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Research on STOF-Model-Based Innovation of E-Waste Recycling Service System

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***Abstract*—E-waste recycling is one of the main issues facing the challenges of resource shortages, environmental pollution and sustainable development. This paper analyzes the e-waste recycling systems, which is considered as a service system. Service System is the theoretical foundation of service science. In service interaction and value co-creation process of e-waste recycling system, producer services surrounding e-waste recyclers are clarified. Service innovation model STOF (Service, Technology, Organization and Finance) is applied to explore the potential innovations in e-waste recycling service system from four different perspectives, such as service, technology, organization and finance. To establish a sustainable e-waste recycling system, stakeholders should assume their responsibility and collaborate effectively concerning information flow, material flow and financial flow. Further, it is proposed that cloud platform can enable e-market for the producer services, to ensure an efficient management of the whole service system.**

Keywords- E-Waste Recycling; Service System; Service Innovation; STOF (Service, Technology, Organization & Finance)

I. INTRODUCTION

With the increasing consumption of electronic products and the rapid upgrading, large amount of electronic products become obsolete. There are valuable materials in e-wastes, such as the precious metal in discarded mobile phones; at the same time, if the e-wastes are treated improperly, a lot of damage will be caused to the environment and to the people involved in the treatment process[1].

Within the last few years, Chinese government has been calling for development of resource regeneration industry, which can not only meet the energy demand by extracting resources from the discarded wastes, but also help reduce the environmental problem caused by the huge volume of End-of-Life products. As one of the major resource regeneration industries, e-waste recycling has strategic importance in the economy. It can help solve the resource shortage and environmental pollution problem, ensuring sustainable development, when the e-wastes are recycled properly. According to the No. 551 order of the State Council [1], "the regulations for the administration of the recovery and disposal of waste electronic and electronic products" has been adopted. This regulation will become effective as of Jan. 1, 2011.

With the economic value and environmental values considered, e-waste recycling becomes one of the main issues of the resource regeneration industry. The establishment of scientific decision making, optimized operation of the recycling system can help solve the following problems simultaneously: resource shortages, environmental pollution and sustainable development problems [2].

Chinese e-waste recycling system is still under development. Regulations have been put into place. The cooperation mechanism among various stakeholders is to be clarified and coordinated. Currently, five major types of electronic products are considered in the e-waste recycling system, such as computer, TV, air conditioner, refrigerator, and wash machine. The recycling activities include collection, dismantling, depollution, treatment, and the final disposal of waste and hazardous material. The collected e-wastes can be transported to primary recycler. After the e-wastes are sorted, disassembled and separated from toxic material, the e-waste bulk will be shredded. The recovered material from primary and secondary recyclers can be sold and used in the forward production process, which builds the closed-loop of the supply chain [3], as shown in Figure 1.

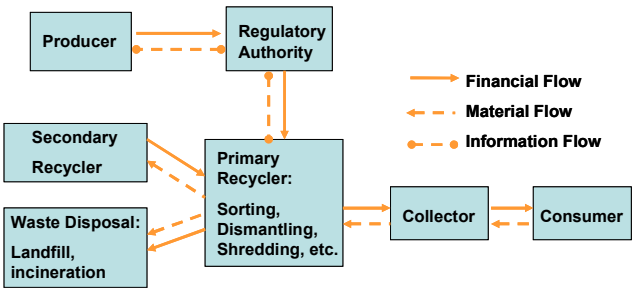

Figure 1. The Structure of the E-waste Recycling Network

Chinese e-waste recycling system bears the following characteristics:

1) Individual consumers sell their e-wastes to collector, which is contrary to the practice in developed countries;

[1] This work is supported by Natural Science Foundation of Shanghai under Grant 09ZR1401300

2) Collectors consist of distributors, manufactures, repair shops, after sale service companies, and operators engaged in collections; Large part of the e-waste volume flows into the non-professional e-waste recyclers;

3) Technologies used in the disassembly and treatment are less advanced, with little concern about the environmental impacts. Much environmental pollution to air, water and land has been caused, and the health of the workforce involved in the e-waste recycling has been damaged.

3) Extended Producer Responsibility (EPR[2]) policy is to be implemented according to the regulation, but the way to determine the recycling fee is not released. The management organization for the e-waste recycling system is under construction;

4) E-waste recyclers can get governmental subsidies. The subsidy to the recyclers is based on the volume (or weight) of the e-wastes treated, with less consideration of the recycling result or environmental value.

5) The system is complex and immature. Management authorities, including local municipal level, provincial level, and state council level, share the management responsibility.

This paper seeks to analyze the way to innovate the Chinese e-waste recycling system. The content of the paper is arranged as follows: four aspects of STOF model is explored in the e-waste recycling system. Firstly, e-waste recycling system is viewed as a service system from service science point of view. Producer services revolving e-waste recycling are clarified. Further, cloud platform is proposed to build e-market for the producer services, and to manage the whole service system in more efficient way.

II. STOF Model for Service Innovation

Service innovation, normally driven by change in service elements, is the combination of technology innovation, business model innovation, social-organizational innovation and demand innovation. Compared with the relatively mature four dimensional service innovation model[3], STOF model is more appropriate for e-waste recycling service system due to the high complexity and the large number of stakeholders involved [4]. Figure 2 shows the structure of STOF model and its domains.

Four domains in STOF model is explained as follows:

- Service domain: it relates to values and functionalities of the service, the interaction of service provider and customer should be defined.
- Technology domain: it includes the technical architecture in facilitating the process that enables the service development, delivery, and management.
- Organization domain: it revolves around the resources and capabilities, mainly related to technology and finance that have to be made available to enable the service. Organization has to collaborate with others in order to be able to provide all the necessary resources and capabilities that are required for developing and offering the service, and to develop a viable business model for involved stakeholders.
- Finance domain: Financial resources are one of the most important resources to be required by the value network. Finance also defines the bottom line of most of the services to be designed. With regard to financial arrangements, there are two main issues: investment decisions and revenue models.

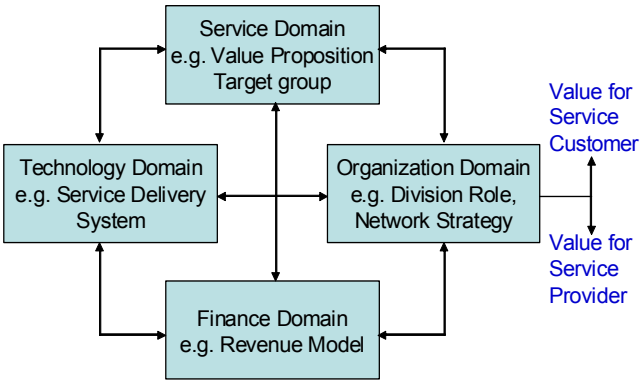

Figure 2. STOF Model Domains

III. Innovation in Services of E-Waste Recycling System

The first domain in STOF model is service domain. This paper considers the e-waste recycling network as a service system. Spohrer defined service system as the theoretical foundation of service science, which was firstly proposed by IBM at 2004 [5]. Service science is a multidisciplinary field that brings together knowledge from diverse areas to improve the service industry's innovation, mainly focusing on the melding of technology with business processes and organization. The view of e-waste recycling network as a service system could help define the potential innovations.

Service system is considered as a value co-creation configuration of people, technology, organizations, and shared information, and value propositions connecting internal and external service systems. Viewed from resource perspective, resources in service system are applied (including competences, skills, and knowledge) to make change that have value for another system [6].

Two abstract roles in service system are service provider and service client. Recyclers are considered service customer, while other stakeholders provide services for recyclers. Their

[2] Many countries have passed the law on e-waste recycling. Different countries have different approaches, but all of the approaches are based on EPR (Extended Producer Responsibility) policy, which requires the producer to take the full responsibility of the e-waste recycling, including recycling fee, information and logistics [4].

[3] Four dimensional service innovation model covers the following four dimensions: 1) new service concept: knowledge of the characteristics of existing and competing services (business intelligence); 2) new client interface: characteristics of actual and potential clients (market intelligence); 3) new service delivery system (capacities, skills & attitude of existing and competing service workers); 4) technological options as enabler of the service system.

services are called producer services[4]. Major producer services included in the service system are information service, financial service, logistics service, quality inspection service, etc. The stakeholders involved in the e-waste recycling system are playing the roles of service provider or customer, depending on the context of service.

A. Service System of E-waste Recycling network

Figure 3 shows the service system of e-waste recycling network. The service system, as an abstraction of the industrial chain, consists of different stakeholders, such as e-waste recycler, producer, consumers, business partners, financial institution, and management authorities, the e-waste foundation management center. Within the system, the recycler serves as the core business, which exchange service with other service providers, i.e. consumers, collectors, logistics service from 3PL, information service from corresponding service providers, etc.

Within the e-waste recycling service system, any two stakeholders interacting with each other are playing the role of service supplier or customer. Service provider gets service in exchange while providing service to the customer. This means the value co-creation process.

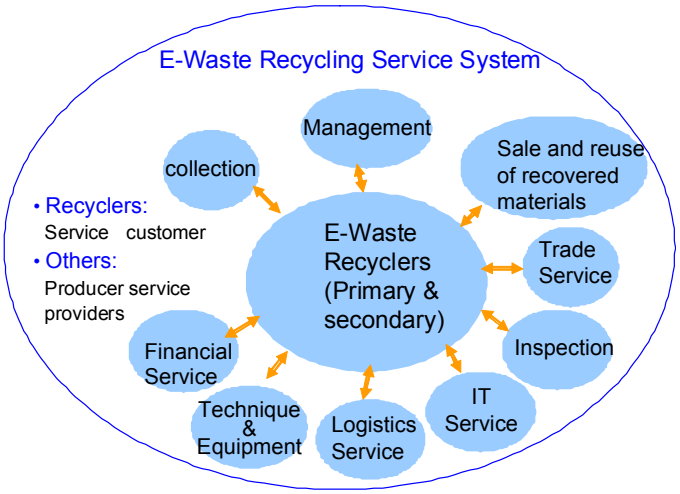

Figure 3. E-waste Recycling Service System

B. Producer Service for E-waste Recycling System

With the ever deepening specialized division, the producer-service has become more sophisticated. Within the e-waste recycling network, the recyclers are considered the "manufactures". The other companies or organizations are just (producer) service providers, whose resources can be integrated in the recycling process.

Producer service industry in e-waste recycling includes quality inspection, logistics service, collection service, IT service, technical support service, recycling equipment related service, etc. These producer services play a more and more important role in the system, because the recyclers can focus on their core competence, leaving other functions delivered by service providers. The seamless cooperation and collaboration among the service providers and clients are critical for the efficient system operation.

Within the recycling network, multiple stakeholders (service provider and customers) are involved. Each stakeholder shares its specific responsibilities in terms of information, material and financial flows [6].

Stakeholders and their responsibilities in e-waste recycling system are listed as follows:

1) Management authorities
- E-waste recycling Fund Management Center: Operation of the system
- State Council: Release of Regulation
- Authorities from local municipal level, provincial level, and state council level: Planning; Technical policy; Environmental inspection, etc;

2) Collectors(Retailer, Professional collector, Repair shops):
- Collection of the e-wastes and submit them to qualified recyclers

3) Other third party Service Provider:
- Logistics Providers: transportation
- Quality Inspector: environmental inspection
- IT service provider: IT service
- Producers: pay the e-waste recycling fee according to market share
- Recyclers: sorting; dismantling; treatment of e-wastes
- Waste disposers: landfill or incineration of hazardous material & waste
- Consumers: submit (or sell) the e-wastes to the qualified collectors

C. E-market for Producer Service

To make sure quick and effective collaboration between service provider and customer, it is proposed to establish an e-market for producer services. Actually, among each producer service field, such as logistics or technology, there is a sub-industrial chain, where multiple enterprises are involved in the business. Current operation in traditional business model requires long time to match the demand and supply of service, resulting in lost demand or delay in service provision.

E-market for producer service can be a critical innovation of IT service to enhance the effectiveness and efficiency of e-waste recycling network. The producer services can be hosted as web-delivered services, which can help improve the efficiency of the total service system. Thus the supply and demand of the service can be integrated on a platform, to ensure better match of supply and demand with quick response.

IV. INNOVATION IN TECHNOLOGIES USED OF E-WASTE RECYCLING SYSTEM

The second domain in STOF model is technology domain. Within the e-waste recycling service system, major technologies are treatment technologies, information technologies applied to boost the efficiency of the service system.

[4] Contrary to the consumer service industry, producer services industry refers to services needed in the process of production (here is the recycling process) rather than in final consumption.

A. *Advanced Treatment Technologies*

The current treatment technologies used in Chinese e-waste recycling plants are not advanced enough, especially more efforts are to be made to guarantee environmentally friendly treatment techniques for the treatment. As we know, the primitive treatment practice in Guiyu has caused healthy and environmental concerns.

B. *Information Technology to Boost E-Waste Service System*

According to the No. 551 Order of the State Council, multiple stakeholders are involved in management of the e-waste recycling system. Producer should provide information about the material used in the product and treatment advice, which help recyclers treat the e-wastes properly. Regulatory authority includes e-waste recycling foundation center and different department from state council, provincial and local level, which share the responsibility to manage the operation of the e-waste recycling system.

- The primary management authorities consist of e-waste fund management center and the three departments of the State Council: Environmental Protection (EP) department, industry & information technology (IIT) department and comprehensive resource utilization (CRU) department. They are in charge of 1) policy& measure drafting; 2) coordination of implementation; 3) supervision & administration of e-waste recycling system.
- The supplementary management authorities include the provincial departments (EP, IIT, and CRU) and State Council's public finance, industry & commerce, quality supervision, customs, taxation departments. They are responsible for the collection, treatment, policy release, and planning.
- Local environmental protection department serves as a link between the recyclers and the fund management center.

Therefore, an efficient information management system or platform is urgently required to ensure the sustainable development of the complex e-waste recycling industry.

Cloud computing is one of the new information technologies, which enables web based information platform. Cloud refers to the internet. One major kind of cloud computing[5] is SaaS (Software as a Service), through which users can get software service from Internet, without having to invest massively in software or infrastructure. Users can lease the web-based software from the cloud platform operated by service provider, which is responsible for the upgrading and maintenance of the software related technology.

The cloud based information platform consists of three level services [7]:

1) web-based information platform for all the stakeholders, which share information on the platform;

2) SaaS (Software as a Service) based ERP (Enterprise Resource Planning) management system for recyclers, who can lease the application from the platform operator, without having to invest in the software license or infrastructure;

3) Expansion of the platform to collection platform and transaction platform for the recovered material. The above mentioned three platforms are considered as three sub-clouds, which are integrated in the e-waste recycling cloud.

Furthermore, in the cloud based e-waste recycling network, financial flow and material flow can be integrated in the information management platform.

V. INNOVATION IN ORGANIZATION OF E-WASTE RECYCLING SYSTEM

The third domain in STOF model is organization domain. As we know, to implement a profitable, fair, transparent, and sustainable e-waste recycling system, there should be a viable organization structure. Cooperation and coordination among different stakeholders are critical to the success of the system [5]. The managing authority should release practical regulations and economic incentives to encourage environmental protection practices.

The No. 551 Order of the State Council defines the organizational structure and roles of multiple stakeholders in e-waste recycling system, and the e-waste fund management center is the central managing organization. However, current regulation entitles diverse government authorities to be in charge of various issues, which makes the management more complex, especially in case of interest-conflict. It would be a desirable innovation to streamline the management authority for e-waste recycling service system.

VI. INNOVATION IN FINANCE OF E-WASTE RECYCLING SYSTEM

The fourth domain of STOF model is finance. Chinese law on e-waste recycling, coming into effect in 2011, stresses the shared (financial) responsibility of e-waste producers and Chinese government. Recycling cost will be paid by producer according to its market share, while the government will compensate the recyclers for proper treatment.

The recycling fee paid by the producers will be gathered and managed by the authority or the e-waste fund management center, which further distribute the money to the recyclers according to the volume and quality of the treated e-wastes.

To make sure long term sustainable financial flow of e-waste recycling system, the environmental performance of the network should also be considered, apart from economic concerns [9-10]. Here it is suggested to design e-waste logistics network with the following multi-objective optimization model, with economic objective and environmental impact objective combined in the model:

- For the economic objective, total cost (including cost of collection, disassembly, machinery treatment, transportation and operations of the plants involved) should be minimized (or total revenue is to be maximized).

[5] Cloud Computing includes multiple levels of services, such as :1) IaaS (Infrastructure as a Service); 2) PaaS (Platform as a Service); 3) SaaS (Software as a Service), etc.[8]

- For environmental objectives, energy consumption, pollution or carbon emission should be minimized. The environmental impacts should be
- To build the economic and environmental model, all the cost and material change in quality and quantity should be analyzed with the help of life cycle assessment tools (such as Simapro or Umberto);
- The economic objective and environmental impacts should be combined into a multi objective optimization model, in which material flow and facility location should be optimized. To solve this multi objective optimization model, constraint programming can be used to tradeoff the economic objective and environmental impact [11]. In this way, the environmental impact of the e-waste recycling practice can be reduced, in order to ensure sustainable development of this resource regeneration industry, without endangering the environment and the health of the workforce to an extreme extent.

VII. CONCLUSIONS

From service science perspective, this paper analyzes the e-waste take-back and recycling network as a service system. Service interaction and the related two key roles (service provider and service customer in this service system are defined among multiple stakeholders. Four domains of STOF model (service, technology, organization and finance) are used to explore the potential innovations in e-waste recycling system. The proposed cloud platform can help build e-market for producer services for e-waste recycling service system, to allow efficient information flow, material flow and financial flow. It is also discussed that e-waste recycling network design should include both economic value and environmental impacts, to ensure sustainable development of e-waste recycling industry.

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