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Combination Two-Dimensional Non-Renewable Warranty Policy Analysis for Remanufactured Products

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Abstract

This paper considers remanufactured Sensor Embedded Products (SEPs). SEPs can deal with the uncertainty by providing information on the condition of components prior to disassembly and remanufacturing. The goal is to determine how a Two-Dimensional Warranty period for remanufactured products using the sensor information about the age and usage of each and every End-Of-Life (EOL) product on hand to meet product, component and recycled material demands while minimizing the cost associated with warranty and maximizing remanufacturer's profit. A case example is considered to illustrate the implementation and use of the methodology.

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1. Introduction

Consumers are often unsure if a remanufactured product will perform as expected. This ambiguity about a remanufactured product could lead the consumer to decide against buying such a product. To mitigate this, remanufacturers can seek market mechanisms that provide assurance about the durability of the products. For example, the remanufacturer could offer warranties on their products. To further explore this, this paper considers an Advanced Remanufacturing-To-Order system for sensor embedded products (SEPs). Remanufacturing is defined as the process of restoring used products to like-new conditions with the help of disassembly and assembly by extending the life of the original product and thus reducing the consumption of virgin materials and energy. The sensors facilitate the data collection process.

The primary contribution offered by this paper is that it presents a quantitative assessment of the effect of offering warranties on remanufactured items from a remanufacturer's perspective in that it proposes an appealing price to the buyer as well. While there are developmental studies on warranty policies for brand new products and a few on secondhand products, there exists no study that evaluates the potential benefits of warranties on remanufactured products in a quantitative and comprehensive manner.

2. Literature Review

Recently, the number of studies dealing at the end-of-life (EOL) stage of a product has gained much attention from researchers [1,2]. This is due, on one hand, to environmental factors, government regulations and public demands, and on the other hand, to potential economical profits that could be obtained by implementing reverse logistics and product recycling resolutions. Manufacturers try to cope with consumer awareness towards environmental issues and stricter environmental legislation by setting up facilities that involve the minimization of the amount of waste sent to landfills by recovering materials and components from returned or EOL products [3].

In product recovery, the disassembly process plays an important role since it allows for selective separation of desired

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parts and materials. EOL products containing missing and/or nonfunctional components increase the uncertainty associated with the disassembly yield. Sensor-embedded products (SEPs) eliminate a majority of uncertainties involved with EOL management by providing life-cycle information [4,5]. A sensor is a device that detects the value or change in the value of various parameters such as temperature, and pressure and converts that in to a signal to have it recorded. Sensors embedded in the products monitor the product during its life cycle and record the life-cycle data. This enables the estimation of remaining useful life of components which helps to eliminate the uncertainties related to the quality and quantity of EOL products. Once this data is obtained, the optimal recovery decisions can be made without actual disassembly or inspection operations [6,7,8]. Once the components are retrieved, the products can be remanufactured.

SEPs have a significant and encouraging impact on product life-cycles. SEPs can improve product performance, effectiveness, reliability, maintainability, serviceability, recyclability, and cost. Furthermore, SEPs can reduce costs associated with product design, operations, and retirement. The idea behind SEPs are to implant sensors during the product manufacturing phase in order to monitor the product's critical components throughout their use. Sensors may be used in addition to the radio frequency identification (RFID) technology that has recently gained importance in life-cycle assessments (LCA), as a way of data storage and transfer. The nature of data that SEPs will be able to provide are existence, types, conditions and remaining lives of components EOL products. Therefore, using the information obtained from sensors allows the remanufacturer to be able to construct resilient recovery facilities that accommodate remaining life based demands and guarantee a minimum customer satisfaction level on recovered products while optimizing various system criteria [9].

The quality of a remanufactured product is often a suspect for consumers. The consumers are unsure if the remanufactured products will render the expected performance. This ambiguity about a remanufactured product could lead the consumer to decide against buying it. With such apprehension held by consumers, remanufacturers often seek market mechanisms that provide assurance about the durability of the products. One strategy that the remanufacturers often use is to offer warranties on their products [10].

Product warranties have three key roles. The first role is insurance and protection, allowing consumers to transfer the risk of product failure to sellers [11]. Next, product warranties can also signal product reliability to customers [12-16]. Lastly, the sellers use warranties to extract additional profitability [17]. There are several articles and books that consider warranty policies for new products [18,19]. However, there are only a few papers that consider the warranty for the remanufactured products. Base and extended one-dimensional warranty can be offered for remanufacturing products using Free Replacement Warranty (FRW) and Pro-Rata Warranty (PRW) policy [20-26]. The warranty policy and its effect on consumer behavior from the perspective of consumers has been studied by Liao et al., [27]. A novel mathematical–statistical model is proposed where decisions involve pricing of returned used products (cores), the degree of their remanufacturing, selling price and the warranty period for the final remanufactured products to investigate the joint optimization of remanufacturing, pricing and warranty decision-making for end-of-life products [28]. Kuik et al., presented mathematical models to examine two types of extended warranty policies for manufacturers to make the comparisons of their possible gained profit of remanufactured products by manufacturers [29].

3. System Description

The Advanced Remanufacturing-To-Order (ARTO) system deliberated in this study is a product recovery system. A sensor embedded air conditioner (AC) is considered here as an example product. Based on the condition of EOL AC, it goes through a series of recovery operations similar to the one shown in Figure 1. Refurbishing and Repairing processes may require reusable components to meet the demand of the product. This requirement satisfies the internal and the external component demand. Both are satisfied using disassembly of recovered components.

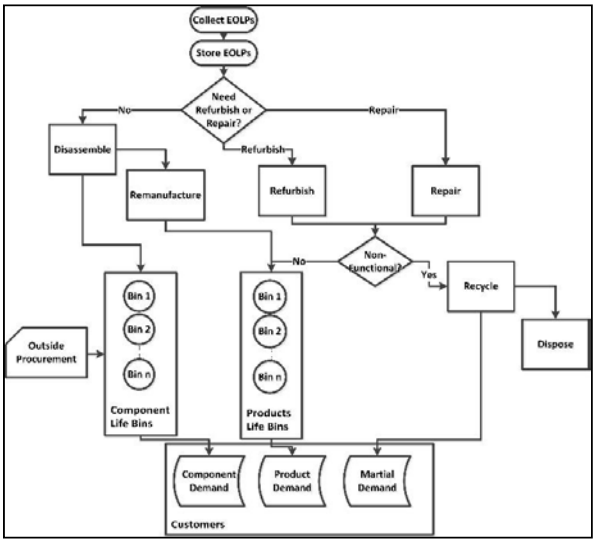

Fig 1. ARTO System's recovery processes

EOL ACs arrive at the ARTO system for information retrieval using radio frequency data reader that are stored in the facility's database. Then the ACs go through a six-station disassembly line. Complete disassembly is performed to extract every single component. There are nine components in an AC consisting of, evaporator, control box, blower, air guide, motor, condenser, fan, protector, and compressor. Exponential distributions are used to generate the disassembly times at each station, interarrival times of each component's demand, and interarrival times of EOL AC (the exponential distribution fits the events cited above because it is the only distribution with the "lack-of-memory" property. After waiting a minute without an arrival of SEPs arrival, the probability of a product arriving in the next two minutes is the same as was the probability (a minute ago) of getting a product in the following two minutes. As one continues to wait, the chance of something happening "soon" neither increases nor decreases [30]). All EOLPs after retrieval of the information are transferred either to station 1 for