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Remanufacturing of short life-cycle products

Shu San Gan[a, b], I Nyoman Pujawan[a 1], Suparno[a]

[a] Department of Industrial Engineering, Sepuluh Nopember Institute of Technology, Surabaya 60111, Indonesia
[b] Department of Mechanical Engineering, Petra Christian University, Surabaya 60236, Indonesia
gshusan@peter.petra.ac.id, [1]pujawan@ie.its.ac.id, suparno@ie.its.ac.id
[1] Corresponding author

ABSTRACT

Rapid development and innovation in science and technology have resulted in shorter product life cycle, especially in technology-based commodities like mobile phones and computers. Mounting wastes from such products have received increasing attentions from government, society, as well as industries, and it has created global sustainability concerns. Numerous studies on remanufacturing have been found on automotive sector and durable goods, but only a few studies focusing on short life-cycle products. Even though several studies implied that successful remanufacturing requires products to have long useful life and stable technology, there are several findings that support remanufacturing of short life cycle products. It is our intention to investigate the potential of remanufacturing a short life cycle product. A literature review is conducted to study the pros and cons, life-cycle implication, and remanufacturing aspects of short life cycle products. Then we conduct a survey to obtain descriptive analysis about the market of remanufactured short life cycle products. The factors investigated are market potential, customers' willingness to pay (WTP), and comparison between remanufactured and reuse products. The surveys results show that remanufactured product's market segment is low-end customers with highest preference toward remanufacturing and 95% of them chose remanufactured product when the price is less than 40% of new product. However, business to business (B2B) returns and consumer returns are best remanufactured and sold at primary market as identical to the new product. We conclude the discussion by proposing a framework for short life-cycle product remanufacturing, which can be used as a guideline to decide and plan the remanufacturing system.

Keywords: *Remanufacturing, Short life cycle product, Market potential, Framework*

1. Introduction

In an increasingly competitive global market, innovation has become one of the keys for successful enterprises. Rapid innovation and development in science and technology coupled with rapid changes in consumer behavior due to internet technology has shortened product life cycles [1,2,3,4]. As a result, technology-based product becomes obsolete quickly and reaches its end-of-use (EOU), when consumer switches to product with newer technology even though the old product is still functioning. Technology-based product at its EOU usually still has a relatively high value, so it has the recovery or reuse potential as an attempt to retrieve the remaining value. In addition to the economic benefit, the motivation for performing recovery process is reducing the waste disposed to the landfill by extending the life cycle of the EOU, delaying product disposal or diverting its function. Thierry et al. (1995) identified several alternatives for recovery process, i.e. repairing, refurbishing, remanufacturing, cannibalization, recycling, and direct reuse [5]. Remanufacturing is an option that gives the upgrade effect on the highest scale, which is expected to be a feasible option for recovering short life-cycle product at its EOU. The purpose of this study is to investigate the potential to remanufacture short life-cycle product. A literature review on short life-cycle product remanufacturing is presented section 2, and market survey is discussed in section 3. A Framework proposition is given in section 4, followed by conclusion in section 5.

2. Remanufacturing of short life-cycle product

2.1. Pros and Cons on short life-cycle product remanufacturing

Remanufacturing is a process of transforming non-functional, removed or exchanged products into "like-new" condition [6, 7]. Remanufacturing also results in reduction of energy and the use of natural materials, as well as reduction in the cost of production [6]. Additionally, Kaebernick et al. (2006) proposed that remanufacturing can improve the eco-efficiency and reduce environmental impact through the use of technology [8]. Remanufacturing process involves collection of used products, inspection, disassembly, cleaning, reconditioning (includes repairs and upgrades), reassembly, and testing. One of the main problems in remanufacturing is retrieving sufficient amount of used products at the right quality. The amount and timing of product returns depends on the type of product. Factors such as products' useful life, the pace of technological innovation and the rate of components' failure also influence the rate of return from EOU products [9].

There are several findings that claim durability as one of the critical factors for successful remanufacturing. Lebreton & Tuma (2006) claimed that by promoting aspects such as prestige, modernity or security, remanufactured items of those products tend to be discredited. Also, technology based commodities (such as mobile phone, computer) face short innovation cycles, which consequently make the previous generation psychologically and functionally obsolete [1]. Gray & Charter (2007) suggest that successful remanufacture requires that product technology is stable over more than one life cycle and unlikely to be successful when the evolution rate is high. The term evolution used here refers to technological change, legislation, and upgrade potential [6]. In the mean time, Ostlin et al. (2009) and Ferguson & Souza (2010) find that the rate of technological innovation and long useful life are the major influencing characteristics to the balance between product returns and demand for remanufactured products [9, 10].

However, several studies find that life cycle of technology based products such as computers, mobile phones, and networking equipment is getting shorter due to rapid innovation in technology as well as rapid changes in customer preference [1,2,3,11,12,13,14]. When product life cycle is getting shorter, there would be more products discarded even though they are still in good conditions and well-functioning. This ultimately creates a problem on waste disposals.

Even though some studies mentioned earlier implied that successful remanufacturing requires products to have long useful life and stable technology, there are several findings that support remanufacturing of short life cycle products. Steinhilper (1998) found the increasing volume of electronic products disposals that are not just look like new but also 80% of them are still working. This condition offers an ideal base for remanufacturing including modernization by upgrading or upcycling. He also suggested, if the whole electronic product can not be remanufactured, then remanufacturing of the components is also an important solution approach, which is also supported by Xing et al. (2007) [15,16]. Guide et al. (2003) show that remanufacturing of short life-cycle product is not only feasible, but can be profitable given well managed product acquisition [17]. Remanufacturing of mobile phones has been studied by several authors in different countries and the findings shows that it has great potential in recapture value, recover assets, reduce energy and provide economic benefits [18,19,20,21,22,23]. Remanufacturing also 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. The period of the life cycle in which the product is returned to recovery, the quality of the product, the easiness to remanufacture and the consequent recovery costs can affect whether remanufacturing is more eco-efficient than manufacturing [21,24,25]. Within the context of electronic and electrical equipments, Nnorom & Osibanjo recommend careful use of products, repair, refurbishing and remanufacturing, as attempts to extend product life cycle. Again, the importance of remanufacturing of electronic products is stressed since remanufacturing can extend a product's life, improve the re-usability of components, reroute waste and energy, and at the same time create economic value [26,27]. This finding is a corroboration of similar claim by Kerr & Ryan (2001), Kaebernick et al. (2006), and Lee et al. (2010) [8,28,29]. Kwak & Kim (2013) recognize there is a significant challenge to product recovery for technological obsolescence of end-of-life product, and use the concept of part upgrades in remanufacturing [30]. In Europe and the United States, the decision to remanufacture electronic products are encouraged by government regulations such as WEEE (2003) and RoHs (2003), and as a form of responsibility for environmental conservation [31]. Considering the mounting wastes from electronic products nowadays, the potential of remanufacturing practices in reducing waste sent to the landfill, as well as in reducing production costs becomes clear. We believe that remanufacturing short life cycle product is rewarding economically as well as environmentally.

2.2. Life-cycle implication

Several studies have been done to investigate the life cycle impact on the reverse flow of the supply chain. Tibben-Lembke (2002) studies how reverse logistics is affected by changes in sales throughout the product life cycle. Product life cycle is divided into three levels, namely the product-class, products-format, and product-model. A new type of product belongs to the first category; a new form of existing product-class goes to second category, while a new model of existing product-form is placed in the last category [32]. Georgiadis et al. (2006) studied how the product life cycle and optimal patterns of product-returns relate to the expansion decisions for collection and remanufacturing capacity, and influence the remanufacturing decisions. The relationship between residence time and length of product life cycle is also considered [33]. As for the problem of balancing the supply and demand for remanufactured products, Ostlin et al. (2009) analyze the implications of the life cycle to the remanufacturing system, using three scenarios namely product remanufacturing, components remanufacturing and parts cannibalization [9]. The period a product in the hands of consumers also influences the residual value of the product, which in turn affects the strategy of the reverse supply chain [34].

2.3. Remanufacturing aspects

There are numerous studies in investigating 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, consists of (1) innovation rate, fast versus slow, as an extension to technology factor [7,10]; (2) residence time [35]; (3) product residual value [36]; and (4) qualitative obsolesce, as an extension to product characteristics [37,38]. Second aspect is demand-related factors, consists of (1) market size or existence of the demand [10,39]; (2) market channel, selling remanufactured products using the same channel as the new product, or differentiated [5,7,10,17,35,39,40]; (3) pricing of new and remanufactured products, with demand as a function of price [10,17,39,41,42,43,44],; and (4) existence of green segment, [37,45]. Supply-related factors can be described by: (1) acquisition price, and (2) source of return, whether it is limited and poses as a constraint, or unlimited [7,10,37,39,46,47]. The last factors, which are process-related, consists of (1) remanufacturing technology availability [7,10,47]; (2) remanufacturing cost [7,10,35,36,39,47]; (3) reverse flow structure readiness [7,40,46,47,48,49].

3. Market survey for remanufactured mobile phones

In search of the market potential of remanufactured short life cycle products, we conducted a survey that would provide a descriptive statistics of some attributes. The objectives of the survey are obtaining insights and preliminary information about existence of demand on remanufactured short life cycle products, customers' willingness to pay (WTP), customers' preference toward remanufactured product compared to reuse, and existence of green segment. Short life-cycle product considered here is a product with a high innovation rate and with characteristic that EOU occurs before product's end-of-life (EOL), specifically mobile phones.

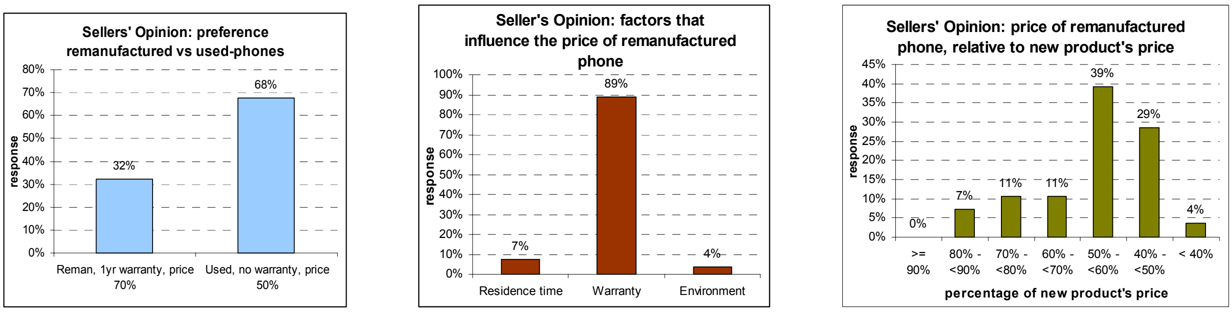
3.1. Survey methodology

There are two product types considered, namely (1) reuse product, a used product that is sold without reconditioning (as it is) through stores or directly among customers, and (2) remanufactured product, a used product that is sold after reconditioned to "as good as new" state. There are 2 major groups of samples, sellers and buyers, which the latter was further divided into 3 sub-groups, i.e. high-end groups with high income and high IT awareness; low-end group with low income and typically low IT awareness; and student group with typically low income but high IT awareness. Numbers of samples are 30 for sellers and 55 for each group of buyer. A set of questionnaires was prepared to obtain the required data, and the survey took place in Surabaya, a second largest city of Indonesia with a total population of over 3.1 millions. The sellers and buyers were interviewed informally and responses were recorded.. This study is explorative in nature with the main objective is to assess the market potential of remanufactured products. The results will be presented with the use of descriptive statistics.

3.2. Survey results and analysis

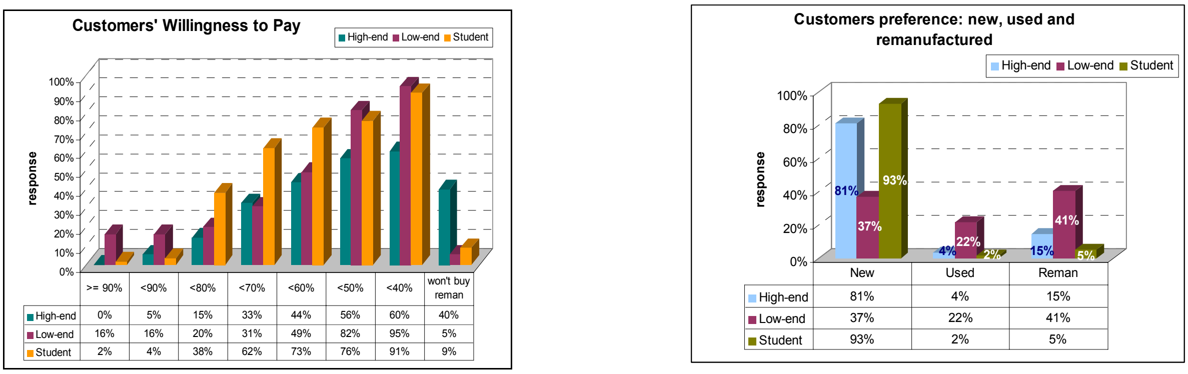
The results show that demand of remanufactured mobile phone does exist, even though it is relatively low. From the seller's point of view, most customers would prefer to buy used mobile phones rather than remanufactured ones. 68% respondents believe that given remanufactured or used-phones options, customers would choose used phones at lower price even though there is no warranty. However, when consumer decides to buy remanufactured phone, 89% respondents believe that warranty is an important factor. 68% respondents consider the appropriate price of a remanufactured phone is between 40%-60% of the price of the respective new product. **Figure 1** shows the survey results.

Customers willingness to pay is different among high-end, low-end and students. The cumulative customers' WTPs are depicted in **Figure 2a**. When the remanufactured item's price is less than 40% of new product, 95% of low- uend cstomers and 91% of students will buy it, but only 60% high-end customers are willing to buy. As for the factor that effect the price of remanufactured product, the highest choice of high-end and student customers is warranty and then "remanufactured by OEM", but for low-end customers the highest tally is environment awareness followed by warranty. However, when given the option to buy new products besides remanufactured ones, 81% high-end customers and 93% students choose to buy new phones; only 15% and 5% favor in remanufactured phones, respectively. On the other hand, 41% low-end customers prefer to buy remanufactured phones with warranty, 37% choose new products, and 22% favors used phones. Customer's responses can be seen in **Figure 2b**.



(a) (b) (c)

Figure 1. Survey results – seller's opinion on remanufactured products



(a) (b)

Figure 2. Customers' responses to WTP and preference

The results indicated that remanufactured product is not attractive for high-end customers, since they prefer to buy new products. Hence, remanufactured product should be sold at secondary market for low-end customers. Since warranty is an important factor of attractiveness, it should be provided for remanufactured product as a contrast to reuse product. In this survey, we were not able to study consumer returns since such policy is not applied in the country.

4. Framework of short-life cycle product remanufacturing

From the literature review and survey results, we are able to develop a framework for remanufacturing of short life-cycle products. The framework is built started from identifying forward and reverse flow of the supply chain, and consider the possible alternatives when dealing with short life-cycle products. In term of product life-cycle level, we only consider product model, since technology-based commodity launch new model in a very short period after the launching of current model. But for product form and product class, the length of life-cycle is quite long.

4.1. Short life-cycle remanufacturing flow

New product model introductions are usually very effective for early adopters and high end customers, where added features are not too significant to change the product form but mostly for improving convenience or fashionable design, as well as for increasing the level of emotional attachment between product and user [32]. Since product-class and product-form have been introduced earlier, and remanufacturing has been implemented, then the collection scheme at this level is ready and often similar to the one for product-class or product-form. Quality problems usually are not too significant since customers have learned from the previous levels about the quality of remanufactured product compared to new product. Since maturity phase is typically very short, the design of supply chain flow is important. We propose a short life-cycle product remanufacturing flow as depicted in **Figure 3**.

4.2. Recovery Options

Product returns may occur for several reasons over the product life-cycle [50,51], and Guide & Wassenhove (2009) provide dominant pairings between type of returns and recovery options [51]. As suggested by Ostlin et al. (2009), remanufacturing is not limited to product remanufacturing but also include component remanufacturing [9,15,16]. A pairing between type of returns and recovery options is given to decide the type of market for recovered items, which is shown in **Figure 4**.

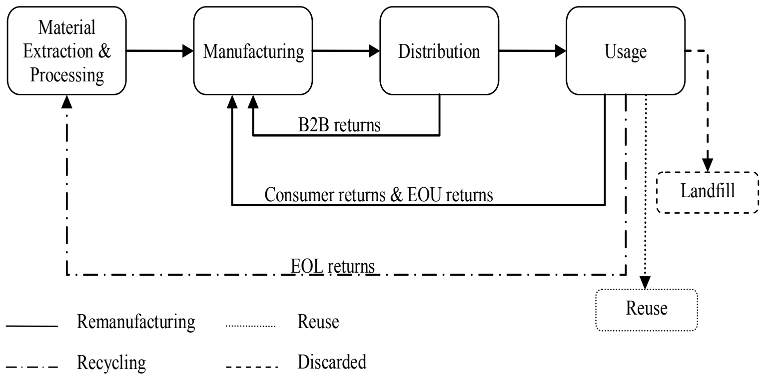


Figure 3. Short life-cycle remanufacturing flow

Recycle			material primary market
Component remanufac-turing		component primary market	component secondary market
Product remanufac-turing	product primary market	product secondary market	
Recovery / Returns	**B2B & Consumer returns**	**EOU**	**EOL**

Figure 4. Recovery options and type of returns

4.3. Framework

Before engaging in remanufacturing, there are several considerations need to be taken into account. The first step is identifying the remanufacturing flow and recovery options. When remanufacturing is considered as an appropriate option, whether product or component remanufacturing, then it is necessary to design the remanufacturing system based on the aspects described in section 2.3. In this way, a comprehensive analysis is performed to ensure successful remanufacturing. The framework is presented in **Figure 5**.

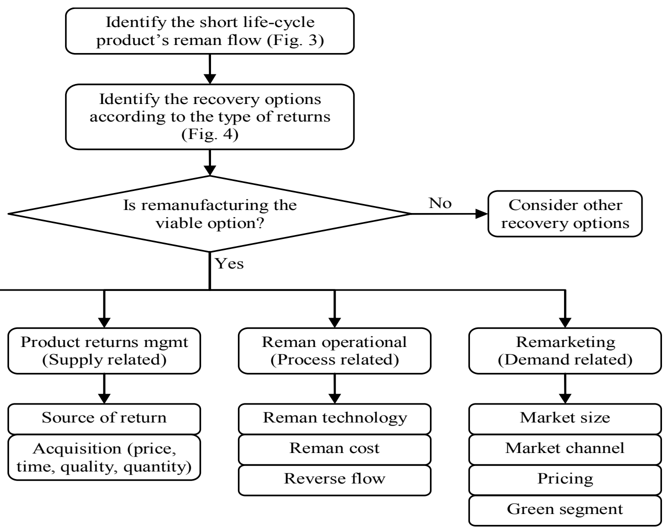


Figure 5. Framework for remanufacturing of short life-cycle product

5. Conclusion

The presented discussion has shown that despite the common idea that remanufacturing requires product with long life-cycle and stable technology, we are able to show numerous findings that support remanufacturing of short life-cycle product. The literature review results in the findings about life cycle implication as well as factors that influence the decision to remanufacture and to perform successful remanufacturing. We also conducted a survey, which is intended to provide insights on market potential of remanufactured mobile phone. The literature review coupled with survey results have enabled us to propose a framework for remanufacturing of short life-cycle product. Empirical and modeling approaches can be applied for further research, to gain a more statistically robust survey results, and analytical findings from the modeling of remanufacturing aspects.

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