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Pricing decision model for new and remanufactured short-life cycle products with time-dependent demand

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ABSTRACT

In this study we develop a model that optimizes the price for new and remanufactured short life-cycle products where demands are time-dependent and price sensitive. While there has been very few published works that attempt to model remanufacturing decisions for products with short life cycle, we believe that there are many situations where remanufacturing short life cycle products is rewarding economically as well as environmentally. The system that we model consists of a retailer, a manufacturer, and a collector of used product from the end customers. Two different scenarios are evaluated for the system. The first is the independent situation where each party attempts to maximize his/her own total profit and the second is the joint profit model where we optimize the combined total profit for all three members of the supply chain. Manufacturer acts as the Stackelberg leader in the independently optimized scenario, while in the other the intermediate prices are determined by coordinated pricing policy. The results suggest that (i) reducing the price of new products during the decline phase does not give better profit for the whole system, (ii) the total profit obtained from optimizing each player is lower than the total profit of the integrated model, and (iii) speed of change in demand influences the robustness of the prices as well as the total profit gained.

1. Introduction

Technology-based product has shorter life cycle due to rapid innovation and development in science and technology, as well as customer behavior in pursuing latest innovation and style. Lebreton and Tuma [1] pointed out that technology based commodities such as mobile phones and computers have shorter innovation cycle so that the previous generation becomes obsolete faster, either functionally and psychologically. Similarly, Hsueh [2] also argued that product life cycle in electronic industry is shorter than before, due to technology advances, and as a result, an outdated product could reach its end-of-use even it is still in a good condition. Shorter life-cycle has negative contribution toward sustainability, since there is an increase in product disposal. Customers want newer products and discard the old ones, and these preferences would exhaust landfill space in shorter time. In addition, there are more natural resources and energy used to create new products than actually needed, due to unnecessary increased obsolescence. To make it worse, electronic products are prominent as the ones with shorter and shorter life cycle, while the wastes are toxic and not environmentally friendly. There are many attempts made in developed countries to control electronic wastes such as Waste of Electric and Electronic Equipment (WEEE) directives, implemented in most European countries since 2003, RoHS in United States, 2003, and Extended Producer Responsibility (EPR) issued by OECD in 1984. However, these regulations pose as burdens to the industries when implemented only for conformity, because there are additional costs for handling e-wastes and increased material cost for avoiding or minimizing toxic materials.

Several strategies have been introduced to mitigate products disposal and wastes, such as life cycle approach, regulation and society approach. One aspect of life cycle approach is dealing with products at their end-of-use. According to de Brito & Dekker [3], there are situations where customer has the opportunity to return a product at a certain life stage, which can be referred to leasing cases and returnable containers, and is called end-of-use return. Hsueh [2] considered a different kind of return, where a product may be returned because it has become outdated, and the customer

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wants to buy a new product. Herold [4] proposed alternatives to end-of-use products which are reprocessing, collect-and-sell, and collect-and-dispose. Remanufacturing is one option to manage products at their end-of-use which offers opportunity for complying with regulation while maintaining profitability [5–7].

Remanufacturing is a process of transforming used product into "like-new" condition, so there is a process of recapturing the value added to the material during manufacturing stage [8,9]. The idea of remanufacturing used products has gained much attention recently for both economic and environmental reasons. As suggested by Gray and Charter [9], remanufacturing can reduce production cost, the use of energy and materials.

There are numerous studies on remanufacturing. However, most of the published works on remanufacturing have considered durable or semi-durable products. Very little attempt has been made to study how remanufacturing maybe applied to products with short life cycle. In some developing countries like Indonesia, there is a large segment of society that could become potential market for remanufactured short-life cycle products like mobile phones, computers and digital cameras.

In remanufacturing practice, there are three main activities, namely product return management, remanufacturing operations, and market development for remanufactured product [10]. In terms of marketing strategy, there are general concerns that remanufactured product would cannibalize the sales of new product. However, Atasu et al. [11] concluded that remanufacturing does not always cannibalize the sales of new products. He proposed that managers who understand the composition of their markets, and use the proper pricing strategy should be able to create additional profit. Therefore, pricing decision is an important task in an effort to gain economic benefit from remanufacturing practices.

There are several studies that focused on pricing of remanufactured products, but many of them have not considered the whole supply chain, and also only a very few concern about obsolescence of short life cycle products. Our study will be focused on pricing decisions in a closed loop supply chain involving manufacturer, retailer and collector of used products (cores), where customers have the option to purchase new or remanufactured short life cycle products in the same market channel. We consider a monopolist of a single item with no constraint on the quantity of remanufacturable cores throughout the selling horizon.

2. Literature review

Remanufacturing of mobile phones and electronic products has been recognized as an important practice in the United States, and as a potential in China and India. Helo [12] claimed that product life cycle has significantly shortened by rapid technological advancement, and coupled with fashionable design that attracts frequent purchases of new products, has generated pressure on and opportunities for reverse logistics. Franke et al. [13] suggested that remanufacturing of durable high-value products such as automobile engine, aircraft equipment, and machine tools, has been extended to a large number of consumer goods with short life cycle and relatively low values, like mobile phones and computers. He also quoted market studies by Marcussen [14] and Directive 2002/96/EC which revealed that there is a significant potential for mobile phone remanufacturing due to the large supply market of the used mobile phones in Europe and the high market demand in Asia and Latin America.

Neto and Bloemhof-Ruwaard [15] found that remanufacturing significantly reduces the amount of energy used in the product life cycle, even though the effectiveness of remanufacturing is very sensitive to the life span of the second life of the product. They also proposed that the period of the life cycle in which the product is returned to recovery, the quality of the product (high-end versus low-end), the easiness to remanufacture and the recovery costs can affect whether or not remanufacturing is more eco-efficient than manufacturing. Rathore et al. [16] studied the case of remanufacturing mobile handsets in India. They found that used phone market is very important, even though with a lack of government regulation for e-wastes. It is also observed that there is a negative user-perception of second hand goods and that the process of remanufacturing has not been able to capture much required attention from its stakeholders. Wang et al. [17] showed that the mobile phone market in China is growing rapidly. The number of mobile accounts was 565.22 million in February 2008 according to a report from Ministry of Information Industry of the People's Republic of China. The above mentioned studies have affirmed our intuitive proposition that there is a high potential for remanufacturing short life cycle products.

Motives for deploying reverse chain can be for profitability (or cost minimization) or for sustainability (environmental impact mitigation), which either could be driven by regulation and/ or morale. In our research, the underlying motive considered would be focused on profitability, which seems to be the suitable motive applied to industries in a situation with the absence of environment protection regulation, like in most of the developing countries. There are numerous studies that investigated the factors that influence decision to remanufacture as well as the factors for successful remanufacturing. We categorized the factors into four aspects, namely product characteristics, demand-related factors, process-related factors, and supply-related factors.

The first aspect, product characteristics of short life cycle products, consist of (1) innovation rate (fast vs. slow) as an extension to technology factor [8,18–20]; (2) residence time [21]; (3) product residual value [22]; (4) qualitative obsolesce, as an extension to product characteristics [3,23].

Second, demand-related factors, consist of (1) market size or existence of the demand, [18,19,24]; (2) market channel, which is about selling remanufactured products using the same channel as the new product, or differentiated [8,18–21,25–27]; (3) pricing of new and remanufactured products, with demand as a function of price [28,32,33,30,18,19,26]; (4) existence of green segment, [23,31].

Supply-related factors can be described by (1) acquisition price and (2) source of return, whether it is limited and then pose as a constraint, or unlimited. These factors were studied in [8,18,19,23, 24,32].

The last factors, which are process-related, consist of (1) remanufacturing technology availability [8,18,32]; (2) remanufacturing cost, [8,18,19,21,22,32]; (3) reverse flow structure readiness [8,20, 24,32–34].

There are several studies that discuss pricing strategies involving remanufactured products, obsolescence, and nonlinear demand function. However, none has considered the situation that we address in this paper. Table 1 shows the review result and where our proposed model stands.

3. Problem description

A closed-loop supply chain consists of three members, which are manufacturer, retailer, and collector, as depicted in Fig. 1. The closed-loop is initiated by production of new product, which is sold at a wholesale price P_{nw} to the retailer. The new product is then released to the market at a retail price P_{n1} for the period when product life-cycle is within introduction–growth–maturity (IMG) phases, or during increasing and stable phases. When the new product has reached its decline phase, retailer starts to apply different pricing, P_{n2}. In the model development, the price is differentiated between IMG phases and decline phase to study the impact of this differentiated pricing, as Kotler & Armstrong [52] suggest that reduced price during decline phase could increase the quantity of demanded goods. An example of short life-cycle product where the new product reaches its decline phase in a short time is, Samsung Galaxy Tab 10.1 that was released on second quarter