Research on Decision-making of Green Reverse Logistics in Enterprises: A Case Study on Electronic Products Manufacturers from the Perspective of South Africa

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Abstract: In recent years, the environmental problems caused by the traditional implementation of reverse logistics enterprises have become more and more serious. Especially for the enterprises of electronic products, the heavy metal pollution problems caused by the waste of electronic products have made more and more enterprises and researchers begin to seek a green approach of reverse logistics. Based on the idea of "*Cradle to Cradle*" industry model, by the use of relevant theory of activity-based costing and quality management theory, the conceptual model of decision-making of reverse logistics activities for the electronic products manufacturing enterprises will be established; to decrease the influence on environment when implementing reverse logistics activities.

Keywords: Electronic products; Green reverse logistics; Activity-based costing; Decision-making model

1. Introduction

In recent years, the improvement in people's lives is due to development of technology, and more consumers have sought personalized goods and the diversification of goods, which is reflected in the consumption of electronic products. Because of the industrial competitive environment and the changing of consumers' demand, the upgrading speed of high-technology electronic products has accelerated, which meets the customers' demand, and meanwhile, the fast upgrading and updating of electronic products has brought many hidden troubles. Some of the products don't get enough time in the research and development stage, which consumers—even products under warranty. The logistics

caused by these problems is reversed logistics which is related to forward logistics.

Since the 1980s, many developed countries have focused on how to decrease the bad influence on the environment when dealing with problematic and abandoned products, and many foreign researchers have conducted research on these problems, especially electronic products recycling—how to select the method of recycling, optimization models, and analysis of relevant theories. With the increasing awareness of environmental protection, green logistics has been the research object for more and more researchers, and many consumers have begun to focus on whether companies use sustainable materials or services in their products, taking responsibility to protect the environment and society, which makes the traditional industrial model of "*Cradle to Grave*" inadequate in meeting consumers' demand of decreasing the bad influence on the environment. So the idea of supply chain management has shifted from "*Cradle to Grave*" to "*Crade to Cradle*."

This paper will construct a conceptual model by using activity-based costing and relevant theory of quality management. From the perspective of electronic products manufacturers, this model help enterprises to make good choices in the reversed activities of recycling products, taking good advantage of the idea from "*Cradle to Cradle*", while expecting to decrease environmental harmfulness of the reversed logistics.

2. The green reversed logistics of electronic products

2.1 The significance to electronic products manufacturers of implementing green reversed logistics

Through management planning and by the use of relevant techniques, green reversed logistics reduces the bad influence on the environment, saves resources during reversed logistics activities, make full use of logistics resources and makes sure that the waste can get green treatment without harmfulness. Green reversed logistics has substantial social and economic significance for electronic products manufacturers.

2.1.1 Social value

Green reversed logistics is put-forward from the perspective of saving resources and protecting the environment, and it is good for the sustainable development of society. That enterprises would implement green reversed logistics is a reflection of their willingness to take social responsibility. For electronic products manufacturers, whata they need to recyce is the product with too many metal elements. If there is something wrong with recycing activities, it will harm the environment badly; that's why green reversed logistics should be implemented as soon as possible. Meanwhile, green reversed logistics not only decreases the harmfulness to the environment, but also helps enterprises to realize social value, such as enterprise image, enterprise reputation, and so on.

2.1.2 Economic value

According to Benjamin T. Hazen and Casey Cegeielski (2001), through the implementation of

green reversed logistics, enterprises would achieve competitive advantage, which in the long run could improve profit indirectly. The enterprises that implement green reversed logistics would get the residual value from the recycling products, which would have much economic significance for the enterprises to produce electronic products that are upgrading or updating fast, and the parts with good characteristics of defected products could be in the recovery utilization. Electronic products manufacturers would reduce the cost of raw materials, reduce the cost of purchasing and processing, save enterprise resources and improve competitive advantage; if they were to implement green reversed logistics.

2.2 The model of "Cradle to Cradle"

C2C is the abbreviation for "Cradle to Cradle" which was put forward in the book—"*Cradle to Cradle*" written by Michael Browngardt and William Mcdonough. The theory presented is a reference to Chinese theory of nature and man united as one, which is the new perspective of sustainabe development. The base viewpoint is that safe recycling and use of raw materials should be taken into consideration with product design, with nurient management instead of traditional waste management.

C2C seeks green innovative design; namely, from the first stage of product design, research and development, the products should be well-designed to easily disassemble, so that the raw materials can be easily recycled, the recycling system can built, and the network platform for raw materials recycling can be constructed, which makes the raw materials in the biological cycle or processing cycle. So the waste of raw materials and energy will be avoided effectively, and also will minimize the cost. In the manufacturing process, clean energy should be used as much as possible. In the stage of sale, C2C mode helps to make a new market for raw materials, changing waste into valuable material, which promotes an enterprise's competitive power through innovation.

The reversed logistics of electronic products objects are mainly the products with serious problems or returns by customers, which need recycling. These products not only include the parts that can be recycled, but also include the parts that are harmful for the environment and cannot be recycled. So trying to make the reversed logistics green and reduce the environmental pollution as much as possible is not to abandon the industrial model of "*Cradle to Grave*" simply and directly, but to combine C2C with it, implementing decision-making of reversed logistics activities reasonably under the idea of protecting the environment.

Because of the short life-cycle of electronic products, greater is the quantity of defective products. But because of Hg, As, Cr, Pb and other heavy metal elements inside the products, the traditional processes, like incineration, break and bury, cause significant harm to the environment. If the C2C model were to be implemented in the product design process, the materials which could be recycled would be in use to the greatest extent possible, so the enterprises could recycle parts of components and products to reduce the bad influence on the environment during recycling, and parts of products would be in the process of "Cradle to Grave", and after being confirmed to be of no use, they would release less pollution. The effective combination of the two models would be

more suitable for the manufacturing activities of enterprises.

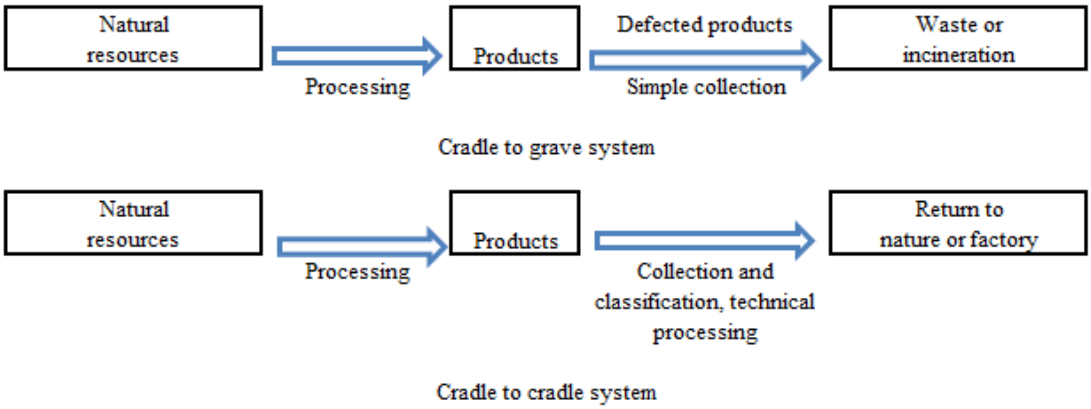

Figure 1: Industrial model of "cradle to grave" and "cradle to cradle" system

Figure 1 shows two industrial models, “Cradle to Cradle” and “Cradle to Grave,” how they work. Figure 2 is a diagram of the supply chain of electronic products after the combination of the two models.

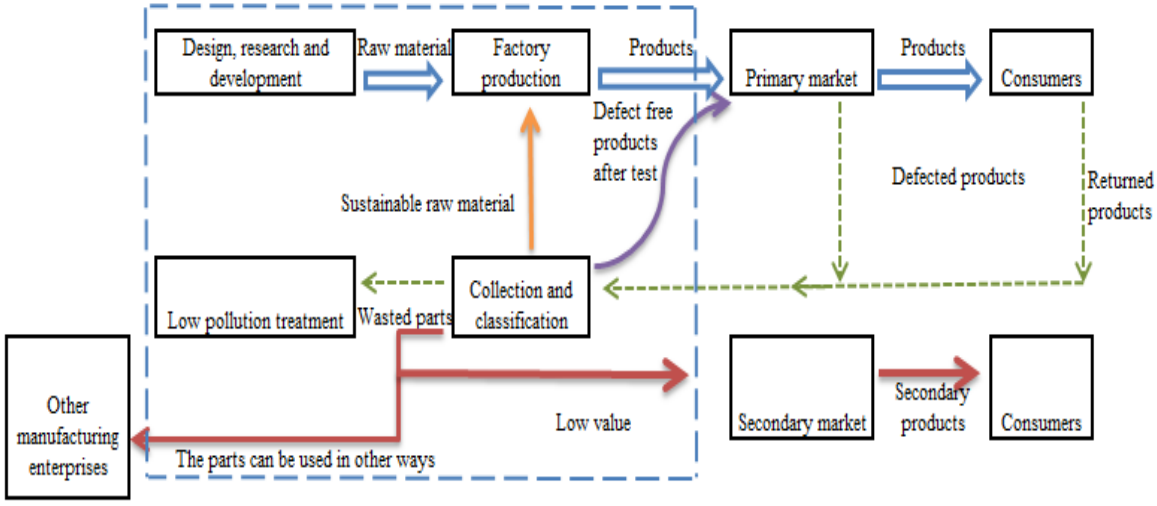

Figure 2: The Supply Chain Management Map of Electronics Products

With the idea of supply chain management, which is shown in Figure 2, the enterprises should use the environmental friendly and recycling materials as much as possible in the initial product design, and deal with the returned products, improving the product quality and bring them into the recycling circle. But during the process, there are some products and parts which cannot be recycled unavoidably, in which case, under the consideration of cost, techniques and other issues, the enterprises select the best way to reduce harmfulness to the environment.

Through a comparison of Figure 1 and Figure 2, we can see that after the combination, the reversed logistics activities focus on environment-protection problems, and meanwhile, the reverse logistics cost and relevant quality issues. For the products that cannot be recycled or reused, the cost will be more than the low pollution treatment cost; then the manufacturers will not bring them

into the recycling circle, but give them low pollution treatment.

3. The construction of conceptual model

For the manufacturers of electronic products, when implementing the above idea of management, how to select the proper way of dealing with every recycling product and maximize the processed product value has been the significant problem for enterprises to implement reversed logistics. They not only take the cost of reversed logistics into consideration, but also of each link or stage in the process. So the conceptual model based on activity-based costing and using quality management methods will help the enterprises' management to make good decisions.

3.1 Model assumptions

- "Principle of Producer Responsibility" will be implemented in electronic products recycling. The manufacturer will be responsible for the influence on the environment during product life-cycles, and the enterprises are responsible for making all activities in the recycling, and reducing the influence on the environment as much as possible.

- The products are stored in the manufacturer's store; namely, the manufacturers manage recycling inventories themselves.

3.2 The steps of model construction

The key to activity-based costing is to distribute most of the cost, based on the activities, and in activity-based costing, the reversed logistics of enterprises is the collection of all kinds of activities, and those activities which cost resources cause a series of cost. If the enterprises want to decrease the cost caused by reversed logistics, they must analyze these activities and make good selections in these activities. classifying the recycling products according to quality is another key factor for the model, which is also the critical condition for the enterprises to choose the right dealing way. The decision-making steps for electronic products manufacturers are as follows:

3.2.1 Identify the type of activity and cost factors in every stage of reversed logistics based on activity-based costing

The reversed logistics of electronic products can be divided into four stages:

1. Collection
2. Classification
3. Transportation
4. Warehousing

Collection is the collection of the products that need recycling. Classification is the classification of recycling products through different ways and dividing them into different levels. During classification, the shortcomings and returned products will be classified in the perspective of

quality or product function. Transportation and warehousing are different from transportation and warehousing in forward logistics. Transportation is the transport of the products from reclaimed place to reprocessed place. warehousing is the placement of recycling products in warehouse and centralized management. Figuring out the warehousing cost is relatively simple, because some factors can be obtained directly, like the costs of warehouse construction and daily management expense.

Analyze the activities in reversed logistics by using activity-based costing, classifying the types of activities involved into manual operation, machinery equipment operation and daily management operation. Every kind of activity contains different cost factors. For example, machinery equipment operation contains depreciation of equient, energy consumption, and other costs. Identifying every cost factor involved in reversed logistics exactly is very important, which will influence the accuracy of the final decision model. To decrease the mistake made during the process of identifying cost factors, electronic products manufacturers should check their balance sheet duly, and use that as a primary reference to trace back the cost of reversed logistics. The activity types involved in every stage of reversed logistics are showed in Table 1.

Table 1: The definitions and cost factors of different processing methods

Processing methods	Definitions	Cost factors	Logistics stages
Reconditioned	Through cleaning and maintenance (the recycled products will be made like whole new products, which is more complex than simple maintenance).	Labor cost, equipment cost ,raw material cost, and daily expenses.	Collection, classification, transportation.
Remanufactured	Like recondition, but the recycled products are totally removed, which needs more processing work than recondition.	Labor cost, equipment cost, raw material cost, and daily expenses.	Collection, classification, transportation.
Resale	Sell the recycled products without defects in primary market directly.	Labor cost, and lost value.	Collection, classification, transportation.
Recycling	Remove the extra parts of the recycled products that cannot be reused, and reuse the remaining parts.	Labor cost, equipment cost, raw material cost, and daily expenses.	Collection, classification, transportation, warehousing.
Maintenance	Try to use fewer resources and less processing to maintain and recover the recycled products.	Labor cost, equipment cost, raw material cost, and daily expenses.	Collection, classification, transportation, warehousing.
Disposal	Give disposal processing to those recycled products which cannot be dealt with above-mentioned treatments.	Labor cost, equipment cost, raw material cost, and daily expenses.	Collection, classification, transportation, warehousing.

For identifying and expressing the expense of every activity, each activity can be broken

down into different cost factors. Workers' salaries, depreciation of equipment, water and electricity costs should be considered individually in the manual operation, machinery equipment operation and daily management operation. This decomposition is more helpful for analyzing the cost factors in each activity. In this model, in order to difer from the cost factor in following dealing way, not only are the cost factors involved in every activity type displayed, but also they are generally called collection fee, classification fee, transportation fee and warehousing fee.

3.2.2 Define the cost of different processing methods in reversed logistics

For recycled electronic products, there are many processing methods that can be chosen. In order to describe the cost of every processing method, every processing method should be explained exactly and accurately. According to general view and definition of relevant literature, there are six major processing methods for electronic products: renovation, re-manufacture, resale, recycling, maintenance and disposal of waste. Manufacturers must analyze each processing method thoroughly, so that the best decision can be made. In Table 2, the cost factors that every processing method involves are shown, according to logic procedure of each processing method.

Table 2: The definitions of reverse logistics stages

The stages of reverse logistics	Definitions	Activity type
Collection	Collect the recycled products which are scattered.	Manual work.
Classification	Divide the recycled products, which are collected into different levels.	Manual work, the operation by machine and equipment.
Transportation	Transport the recycled products from collection point to processing point.	Manual work, the operation by machine and equipment.
Warehousing	Store the recycled products in warehouse.	Manual work, daily management operations.

There is one thing that needs to be made clear: The cost factors in Table 2 are only the fees that different processing methods involve; however, in the whole reversed supply-chain, every logistics stage makes sure that the processed products enter recycle procedure and implement the recycle. So choosing different processing methods when recycling the products will involve different logistics stages: resale mainly involves the logistics stages of collection, classification and transportation; and recycling involves stage of warehousing. Because the products that are under resale after testing/inspection go back to the production line, repackaging, and finally enter the primary market, nowadays, the flow of the products is forward logistics, and the warehousing also belong to the warehousing stage of forward logistics. And the processing method of recycling has changed the partial performance; the processed products cannot enter into forward logistics of the original products—like totally new products. So the warehousing activities cannot be divided into forward logistics of original products.

3.2.3 Classify the recycling products according to their quality

Through step 1 and 2, the related activities and cost factors in the early stages are clearly defined, and after that enter the stage of processing for recycling products. Quality management, especially the quality detection method, plays a significant role in making correct decisions in reverse logistics. Based on the characteristics of different product-types, the quality detection method will be selected, and common methods will be defined into two directions:

1. Qualitative
2. Quantitative.

Under the quantitative detection method, whether the recycling products will be accepted or not depends on whether the deviation of the test result is in an acceptable range. The quantitative detection method to determine whether the recycling products will be accepted or not is decided through comparison with the products that can be accepted by customers. In this study, it is assumed that the electronics manufacturing enterprises make it clear how to use every method and have the ability to make right decisions. Although, there is no detailed explanation for one method, for ech enterprise, the acceptable quality standard of recycling products should be defined in the decision-making model in advance.

Generally, the quality of recycling products can be divided into the following four standards:

1. **High quality:** The recycled products have the same characteristics and functions as new products.
2. **Good quality:** The recycled products will be put in the market for new products and will be sold at a relatively low price.
3. **Medium quality:** There are some bigger flaws with the recycled products. So, more investment will be needed for improvement and upgrading. They can be sold in the secondary market or some parts of the products can be removed and used in other methods.
4. **Scrap products:** The returned products will have large defects, so they need to be scrapped or undergo some related processing.

After defining the quality level of recycled products, the reference for enterprises to choose a proper processing method in the next stages will be provied. In Table 3, there are processing method that are suitable for recycled products of different quality levels.

Table 3: The processing methods for products in different quality levels

Processing method	**Quality level**
Reconditioned	Good, and medium quality
Remanufactured	Good, and medium quality

Resale	High, and good quality
Recycling	Medium-quality, and scrap products
Maintenance	Medium-quality, and scrap products
Disposal	Scrap, and discarded products

4.Decision-making model in reversed logistics of conceptual electronic products

The conceptual decision-making model is used to provide the best choice for electronics manufacturing enterprises to recycle products. In Figure 3, the final decision-making model is given, which will provide to the decision-maker better and suitable choices through the determination for recycled electronic products and definition for relevant cost factors. According to the standard of minimizing cost and optimizing quality, the processing methods will be chosen suitably for every kind of recycled products; different processing methods will decide different flow directions of reversed logistics for recycled products. The model is established under the basic idea of decreasing the influence on the environment. So the environmental factors were not shown in this model. However, the choices of processing method for recycled products are implemented based on the industrial models of "*Cradle to Grave*" and "*Cradle to Cradle*"

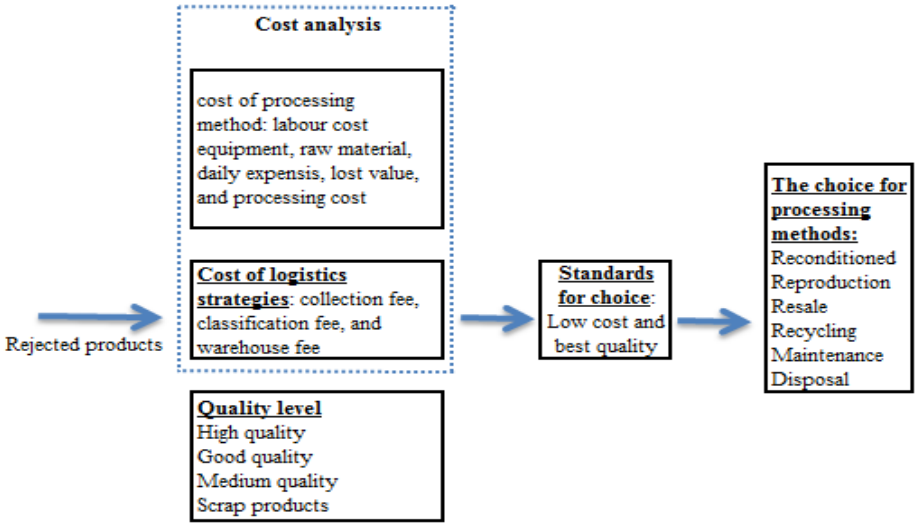

Figure 3: The conceptual decision-making model

5.Conclusion

Under the idea of protecting the envionment and reducing pollution, we have built a decision-making model for electronic products enterprises to implement reverse logistics, which also promotes green reverse logistics. However, the real realization of green reverse logistics not only needs the manufacturing enterprises to do something, but also needs the participation of customers and

support from government. Many European and American countries have formulated a series of laws and regulations for serious pollution of reverse logistics, such as “Electronic Waste Management Act” and so on. With the rapid development of the logistics industry, more and more enterprises have outsourced their logistics activities to third-party logistics enterprises. But it is better to partner with third-party logistics, because that provides a better development path for the implementation of green reverse logistics. So, third-party logistics can use their professional employees, processional equipment, perfect logistics network and logistics information management system in making a plan of forward logistics for manufacturing enterprises, when they also undertake part of reverse logistics activities, which makes the enterprises more focused on developing their own core competencies. Third-party logistics problems related to green reverse logistics willl be an significant direction in the future.

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