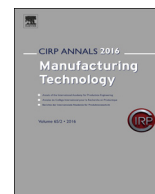




ELSEVIER

Contents lists available at ScienceDirect

CIRP Annals - Manufacturing Technology

journal homepage: <http://ees.elsevier.com/cirp/default.asp>

Modeling competitive market of remanufactured products

Yasushi Umeda (1)^{a,*}, Kazuma Ishizuka^a, Mitsutaka Matsumoto^b, Yusuke Kishita^a^a Department of Precision Engineering, Graduate School of Engineering, The University of Tokyo, Japan^b National Institute of Advanced Industrial Science and Technology, Japan

ARTICLE INFO

Keywords:

Lifecycle
Simulation
Remanufacturing

ABSTRACT

Although remanufacturing is effective for increasing resource efficiency, its market share is very small in some developing countries. For analyzing market conditions for remanufacturing, this paper proposes a market model to be incorporated in Life Cycle Simulation by employing polynomial logit model. This model successfully simulated market competition among new, remanufactured, and refurbished products. The results suggest the possibility of diffusion of remanufactured products if the circulating system is well established. Polynomial logit model is effective for discussing policy, life cycle design, and product design, since it can map customers' preference to the attributes of products through the utility function.

© 2017 Published by Elsevier Ltd on behalf of CIRP.

1. Introduction

Remanufacturing is one of the most important life cycle options for increasing resource efficiency and realizing circular economy [1]. While photocopiers, automobile parts, and construction machinery in developed countries are good practices [2], remanufacturing in developing countries is struggling in the competition with new products and refurbished products, and cannot achieve good market shares. On one hand, it should be competitive to the quality of brand-new products and on the other hand it should be competitive to the price of refurbished products.

In the CIRP community, remanufacturing has been studied enthusiastically. Duflou et al. [3] discussed the importance of disassembly in remanufacturing with indicating cases. Sutherland et al. [4,5] intensively study remanufacturing in terms of energy, environmental loads, and cost. Sakai and Takata [6] proposed reconfiguration management of remanufactured products by using Life Cycle Simulation. Wang et al. [7] proposed cloud-based remanufacturing platform. Widera and Seliger [8] discussed obstacles of remanufacturing business. Lieu et al. [9] mathematically evaluated optimal timing of remanufacturing. However, market competition of remanufactured products with other types of products has not been studied in this community.

This paper focuses on remanufacturing in Southeast Asia. We executed some field studies in this area and found some difficulties of remanufacturing in achieving a certain market share under the competition with new products and other circulating products like refurbished products, reused products, second-hand products, etc. In order to diffuse remanufactured products, some conditions including price and quality comparing to competing products should be satisfied and/or changes of business models are needed. The goal of this research is to find out such conditions and business

models and then to specify requirements for life cycle design of the products to be remanufactured. As the first step, this paper proposes a model to simulate the market competition among new, remanufactured, and other circulating products, in order to find out the above-mentioned conditions. For this purpose, we expand Life Cycle Simulation [10] by incorporating a market model. Life Cycle Simulation [10] is a method to simulate flows of products, parts, materials, energy, money, information and so on throughout a product life cycle by employing a discrete event simulation technique for supporting life cycle design.

The rest of this paper is organized as follows. Section 2 summarizes our field studies in Southeast Asia and points out difficulties of remanufacturing. Section 3 describes the market model. Section 4 illustrates the life cycle model we developed and its simulation results. Section 5 discusses the simulation results. And, Section 6 concludes this paper.

2. Remanufacturing in Southeast Asia and its issues

In this paper, we focus on markets in Southeast Asia and assume the following three kinds of products as representatives:

New product: A new product is manufactured by an OEM (e.g., Xerox) with newly manufactured parts. The product is sold and used in a target market. And, a certain rate of end-of-life products is collected by the OEM.

Remanufactured product: A remanufactured product is made by the OEM from the collected end-of-life new products with genuine spare parts in the target area. The 'like new' quality is guaranteed by the OEM. At its end-of-life, the product is no longer remanufactured as a product.

Refurbished product: An independent refurbisher imports end-of-life new products from developed countries (e.g., U. S. A.) and refurbishes them with replica new parts made by third party manufacturers and reused parts. In general, its quality is inferior to new or remanufactured products and the life time is shorter than

* Corresponding author.

E-mail address: umeda@pe.t.u-tokyo.ac.jp (Y. Umeda).

them. At the end-of-life, the products are no longer refurbished as a product.

This paper takes the position to promote remanufactured products in Southeast Asia. We here take Southeast Asia as a typical example of developing countries. Since the population and the consumption of goods increase in developing countries, ensuring resource efficiency in these countries is an urgent and important issue, which also leads to sustainable consumption and production in developing countries.

We executed field studies in Singapore and Thailand, in which we made interviews to OEMs, remanufacturers, and refurbishers of photocopiers, construction machinery, and factory equipment. We found out cases that are impeding the promotion of remanufactured products as follows

Not enough needs: Refurbished photocopiers sell better than remanufactured ones because of their cheaper prices. 'Like-new' quality of remanufactured photocopiers is excessive. Refurbished products are cheap, because the refurbishers do not use OEM's genuine spare parts but use replica new parts. While this may reduce the quality of the products, the quality of such replica parts is increasing. On the other hand, large firms often employ product service systems (PSS). The firms do not care whether the photocopiers are brand-new or remanufactured as far as the contracted service level is kept. Then, PSS is a good target of supply of remanufactured photocopiers.

supply of cores: Supply of cores (i.e., end-of-life new products) is problematic. The customers or lease companies do not return end-of-life products to OEMs. Since they do not have service contracts with OEMs, OEMs cannot grasp products to be discarded.

Price destruction: In the Thai market, an OEM drastically reduced the price of new photocopiers. As a result, many refurbishers disappeared very quickly because the refurbished products lost the price competitiveness.

The market of circulating products is very complicated and dynamic, and we are not sure to whom we shall support; OEMs, OEMs' remanufacturing, refurbishers, or third party parts manufacturers. According to this field study, we can summarize the essential issues of remanufacturing as follows:

1. *Market competition*: The market competition among new and circulating products is very severe. There seems to be some implicit balance of price, quality, and durability.
2. *Establishment of circulation*: For expanding the share in the competitive market, the supply of cores is quite critical.
3. *Business model*: Quality assurance by PSS is a hopeful approach to expand the share of the circulating products.

This paper focuses on the issues 1 and 2. For discussing conditions for diffusing remanufactured products, we simulate the market competition among three products by expanding Life Cycle Simulation [10]. This will be discussed in Section 3.

3. Market model

In this paper, we employ 'polynomial logit model' [11] as the market model, since this model can represent the situation where a customer selects a choice among multiple candidates and is a simple fundamental model. The model represents the utility of a product as a weighted sum of attributes and calculates the probability for choosing a product by applying a logistic function to the utility value. Namely, the model represents the utility Y_j of a product j ($1 \leq j \leq T$) for a customer as shown in Eq. (1), where T, M, X_{jk}, A_k ($1 \leq k \leq M$) denote the number of candidates, the number of focused attributes of a product, the value of the attribute k of product j , and the weight of the attribute k for the customer, respectively. Moreover, the probability P_j for choosing a product j is defined as shown in Eq. (2).

$$Y_j = \sum_{k=1}^M A_k \times X_{jk} \quad (1)$$

$$P_j = e^{Y_j} / \sum_{j=1}^T e^{Y_j} \quad (2)$$

The methodology [11] also provides a method to determine the weights of the attributes A_k . Namely, when the choice j_n of each customer n ($1 \leq n \leq N$) are given where N is the number of the customers, the weights are determined so as to maximize the likelihood function L defined as Eq. (3).

$$L = \prod_{n=1}^N P_{j_n} \quad (3)$$

4. Simulation

We construct a life cycle model for simulating the market competition of remanufactured products against new and refurbished products. We here take a photocopier market in Thailand as a target case study. While the photocopier markets are shrinking in developed countries, the markets increase in developing countries [12]. Since photocopier is a typical circulating product, data on circulating products are available and reliable. We then focus on the photocopier market. Of course, the model is applicable to other products in other areas.

4.1. Simulation conditions

The life cycles of the three products are modeled as described in Section 2. Fig. 1 depicts the life cycle model of these three products. In this figure, the process 'Product Purchase' implements the market model described in Section 3.

As the reference scenario, we set the following conditions. Table 1 indicates attributes of the three types of products according to the interviews to local experts. For representing the life times, we modeled the disposal density function, denoting rate of disposal per time unit, as a Weibull distribution with shape parameter of 1.82 from the Reference [13] and scale parameters of 55.2 (months) (new product), 42.9 (remanufactured), and 31.8 (refurbished) so as to fit the life times in Table 1.

The simulation covers 200 months from January 2002, since we obtained the market data in Thailand from 2002 [12]. We assumed that an OEM started to sell the remanufactured products from 2010. The simulation is divided into two phases; preparation phase (Phase I) between 2002 and 2009 and main phase (Phase II) from 2010. In the main phase, the remanufactured products are sold and the three types of products are purchased according to the market model. Since the remanufactured products are made from end-of-life new products, we should simulate the market state in 2010, which consists of new products of different ages and refurbished products of different ages. This is the simulation in Phase I; in this

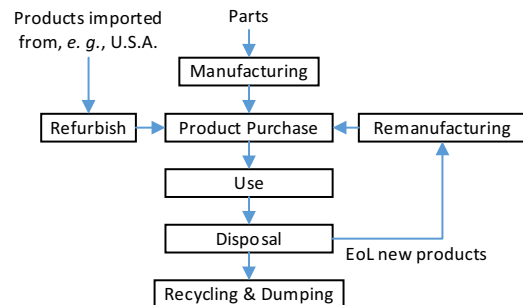


Fig. 1. Life cycle model of photocopiers in Thailand.

Table 1
Attributes of photocopiers.

| | New | Remanufactured | Refurbished |
|-------------------|-----|----------------|-------------|
| Sales price | 1 | 0.7 | 0.33 |
| Life time (years) | 10 | 8 | 5 |
| Quality of image | 1 | 1 | 0.7 |
| Reliability | 1 | 1 | 0.33 |

The values of 'sales price', 'quality of image', 'reliability' are relative to new products.

Download English Version:

<https://daneshyari.com/en/article/5466936>

Download Persian Version:

<https://daneshyari.com/article/5466936>

[Daneshyari.com](https://daneshyari.com)