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Procedia CIRP 61 (2017) 195 – 200

www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

Pricing Decision Models for Remanufactured Short-Life Cycle Technology Products with Generation Consideration

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Abstract

Although the analysis of remanufactured durable products dominates the environmentally conscious manufacturing research, more and more researchers try to focus on modelling short-life cycle products remanufacturing decisions. High-technology products, such as smartphones and laptops are the cases in point. Smartphone companies are opening remanufacturing facilities in third world countries to attract middle-level customers. Remanufacturing of high technology short life products can have a positive impact on the profits as well as the environment.

A common strategy for the technology-intensive companies is to update their products continuously to maintain market share as well as customers' appetites for latest technologies. This creates a multiple-generational product line. When a new generation is released, the market value of the previous generation is reduced, and the price of the generation before last is decreased even more. Meanwhile, remanufactured products of each generation also come to market when they are available. This can result in complex cannibalization among various generational product lines as well as new and remanufactured products.

In this study, we develop a model that addresses the issue of pricing the latest generation remanufactured products and old generation new products. The demands are time-dependent and price sensitive. The market is separated from that of the brand new product of latest generation. The system consists of a retailer and a manufacturer. Two scenarios are evaluated in the system. First, each party tries to optimize profit independently. Second, the joint profit is optimized. The results provide optimal pricing decisions in different selling periods.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

Keywords: Short-life cycle, Multiple-generations, Remanufacturing, Pricing

1. Introduction

Remanufacturing is an industrial process of recovering used parts from an end-of-life product, and assembling, maintaining, cleaning, and creating a new product with qualified quality. The remanufacturing process extends the production life-cycle and plays a major role in the business world because of legislation of waste control, people's awareness of environmental protection and wider economic margin of refurbished products. Gungor and Gupta [1] presented a review on environmentally conscious manufacturing and product recovery (ECMPRO) and stated that the end-of-life management of a product after its useful life is one of the elements of ECMPRO. Ilgin and Gupta [2] extended the review to the development of environmentally conscious product design, reverse and closed-loop supply chains, remanufacturing, and disassembly. Although it is believed that a remanufactured product has a larger economical margin, yet there is a significant difference in pricing between new and remanufactured products because of customers' perception. The pricing analysis of these two kinds of products is worthy of study. When a product is launched into the market with a label of "remanufactured product" or "refurbished product", it provides customers with almost the same functionality as a new product but at a lower price.

The remanufactured product is derived from an end-of-use product. Therefore, its availability highly depends on the lifecycle of the product. A new product with a short lifecycle will lead to limited availability of used products. The price of the remanufactured product can be higher because of the

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.208

supply shortage [3]. Therefore, lifecycle becomes an important factor for considering pricing problems, especially short lifecycle products. Consumer high technology products, such as smartphones, digital cameras and laptops are cases in point.

Nowadays, smartphones are widely used in developed countries. People have a huge desire to acquire the latest technology and new products. Smartphone companies have to develop the technology and design of the current generation and release it at an appropriate time to maintain market share. When a new generation is released, the market value of the previous one is reduced, and the price of the generation before last is decreased even more. This creates a potential cannibalization within the multiple-generational product lines [4]. This also opens great opportunities in the third world countries. Smartphone companies are opening remanufacturing facilities in developing countries to attract middle-level customers. For example, Apple Inc. is trying to sell refurbished smartphones in India at a discount of between 10 and 20 percent to position them in the price-sensitive market and capture market share from other middle-level brands. Researchers also point out that many buyers in India prefer older iPhone models [6]. For these reasons, selling refurbished or old model smartphones becomes a great marketing strategy in the third world countries. That leads to competition and cannibalization between latest generation remanufactured product and past generation new product in middle level market. Remanufactured product may attract price sensitive but technology-savvy customers. Old generation new product may appeal to price sensitive but quality-conscious customers. Our study will focus on pricing decisions in a closed loop supply chain involving manufacturer and retailer, where customers have the option to purchase old generation new product or new generation remanufactured product in the same market. We consider a monopolist case of two generation items with the constraint on the quantity.

2. Literature review

The smartphone has two primary characteristics: Short lifecycle and intensive generational update. We provide brief reviews of prior work on pricing models for new and remanufactured short lifecycle products and new products with two or multiple generations.

2.1. Pricing models of new and remanufactured products

Gan, et al. [7] provided an example of a short lifecycle product and stated that new products are met with a demand decline in a very short time. New generation is expected to be released at the point when the old product reaches its decline phase. They established a pricing decision model for new and remanufactured short-life-cycle products in a closed-loop supply chain. They considered a monopolist case of a single item with no constraint on the availability of remanufacturable cores. Three parties are involved in the supply chain. They are manufacturer, retailer and collector. The authors optimized profit for each party and then maximized joint profit along the supply chain. The demand function was time-dependent, which matched the market behavior of smartphones. They claimed that reduction in price of the new product during the decline phase does not provide more benefit for the whole system. Considering the total supply chain profit is a better way to separate each party. Demand change causes a little robustness of prices and the total profit. Ferrer and Swaminathan also analyzed a monopoly model from a supplier's viewpoint in several planning horizons. Different from Gan *et al*. Ferrer and Swaminathan [8] take the constraint on the availability of remanufactured product into account. The number of reusable cores for remanufacturing depends on the actual sales of new products. The demand for new product has a negative coefficient with the price. They pointed out that when the remanufactured product is more profitable, there will be a tendency to provide more units in the first selling period to supply additional used cores for remanufacturing later. Also, Chen and Chang [9] built a model with the constraint of availability in a multiple period setting, but used Lagrangean relaxation and dynamic programming techniques instead. Some researchers keep an eye on the potential cannibalization between new and refurbished products. Guide and Li [10] carried out auctions to understand consumers' willingness to pay for both new and remanufactured products. They concluded that consumer product has a minimal risk of cannibalization. Additionally, Vadde, Kamarthi and Gupta [11] focused on the pricing strategies with obsolescence. They considered two models to counter the prospect of product obsolescence gradually and suddenly with the consideration of the risk in demand decrease and inventory increase.

2.2. Pricing models for short lifecycle products

It is well known that a new smartphone has a short lifecycle and its price varies over time. Companies always have innovation strategy to release a new model with the latest technology and fashion style. The launch of new model influences the price of the old one. Zhou, Zhang, Gou, Liang [12] analyzed three launching strategies for a fashion firm with the consideration of consumers' satiation effect. They are "no launch of a new style", "introduce a new style and stop selling the outdated one", and "sell new and old style simultaneously". The authors claimed that the optimal strategy depends on the production cost and consumers' metal book value. Li and Huh [13] also noticed this demand trend during the product's lifecycle. They maximized the profit with the set of discrete prices variations. Only limited number of price changes was allowed.

2.3. Pricing models of multiple generation production

High technology companies always update the current model to maintain technology competition and market share. This causes internal competition among generations. Plenty of previous researchers pointed out and analyzed the effect of cannibalization. They developed pricing models for multiple generations of products to maximize the total profit. The Bass model is a traditional diffusion model [14]. Many followers transitioned from this diffusion model to pricing model. Norton and Bass [15] applied this theory to the substitution for generations of high-technology products. Others focused