000+26828000+22600000+25212000+5140000+13224000)}{(6800+7500+5200+2200+8600+6500+5400+8400+7500+8600+2000+4700)} / 365 \approx 7 \text{(RMB/day)}. \]

\[ h_r = \]
\[ \frac{(3723000+4106250+2847000+1004500+4908500+3558750+2756500+9398000+4106250+4868500+945000+2573250)}{(6800+7500+5200+2200+8600+6500+5400+8400+7500+8600+2000+4700)} / 2 / 365 \approx 4 \text{(RMB/day)} \]

\[ C_r = \]
\[ \frac{(74460000+82125000+56940000+24090000+94170000+70175000+59130000+91980000+82125000+94170000+21900000+51465000)}{(6800+7500+5200+2200+8600+6500+5400+8400+7500+8600+2000+4700)} / 2 / 365 \approx 50 \text{(RMB/unit)} \]

\[ C_p = \]
\[ \frac{(112030000+123562500+85670000+36245000+141685000+107087500+88965000+138390000+123562500+143685000+30950000+77432500)}{(6800+7500+5200+2200+8600+6500+5400+8400+7500+8600+2000+4700)} / 2 / 365 \approx 90 \text{(RMB/unit)} \]

Assume the precision \( \varepsilon = 0.00005 \), based on the model given above, \( Q^*_p = \frac{-CT^*_r}{AT^2 + B} \), \( A=2 \), \( B = \frac{355}{4} \), \( C=-17750 \), then
\[
f(T^*) = \frac{-100}{4000} \frac{17750^2 T^*^2}{(2T^* + \frac{355}{4})^2} + \frac{1}{200} (-1-2T^*) - \frac{17750^2}{4} \frac{355}{2T^* + \frac{355}{4}} - \frac{1}{2} (-1-2T^*)^2,
\]

T* is integer, initial point is \(T_0^* = 1\), \(T_{k+1}^* = T_k^* - f(T_k^*)[f(T_k^*)]^{-1}\), by using software lingo, to run the formula, the codes are as following:

**model:**

sets:

- quarters/1..100/:k;

endsets

min=@abs(t);

\(f=-\frac{100}{4000}*((17750^2)*(t^2))/(2*t+355/4)^2)+1/200*(-1-2)*(17750*(t^2))/(2*t+355/4)-(17750*355/4*t)/(2*t+355/4)-1/2*(-1-2)*(t^2);

@for(quarters:t=t-f*(@abs(t))^(-1));

@for(quarters:t=f*(@abs(f))\((-1))));

\(t>1;\)

@bin(t);

@for(quarters:@bin(k));

@free(f);

end

by running the software, we can get the result that when \(T^*=1\), \(T^*\) get the optimize value. \(Q^* \approx 195\). Further more, the optimize inventory cost is approximately 965.

By using the model with data from case 2, we can see when the remanufacturing process period is single, inventory cost of products and return products can be optimal. The same result of \(T^*=1\) with in Haier reflects that the inventory control of WEEE reverse logistics in Haier is under a uncertainty environment, which means that the reverse logistics process is hard to calculate in regular way, for there are no regular cycle in the process.
Both of the 2 cases results reflect that the inventory control cost in reverse logistics process is hard to calculate in regular way, for there are no regular cycle in the process.

5.3.3 Summary of the Ideal Model

Advantages of the model:

1. This model simulates the inventory control of WEEE reverse logistics from manufacturers’ perspective, meanwhile we can obtain the optimal inventory value and the cycle. According to the data we get, we can intuitively understand the situation of inventory control of manufacturers.

2. Quantitative research is an important process to analyze some issues using mathematical methods in order to get better and clear understanding of issues. This model is a typical method of quantitative research. From quantitative analysis of the cost point of view, it analyzes the impact factors of inventory control and the key elements of inventory cost.

3. This model can help us distinguish affects between internal factors and external factors. The internal factors include production rate, remanufacturing rate and ordering cost of finished goods and recycled goods, etc. The external factors include some kinds of factors of environment, such as political, economical, social and technical environment. Because this model is an ideal model which only analyzes the issue from the mathematical point of view, it does not consider the impact from external environment. So we can clearly recognize the impact of internal factors on inventory control.

Drawbacks of the model:

1. The model is too ideal, and it cannot be fully consistent out of the two cases. The obtained data do not completely reflect the actual situation, so it can only be suitable for the reference of other research activities.

2. This model is mathematical model based on a multi-cycle and multiple stock points, symbols are not many enough, and assumptions are incomplete, it is a
simple mathematical method. When analyzing more complex problems in remanufacturing of WEEE reverse logistics, this model may not be applicable because of its limitations. And in this thesis, it is used to analyze remanufacturing process of reverse logistics for only one product in the case.

6. Suggestions and Recommendations

In this chapter, some suggestions of the two cases based on the analysis are given, and moreover some recommendations to inventory control of WEEE reverse logistics in China are applied.

Figure 6.0 Relations between research questions and suggestions and recommendations. (Own design)

Figure 6.0 simply illustrates the relation between research questions and suggestions and recommendations. This chapter mainly answers part of research question 3.

6.1 Suggestions of Case 1—Haier Group

1) Haier logistics should appropriate to reduce the smaller transfer warehouse and eliminate the negative impact on total logistics costs because of high consumption rate and low output value. This can be related in analysis 5.1.1 and 5.2.1, the workflow of reverse logistics and workflow of inventory control.

2) HLES system needs to be used to every warehouse in Haier logistics, with EDI technology making Haier well carry out and achieve “Zero Inventory” goal, make it as possible. As referred in analysis 5.1.1 and 5.2.1, besides, theories 3.3.3 helped to identify the suggestion.

3) From the workflow of WEEE reverse logistics in Haier, we can find some of WEEE were transferred to some qualified enterprises to dissemble, this will costs a lot additional fees, Haier logistics should come up with better ways to
integrate this process, and reduce some unnecessary costs. According to analysis
5.1.1 and 5.2.1, and combined with 5.1.2, the suggestion is reasonable.

6.2 Suggestions of Case 2—Midea Group

1) Annto logistics should build a tighter connection with Midea manufacturing
factories by using ALIS2.0, which means ALIS2.0 should be implanted into Midea
manufacturing factories thoroughly. Besides more elements of the system need to
be developed, such as communication element, database and data analysis return
element, etc. According to analysis 5.1.2 and 5.2.2, based on theories 3.3.3, this
suggestion is reasonable.

2) ALIS2.0 needs to be connected with each warehouse, fast response is the main
point in future work. As referred to 4.2.3 and 5.1.2, the suggestion should be
helpful.

3) JMI can be applied into reverse logistics process, which can help to improve
inventory control level, as mentioned in theoretical framework. According to 3.3.3,
this method could work in Midea.

4) Recycling part in reverse logistics process need to be re-organized. Besides, JMI
can be used in this part with slightly revision. Also, this can be found in 3.3.3.

5) Putting more energy on 4PL, the supply chain consultant is a good way to
improve inventory control. Integration of the supply chain is the best solution to
reduce inventory cost and improve inventory control level. As in 3.3.3 and in 4.2.2,
with the analysis of 5.1.2 and 5.2.1, this suggestion is reasonable.

6) Improve welfare system, especially in busy season, without people, inventory
control would be idle, which based on the analysis of 5.1.2 and 5.2.2.

6.3 Recommendations to inventory control of WEEE reverse logistics
in China (in HEA manufacturer’s perspective)

Based on the theories, empirical findings and analysis, for doing reverse logistics is a
capital costing job, none of the enterprises would like to step in. and reverse logistics
is in an uncertainty environment, doing so need to make sure everything clearly and
orderly, or costs will be a large amount. The best way of improving inventory control of WEEE reverse logistics in China is that the enterprises standing together to restore the orders.

1) Apply for appropriation from the government.
2) Persuade customers pay for the recycling fees, or persuade the government to make consumers pay for the recycling fees of WEEE.
3) Apply modern advanced techniques from western countries.
4) Restoring the orders of reverse logistics. For example, re-organizing the recycling part by setting recycling centers.
5) Integrating the supply chain.

All the recommendations above are all expensive business, so the enterprises have to stand together to make it possible which is difficult for now.

7. Conclusion and theoretical contribution

In this chapter the main results related to the three research questions will be highlighted. Furthermore, theoretical contribution to the existing theory and drawbacks of this thesis will be presented.

7.1 Conclusion

Summary

In this thesis, the authors first gave a background of the inventory control of WEEE reverse logistics in China, showed the motivation of the thesis, and based on the research literatures, made a problem discussion of reverse logistics in China, and inventory control in China, further identified the purposes of this thesis, by considering of the problem discussion, 3 research questions are proposed: 1. What methods of controlling inventory in reverse logistics system exists in the case of HEA manufacturers? 2. From HEA manufacturers’ perspective, what factors could be the origins of these problems they meet in inventory management of WEEE reverse
logistics? 3. How can the identified problems be alleviated? The following texts are mainly made to solve these three research questions.

In method chapter, the methodology choices for this thesis were described. Multiple case studies were discussed as a research strategy. Furthermore, it was described selection of the empirical cases, and the way of collecting data, directed by the methods. Besides, based on the data, data analysis was also outlined, by comparing the data and materials with model in ideal environment, to make a further analysis. Finally, it was presented how requirements on the scientific credibility will be fulfilled.

In theoretical framework, 3 parts were presented, the attempt was to give theories of origins to inventory control problems. Reverse logistics was applied first, by showing reverse logistics’ workflow, and features, a general acknowledge of reverse logistics was shown. Then according PEST analysis, a WEEE reverse logistics in China was presented, the workflow was also showed, and what problems in WEEE reverse logistics in China are, which means the problems caused by environmental factors, and what the origins problems are, then gave some theories which might solve these problems. Then inventory theories were applied, the inventory control workflow of WEEE reverse logistics in China was illustrated, key elements and features of inventory were also showed in this part. After these base theories, advanced inventory theories were applied in the following 2 parts, one was theories about inventory models, and the other one was theories about inventory methods. The first two parts were meant to find external factors of inventory control, in the third part, theories of inventory models was meant to find internal factors. Moreover, the further theories, inventory methods were prepared for how the problems can be alleviated.

Empirical findings chapter started with presentation of the two case companies followed by description of empirical evidence. The empirical evidence was shown in the structures as following: general profiles of the company and the inventory
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in China
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department, then the workflow of the inventory control, methods of inventory control, and inventory costs, nevertheless, problems in inventory control management were also listed in this part. In the empirical findings, research question 1 can be solved, in this chapter, the details of inventory controls were all presented. And preparation of research question was made, for the problems that the case companies meet were also emerged.

In analysis chapter, analysis of the empirical evidence collected from 2 case companies were conducted. First of all, with-in case analysis and cross case analysis were made, external factors and internal factors were outlined based on the above analysis, which solved research question 2. Then a mathematic model was built into the analysis, the model was built on the basis of theoretical framework, according to the inventory models theories and the hybrid manufacturing system theories, a simple ideal model for WEEE reverse logistics was built up. The model could help the case companies to find internal factors of determining inventory control, which could be related to part of research question 3.

In suggestion chapter, suggestions to the 2 case companies were separately proposed, which are based on the analysis above, then recommendations of inventory control improvement in WEEE reverse logistics are outlined.

**Answers to the research questions**

1. What methods of controlling inventory in reverse logistics system exists in the case of HEA manufacturers?

   In empirical findings chapter, the manager of each company answered the question. The strategy of doing inventory control in WEEE reverse logistics are the same, by outsourcing the business to 3PL. and each company has their own way to do inventory control, but the main ideas are both using the traditional forward inventory control methods.
2. From HEA manufacturers’ perspective, what factors could be the origins of these problems they meet in inventory management of WEEE reverse logistics?

In analysis chapter, the main task was to find out what the factors are, and check if the factors hinder inventory controls in practice. The factors can be divided into 2 main aspects, external and internal factors. External factors include politics, environment, society, technique, strategy of doing inventory control in reverse logistics. Internal factors include scale of the company, workflow of doing reverse logistics, workflow of inventory control, inventory control methods, sites and scales of the warehouses, remanufacturing rates, level of IT application, passion of employees.

3. How can the identified problems be alleviated?

In the 3rd part of analysis chapter, a model was built up to reduce the costs of the two cases. Suggestion chapter gave a bullet list to alleviate the identified problems. For each company, there are some suggestions based on the analysis above, moreover, the main recommendation to the two case companies and even to all of the HEA manufacturers in China was: to improve inventory control of WEEE reverse logistics, the inventory control methods are far not enough, to stand together and change the environment they are in is the best way.

7.2 Theoretical contribution

As presented in introduction part, there are not so many studies of WEEE reverse logistics in China, studies of inventory control are mostly about inventory models without empirical cases. In this thesis, the authors developed the inventory control study with empirical cases, which could offer some evidence or as references for the future studies in this area.
The thesis presented 2 main origin factors of affecting inventory, which were on basis of the theories and analysis. These origin factors haven’t discussed in any previous studies, which could be helpful in future studies when doing inventory control of reverse logistics, this theory could even wider to inventory control of forward logistics.

7.3 Drawbacks and limitations

There are also some drawbacks in the thesis for a certain chain of limitations. For one thing, there are not enough previous studies references in China, this brought some difficulties of supporting the view points in the thesis. Two empirical cases are not persuasive enough to represent the whole China due to the limitation of the authors’ knowledge and the huge area of China, the only way to do reduce the negative affects is to choose 2 typical and large scale companies in China, who can cover their business all over China. To protect business secrets, the data collected from the case companies were simplified, which means that the calculation is not exactly precise, the data analysis only assist to further and deeper analysis rather than prove the evidences. But still, the simplified data are checked by the two managers, according to their experiences, the data is available to be analyzed and can be persuasive. Nevertheless, the ideal model in model analysis is not that complicated, which means, for more complex problems and processes, the model would be lame. So the intention of the model is to help the companies find the internal origins of inventory control, rather than exactly use for calculating the optimized costs of inventory. But these drawbacks can be hopefully minified in further studies.
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--The HEA (household electrical appliances) manufacturers’ perspective


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Appendix 1: Case study plan

I. Goal: 3 in-depth case study profiles

a) Research questions:

1) What methods of controlling inventory in reverse logistics system exists in the case of HEA manufacturers?

2) From HEA manufacturers’ perspective, what factors could be the origins of these problems they meet in inventory management of WEEE reverse logistics?

3) How can the identified problems be alleviated?

b) Statement of purpose:

The purpose is to describe the methods of inventory controls in the case HEA manufacturers and the problems of inventory controls, and analyze what are the origins of these issues for HEA manufacturers as well as propose how these issues can be alleviated, and what methods would be suitable. By solving these research questions, the thesis can offer some suggestions about inventory control improvement not only to the cases, but also wider to the some HEA manufacturers in China.

c) Unit of analysis:

Each of the selected companies has to be the part of the reverse logistics process.

II. Methodology:

a) Multiple case design

b) Research strategy: qualitative and quantitative

c) Research techniques: Materials collecting, Half-Opened interviews

d) Case study protocol: case study plan, interview guide

e) Interviewees: 2 managers
f) Data analysis: within case analysis, cross-case analysis

g) Scientific credibility: external validity, reliability, construct validity

III. Theoretical framework
Development of a rich theoretical framework regarding methods of controlling inventory in reverse logistics system including Inventory control methods; what factors could be the origins of these problems they meet in inventory management of WEEE reverse logistics such as reverse logistics, reverse logistics of WEEE in China, Inventory workflow of WEEE reverse logistics in China and Key elements and features of inventory; How can the identified problems be alleviated such as Inventory control models, Inventory control methods and Hybrid Manufacturing System.

III. Data analysis:
a) Within case analysis:
To reveal the origins of the problems according to the external factors and internal factors in each company.

b) Cross-case analysis:
To show the similarities and differences between the two companies according to the data in the empirical findings, and by doing cross case analysis, the origins of the problems that the companies met in reality are double confirmed.

IV. Time table
- PM 0- thesis idea 19/1
- PM 1- introducton chapter 31/1
- PM 2- revised intro+method 17/2
- PM 3- rev ch 1&2 + theory 29/3
- PM 4- rev PM 3 + empiry+ 29/4
- Final seminar 26/5
Interview guideline-1.1 for Haier

Interview guideline

1 请问海尔物流是负责海尔回收物流流程么？
   □是 □否
   如是，请跳至第2题，如否，则访问终止。
2 请问海尔物流在回收物流中有牵涉到仓储业务么？
   □是 □否
   如是，请跳至第3题，如否，则访问终止。
3 海尔物流与海尔集团的关系是如何的？

4 针对海尔集团的废旧家电回收问题，请问海尔物流对于回收物流有无相关经验，公司是如何进行回收物流业务的？

5 海尔物流在海尔集团废旧家电回收中的仓储环节是如何运作的？

6 在回收物流的仓储管理中，海尔物流有否遇到什么困难？

Interview by telephone

Interviewer: Yao Changcheng & Zhang Le (Master degree candidate in Linnaeus University, Major: business process & supply chain management)

Interviewee: Zhan Ning (Logistics Dept. manager of Haier Logistics)

Time: 2011-03-19, 10.00a.m.-12.00a.m. (Beijing Time, Saturday)

姚（常成） & 张（乐）：您好，请问是战总么？
战（宁）：你好，我是战宁。
姚 & 张：战总您好，今天我们想就关于海尔物流的一些问题跟您做一个采访，您应该已经收到了我们之前发给您的调查问卷，非常感谢你在百忙中抽出时间接受采访！
战：不客气，很高兴你们对海尔物流感兴趣，那我们开始吧。
姚 & 张：好的。请问海尔物流现在是在负责海尔的回收物流流程么？
战：是的，海尔集团的物流业务基本都是交由海尔物流去做，这其中也包括回收物流业务。
姚 & 张：谢谢，那贵公司在回收物流过程中有专门强调仓储业务么？
战：众所周知，海尔集团在仓储管理中执行“零库存”的仓储策略，那么海尔物流在进行物流业务时也按照“零库存”策略去实施，针对回收物流这一块，我们在实施过程中同样也会强调仓储业务的重要性。
姚 & 张：好的，谢谢您。海尔物流和海尔集团是什么关系呢？是合作关系还是公司与子公司关系？
战：这个首先可以从名字中看出来，海尔物流是以海尔集团名字命名的第三方物流公司，同时也属于海尔集团下属的一个子公司，所以海尔集团的物流业务主要交由海尔物流去做，同时海尔物流也会为其他的公司提供第三方的物流服务。

姚 & 张：那么请问针对海尔集团的废旧家电回收问题，海尔物流有无相关经验，公司是如何进行回收物流业务的？

战：对于废旧家电的回收问题，大家都知道目前中国仍处于一个起步阶段，所以对于我们海尔物流来说，相关的经验非常少。但是海尔集团作为国内最早从事物流业务的企业，国家也出台了相关的政策支持海尔从事回收物流业务。在2008年，海尔创新性地提出了绿色设计、绿色制造、绿色回收、绿色经营的4G战略。所以绿色回收是海尔物流发展的一个重要战略。

姚 & 张：谢谢，那么我们想了解一下贵公司具体的工作情况，比如说在废旧品回收中，回收物流的流程是怎么样的？

战：好的，首先顾客会选择把废旧家电扔掉或者卖给回收商，还有就是通过海尔的售后服务部门进行以旧换新或者等值兑换，然后经过简单的初步分拣，根据种类的不同回收到相应的仓库，入库时这些废旧家电需要登记传到数据库中。之后经过简单的处理，要进行再一次分拣，一些不能重新使用的交由专业的公司进行拆分处理，可用部件返回公司统一处理，其他的就扔掉或者销毁。对于可以重新使用的进行入库整理同时上传数据库，作为将来再制造或者维修使用。

姚 & 张：谢谢。那么海尔物流在回收物流中的仓储环节具体是怎么做的呢？比如仓储规模，选址，仓储流程，仓储方法以及库存成本等这些方面。

战：是这样。海尔物流拥有16000部卡车，42座大型区域配送中心，投资过亿的世界最先进的SAPLES物流执行系统，同时提供遍及全国的专用和公用的仓库设施管理来满足不同客户的需求。具体到仓储流程和之前提到的回收物流的流程基本一致，在这里我主要讲一下仓储方法。

海尔物流自主研发了全球HLES条码扫描系统，通过对人码，物码和机码的有机结合，实现了产品全过程的单品追踪及先进先出的系统控制以及供应链全过程的透明追踪。VMI-HUB是海尔物流为了集中管理供应商的库存而建立的原材料中转集散中心，供应商送货到VMI-HUB，剩下的全部由我们海尔物流来做，减少了送货环节，实现送货零等待。同时还有使用SAP LES物流执行系统进行全球物流运作管理，海尔国际化物流中心立体高架库采用先进的计算机管理系统进行仓储管理，促使集团在采购订单的管理，生产计划内的调度，资金流的管理等方面与物流中心相配套，推动集团资源管理系统实施。

当然经过在第三方市场的运作成功，海尔物流已经积累了相当丰富的经验，同时也培养了自己的物流专业人才，在强大的资金实力的支撑下，海尔物流开始提供第四方物流服务。

姚 & 张：谢谢您，战总，那么最后想请问您在实行回收物流的仓储业务时会出现哪些问题呢？

战：好的。在实际的工作当中，出现问题时不可避免的，也是我们公司发展过程中必要的经历吧。那么具体到回收物流的仓储业务，主要有这么几点问题，希望对你们的研究有所帮助：

海尔提倡“零库存”策略，但是回收产品的数量和时间是不确定的，这和实现“零库存”策略相冲突，同时会带来随机的库存成本。

零部件的回收率是随机的，这就导致了物料计划的高度不确定性。怎样有效的降低库存成本也是海尔物流面临的问题之一。
在废旧品的回收过程中，在二次分拣的时候，一些不能重新使用的产品被转移给海尔制定的有资格的加工企业进行拆捡，这样增加额外的成本。当然，这只是其中的部分问题，更多的问题需要在实践中去发现，也希望你们的研究能给我们带来一些启发。


**Interview guideline-1.2 for Haier**

1. Is Haier Logistics responsible for Haier’s reverse logistics?
   - Yes □ No □
   If yes, moves to question 2, if no, interview terminates.

2. Is inventory business involved in the reverse logistic process?
   - Yes □ No □
   If yes, moves to question 2, if no, interview terminates.

3. What’s the relationship between Haier Logistics and Haier Group?

4. Does Haier logisitics have any experiences on doing WEEE reverse logistics? How does Haier logistics develop the proce of WEEE reverse logistics?

5. How Haier logistics operate inventory control in WEEE Reverse Logistics of Haier?

6. What problems Haier logisitics met in reality?

Interview by telephone

Interviewer: Yao Changcheng & Zhang Le (Master degree candidate in Linnaeus University, Major: business process & supply chain management)

Interviewee: Zhan Ning (Logistics Dept. manager of Haier Logistics)

Time: 2011-03-19, 10.00a.m.-12.00a.m. (Beijing Time, Saturday)
Y (ao Changcheng) & Z (hang Le): Hello, Is that Mr Zhan?

Z (han Ning): Hello, this is Zhan Ning speaking.

Y & Z: Hi Mr. Zhan, today we would like to have a interview with you about some issues on Haier Logistics, you should have received our questionnaire sent to you before, thank you very much for you taking the time of the interview!

Z: You're welcome, I am glad you are interested in the Haier Logistics, please go ahead.
Y & Z: ok. Is Haier Logistics responsible for Haier’s reverse logistics?

Z: Yes, the Haier Group's logistics operations are basically done by Haier Logistics, which also includes the business of reverse logistics.

Y & Z: Thanks, is inventory business involved in the reverse logistic process?
Z: As we all know, the Haier Group implement "zero inventory" storage strategy in storage management, then the Haier Logistics is in accordance with "zero inventory" strategy to implement when conducting logistics business. For reverse logistics, we will also emphasize the importance of warehousing operations in the implementation process.

Y & Z: Thanks, what’s the relation between Haier Logistics and Haier?
Z: The first can be seen from the name, Haier Logistics is a third-party logistics company named by Haier Group, but also is a subsidiary of Haier Group. So the logistics business of Haier Group is mainly done by Haier Logistics, while Haier Logistics provides the third-party logistics services for other companies.

Y & Z: About WEEE reverse logistics, does Haier Logistics have any experiences before doing Haier’s logistics? How do you work with the reverse logistics?
Z: For the recovery of WEEE, we all know that China is still at an early stage, so for us Haier Logistics, there is a little relevant experience. But Haier Group as one of the earliest enterprises engaged in logistics business, the state also introduced the relevant policy support in the reverse logistics business of Haier logistics. In 2008, Haier puts forward innovative on green design, green manufacturing, green recycling, green business--4G strategy. Therefore, the development of green recycling is an important strategy for Haier Logistic.

Y & Z: Thank you, can you say it in specific, how it runs?

Z: First of all customers will choose to throw away WEEE or sold to recyclers, and collecting by the customer service of Haier. In sorting I, the products from recyclers and customer service are sorted by types of products. Haier logistics arrange the sorted products and delivery them to different transfer warehouses for inventory control. The data of products is recorded by HLES system. After that, in sorting II, the products will be checked in quality. Some of them which can not be reused will be delivered to the qualified environment processing enterprises Haier appointed, they are responsible for disassembling of these products. Others can be reused will be transfer to the goods warehouse, inbound and check again preparing for manufacture or repair in the future.

Y & Z: Thanks, how do you handle the inventory control?

Z: Haier Logistics has 16,000 trucks and 42 large regional distribution centers, the investment of billions of dollars of the world's most advanced SAPLES logistics execution system, while providing all over the country's private and public warehouse facilities management to meet different customer needs.

Haier logistics use HLES (Haier Logistics Executive System) to carry on management of FIFO product, Falsifying Goods and extended inventory, through the combination of human code, object code and machine code to achieve single product tracking through, the system control of FIFO and transparent tracking of supply chain through the whole process.
It is a transit hub of raw materials established by Haier logistics to manage supplier inventory centralized. Suppliers in large quantities and less batch storage, the demand side in small-volume and multi-frequency purchase order for delivery of cargo from storage, centralized logistics and distribution both to reduce delivery cost of suppliers and improve delivery rate of timely, reducing the warehouse area of demand side and increase its production flexibility.

Of course, after a successful operation in third markets, Haier Logistics has accumulated considerable experience, but also develop their own logistics professionals in support of a strong financial strength, the Haier Logistics began providing fourth party logistics services.

Y & Z: Thanks, did you meet any problems when you do inventory control?

Z: Problems are inevitable in the actual work, but it is also the necessary experience in development process of our company. For inventory business in reverse logistics, there are some problems which hope can help to you for your research.

5) Haier promote “Zero Inventory” policy, but the quantity and time of recycling products are uncertain, it is not in accord with “Zero Inventory” policy, causing a random inventory costs at the same time.

6) How to control inventory cost in a low level is a hard problem Haier logistics have to face, and it still not be handled well.

7) The rate of recycling of components is random, it causes a high degree uncertainty of material plan in reverse logistics.

8) In sorting II, Some of products which can not be reused will be delivered to the qualified environment processing enterprises Haier appointed, it causes additional costs.

Y & Z: Thank you very much for the interview!

Z: My pleasure

Y & Z: Goodbye!
Interview guideline-2.1 for Midea

1 请问安得物流是否负责美的回收物流流程？
   □ 是   □ 否
   如是，请跳至第 2 题，如否，则访问终止。
2 请问安得物流在回收物流中有牵涉到仓储业务么？
   □ 是   □ 否
   如是，请跳至第 3 题，如否，则访问终止。
3 安得物流与美的集团的关系是如何的？

4 针对美的集团的废旧家电回收问题，请问安得物流对于回收物流有无相关经验，公司是如何进行回收物流业务的？

5 安得物流在美的集团废旧家电回收中的仓储环节是如何运作的？

6 在回收物流的仓储管理中，安得物流有否遇到什么困难？

Interview by telephone

Interviewer: Yao Changcheng & Zhang Le (Master degree candidate in Linnaeus University, Major: business process & supply chain management)

Interviewee: Liu Shan (Operation Dept. manager of Annto Logisitics)

Time: 2011-03-27, 10.00a.m.-12.00a.m. (Beijing Time, Sunday)

姚（常成） & 张（乐）：您好，请问是刘总么？
刘（山）：你好，我是刘山。
姚 & 张： 刘总您好，非常感谢您在百忙之中同意接受我们的采访！想必您已经收到我们的访问问卷了，下面我们有几个关于安得物流的问题想向您请教。刘：不客气，很高兴能和你们聊一聊我们安得物流。请问吧。
姚 & 张：谢谢您。请问安得物流现在是否负责美的的回收物流流程？
刘：是的，美的的物流业务 80%以上都由我们负责，其中回收物流都是我们安得在做。
姚 & 张：谢谢，那贵公司在回收物流过程中有专门强调仓储业务么？
刘：是的，我们对仓储业务一向抓的比较严，物流中，实现0库存一直是我们的目标，不论是正向物流还是回收物流，虽然现在我们离这个目标还很远，这个我可以慢慢讲给你们听。
姚 & 张：谢谢您。安得物流和美的集团是什么关系呢？是合作关系还是公司子公司关系？
刘：这个要从公司的建立说起，公司作为美的集团的一个独立事业部，成为美的集团的第三方物流公司，可以使用安得物流，也可以选择其他的物流公司，所以简言之，我们源自美的，但是美的将他的物流业务外包给了我们，我们是合作关系。
姚 & 张：谢谢刘总。请问针对美的集团的废旧家电回收问题，安得物流有无相关经验，公司是如何进行回收物流业务的？
刘：我们在做美的的回收之前，并没有接过类似的业务，所以回收物流，我们都是凭借我们团队之前相关物流经验，响应国家号召，再探索中前进。但是我们将回收物流作为工作重点，在2006-2008年发展规范中，大力发展绿色物流为主的业务，同时2009-2011年发展规划中，更加着重此点，在未来工作中，绿色物流将会饰演更为重要的角色。
姚 & 张：谢谢，那贵公司具体的工作有什么呢？比如说您回收物流的流程是怎样的？
刘：首先顾客将废旧家电通过退货，维修手段到供应商手里，或通过卖掉或丢掉到了回收站，通过简单的分拣，把不同种类家电分类，然后根据家电种类及回收地点选择回收仓库，然后将这些家电进行清洁，再入库，入库的时候，我们要将这些废旧家电登记到数据库里，然后分到不同库房里保存，在这过程中，我们还会进行一次分类，把这些家电拆分，可用的部件再分类归入到各个不同的仓库里，留给将来再制造或者维修使用，有剩下的废旧部分，我们就统一处理，要么销毁，要么就给垃圾处理厂再循环利用。
姚 & 张：谢谢您。那您在回收物流中的仓储环节具体是怎么做的呢？我们可以从仓储规模，选址，仓储流程，仓储方法以及库存成本等来讨论。
刘：好的。安得建成了全国一体的仓储体系，公司在全国建立了顺德、杭州、郑州，尧湖4大仓储中心，全部实现信息化管理，实行“一票到底”的管理模式，并建立了顺徳，南京，西安，北京，上海等10哥物流中心，在全国68个城市建立了业务网点。通过安得物流，美的的仓储成本降低了30%，我们可以达到1800万吨的仓储吞吐量。
刚才我也讲到了回收物流的流程，仓储流程也没什么太大的差异，主要是在仓储管理过程中，使用了很多仓储方法。我们自己开发了物流信息系统ALIS2.0（安得物流供应链管理信息系统），这个系统非常好，在我们的工作中，起到了非常大的帮助。其中仓储系统是第一个模块，也是这个系统的重中之重。我们在仓储管理中还运用了很多仓储管理方法，常温，恒温，冷藏库，立体，平面库，金融监管仓，VMI，先进先出，退货批号追踪，批次管理，库存分析生产期管理等。同时也有小货架，搬运设备，装卸平台/升降平台，视频监控，电子标签，等设备，同时地面防尘，小货架与中转箱有定期清洁。上万种入库库位分区，还有根据订单及产品特性组合打包，不同材料打包（木箱，纸箱，薄膜等等），入库除尘（清洁），安全库存设置，持续补货，退货分类管理。
当然，在管理仓储库存时，传统的办法并不实用，尤其是在回收物流中，所以我们会用到我们旗下的第四方物流公司—广州安得供应链技术公司，着眼于供应链，从根本上改善仓储，加强生产企业与上下游的协调，统一标准。

姚 张：谢谢您，刘总，您讲的非常详细，我们也受益匪浅。在您实行回收物流的仓储业务时，会出现问题么？或者说，有什么问题您觉得现在还不易解决？

刘：好的，当然，在我们的工作中，遇到了很多困难，很多挑战，通过我们上下员工的集体努力，我们克服了很多难题，但是目前来讲，还有很多问题需要我们解决，我简单提一下，同时也希望你们在研究中能够找到什么灵感来帮助我们。

每年的 8 月和 2 月是出货旺季，而且大节前 10 天出货率也是很高的，最高时一般是一月底，晚上出货频率比较高。这个时候，我们总是会遇到很多问题，员工积极性不高，而且总是比较混乱，成品库存和回收品库存总是发生冲突。

回收品入库时候的规律多数是多批次，小批量，麻烦且占用了很多装卸成本，库存管理也增加了难度。

回收品的库存成本太高，因为种类很多，分拣时耗时又耗力。刚才也提到了，回收产品很占库存位置，越是销售高峰期，回收品越是收回的多，因为很多客户也要淘汰自己以前的旧家电，买的多，或者是退货或者是维修，很难控制回收量。

我们经过处理的废气部件，在收回回收厂处理的时候要先丢在外面，也占地，但是如果不存的话，运输费用很高，对我们来讲这个虽然是小问题，但是一直想要解决又拿不出很好的解决方案。

经过分拣的回收零件再制造如果需要也是从库存中分批拿，都是用多少拿多少，每次回收分拣的零件并不能一次出库，造成了库存量一直不稳定，无法很好的控制。

我们虽然全国有这么多网点，有这么多仓库，这同时也带来一些问题，就是有的地方库存量多，仓库不够大，有的地方库存少，仓库又有太多空闲，而且回收品的入库量并不稳定。

当然，我们还有很多问题需要解决，希望你们以后能够来到我们公司详细调研，我们热烈欢迎。

姚 张：谢谢您，刘总！如果有机会我们一定会的。非常感谢你百忙之中抽出时间接受我们的访问，和你的谈话让我们受益良多，非常感谢！我们的论文完成之后，也会给你发一份过来，如果我们有什么错误或不妥之处，还请您不吝指正！

刘：一定，祝你们论文顺利，学业有成！

姚 张：谢谢，也祝您生意兴隆，越办越好！那刘总我们今天的访问就到此结束了，再次感谢！

刘：呵呵，不客气。

姚 张：刘总再见！

刘：再见！

Interview guideline- 2.2 for Midea

1 Is Annto Logistics responsible for Midea’s reverse logistics?

□ Yes □ No

If yes, moves to question 2, if no, interview terminates.
Inventory Control of WEEE (Waste of Electronic and Electrical Equipment) Reverse Logistics in China

--The HEA (household electrical appliances) manufacturers’ perspective

2 Is inventory business involved in the reverse logistic process?
☐ Yes  ☐ No

If yes, moves to question 2, if no, interview terminates.

3 What’s the relationship between Annto Logistics and Midea Group?

4 Does Annto have any experiences on doing WEEE reverse logistics? How does Annto develop the process of WEEE reverse logistics?

5 How Annto operate inventory control in WEEE Reverse Logistics of Midea?

6 What problems Annto met in reality?

Interview by telephone

Interviewer: Yao Changcheng & Zhang Le (Master degree candidate in Linnaeus University, Major: business process & supply chain management)

Interviewee: Liu Shan (Operation Dept. manager of Annto Logistics)

Time: 2011-03-27, 10.00a.m.-12.00a.m. (Beijing Time, Sunday)

Y (ao Changcheng) & Z (hang Le): Hello, is that Mr Liu?

L (iu Shan): Hello, this is Liu Shan speaking.

Y & Z: Hi Mr Liu, Thank you for your agreed to the interview! Presumably you have received access to our questionnaire, here we have a few questions about Annto logistics problems to ask you.

L: You’re welcome, please go ahead.

Y & Z: Thanks, Is Annto Logistics responsible for Midea’s reverse logistics?

L: Yes, we are in responsible 80% of Midea’s logistics, we are doing the reverse logistics of Midea.

Y & Z: Thanks, is inventory business involved in the reverse logistic process?

L: Yes, we are doing inventory control by strict management, we have goal of “0 inventory”, no matter forward logistics or reverse logistics.

Y & Z: Thanks, what’s the relation between Annto and Midea?
L: Annto Logistics was founded in January 2000, a subsidiary of Midea Group. Annto is one of the major players in domestic 3PL services in mainland China.

Y & Z: About WEEE reverse logistics, does Annto have any experiences before doing Midea’s logistics? How do you work with the reverse logistics?

L: No, we are also new here, but in 2006-2008 development planning, Annto has set “Green Logistics” as key emphasis in work. And in 2009-2011 development planning, Annto put more efforts on doing better on reverse logistics for Midea Group. Annto has been doing a lot on inventory management in WEEE reverse logistics.

Y & Z: Thank you, can you say it in specific, how it runs?

L: Customers have several ways to deal with WEEEs of Midea, some are sold to recyclers or thrown away then collected by recyclers, and some are refunded or replaced to retailers. In sorting I, different kinds of products are sorted (which are following Midea’s recycling policy). Different returned products are decided to transferred to arranged sites, the site selection is not simply following proximity principle, but also following the functions of the warehouses, and should arranged by Annto logistics. After site selection, clean I is done, in this section, products are simply cleaned such as dedusting, etc., then the sorted WEEEs are transferred into different warehouses, check is done in the same time when the WEEEs are inbound, and should be recorded into ALIS 2.0 database. Inventory control should follow Annto’s inventory methods for the different kinds of products. Sorting II is done to apart the products, some components which cannot be reused are outbound, and these components are stocked outside of the warehouses, somewhere with low inventory costs, wait to be recycled or treated; some components can be reused are transferred into other warehouses or other areas, inbound and check again, record the data into database, they are stocked in inventory methods of Annto, when Midea needs these components for maintenance or remanufacturing, the components are outbound and recorded into database.

Y & Z: Thanks, How do you handle the inventory control?

L: Annto has its own national integrated inventory system: there are 4 inventory centers which are in Shunde, Hangzhou, Zhengzhou and Wuhu, these inventory centers are all reached by information system management, with the management mode of “covered through by a single invoice”. Company has 10 logistics centers all over China and 110 points in the business network.

Annto has several methods in inventory control, which help Annto reduced 30% inventory costs of Midea in the past few years, and help Midea make the whole reverse logistics to run smoothly. Annto develops an advanced logistics information system- ALIS 2.0, which covers a whole supply chain. The inventory module, which is the first developed, helps Annto achieve the management mode mentioned
In inventory control management, it is far not enough to use the traditional methods of inventory control. To deal with problems in inventory control, Annto builds up a 4PL company, in perspective of the whole supply chain, offer solutions for the problems. Also in reverse logistics, the 4PL company helps set up the workflow of WEEE reverse logistics in Midea, and offer solutions for decreasing inventory costs.

Y & Z: Thanks, did you meet any problems when you do inventory control?

L: In inventory control of WEEE reverse logistics, Annto meets several problems which are hard to deal with.

7) WEEE products are usually inbound in small lots, which make it hard to check and difficult to manage.

8) Inventory costs are too high, Annto has no ways to decrease the costs, has even no clue where to start.

9) WEEE products take too much space, and not turnover in short time, what is worse is, the WEEE products stocks are getting much more in busy season, which means that, the normal products need a lot of space as well.

10) After the second sorting process, the wasted components are accumulated outside of the warehouse, these components still take space, and hard to find a balance that can make less inventory costs and less transportation costs.

11) To fit the needs of remanufacturing, the components in stocks are outbound irregularly, which make the amount of components in stocks is high sometimes. Besides, the irregularly amount of components in stocks leads to a difficulty that hard to order components from suppliers regularly.

12) It is common that some warehouses are full used, some are not, and the balance between inventory costs and transportation costs is difficult to control.

Y & Z: Thank you very much for the interview!

L: My pleasure

Y & Z: Goodbye!
L: Goodbye!

(The translation are based on the original interviews, and not exactly the same, but picked some texts from the empirical findings, empirical findings are exactly based on the original interview.)