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Comparative studies of three types of products (remanufacturing, refurbished and new products) on warranty cost and profitability

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Abstract

Employing remanufactured and refurbished products are among the new strategies that companies used to raise their profits as well as protects environment. Although used product equipment gives an opportunity to purchase latest technology, customers are doubtful about quality and reliability of these products. Because of limitation that developing countries faces in buying new products, some countries let companies to deal remanufactured and refurbished product just only under some strict requirement for warranty and servicing. In this paper, we aim to determine the effect of choosing remanufacturing and refurbished strategies on warranty cost and company's profitability. The warranty cost has estimated by existing model in literature and all products considered under FRW warranty policy. Comparing the result of profitability between used and new products is our ultimate outcome. For this purpose, the failure data of 60 medical devices of a leading company has analyzed from 2012 to 2013. For each strategy (remanufacturing, refurbished and new products), 10 devices were selected and monitored over a year. The result shows that remanufacturing strategy causes reasonable warranty costs and profitability. This help manager to have a deep understanding, and decide on the profitable strategies leads to improve their competitiveness.

1. Introduction

In today's world, the countries survival in the political, economical and international competitive arena depends on products, whichhave a strategic role in nations. Medical devices are amongcritical technologies, which play a significant role in health and general growth, and   have a direct impact on sustainability of economy.

Social and legal pressures on the companies enforce them to be very precise about choosing the devices and technologies and to reacheconomicaladvantages as well as protecting environment. One way for medical equipment industries prevent e-waste as well as filling the technological gap between developed and developing countries isto consider used market. Recycling material and recovery optionsof used products are inevitable options to reduce waste generation and the exploitation of natural resources. Accordingly, the managing used market and used products became an area of interest to both practitioners and academics (Saadanyetal, 2013)

Despite the significant share of used products, customers are often worried about the functionality and reliability of used devices. However, companies try to encounter this uncertaintyby applying the best strategies. One way to ensure customer is to offer devices with warranty. However, warranty is would be effective when involved by upgrade strategies such as remanufacturing and refurbished. These strategies help companies to improve the reliability of used products, which make customers to trust inthe appropriate quality of devices.

In this paper, we attempt to evaluate quantitatively the impact of choosing three strategies on warranty costs, and the profitability of companies. We want to know if the profitability of remanufacture and refurbished products can compare to new products for the organization. The structure of this paper is as follow: In the second part, we review the literature. The third part contains our methodology and introduces our case study. The part four includes results and discussion. Our conclusion and managerial implication discussed in the last part.

2. Literature review:

In the industrial world, we observed the significant growth in electrical and electronics equipment (EEE) industry. Wastes of EEE that usually refer to e-waste is an important question due its harmful problems on humans and environment (Li and Tee, 2010). In Today's situation, the question is not how to reduce waste but the important thing is how to make it profitable (Hatcher, Ijomah and Windmill, 2014).

In recent years, protecting the environment is a significant issue for many countries. One way to ensure the sustainability is to develop product recovery strategies. Reuse is one of the most efficient strategies, which protect natural resources as well as preserve the product's functional attributes (Lu and Yu, 2013).

In most time, Customers are uncertain about usage and maintenance history of the first use that put them in uncertain situation, to ensure customer on quality, countries enacted some laws and strategies to protect customers through mandatory warranty requirement (shafiee and chukova, 2013). These strategies cause a lower price, reducing production degradation to control failure rate (Lu and Yu, 2013).

However, Warranty results in additional costs. These costs might reduce through upgrade actions that improve the reliability. These upgrading actions contain some reuse strategies. Reuse is not a new concept, reuse strategies has been an increasingly common industrial activity since the Second World War,

Due to the awareness of its benefits and its role in changing society, interest on these concepts is growing (Hatcher, Ijomah and Windmill, 2011).

One of the most important industries among EEE is the medical industries. Developing new technology is the most important motivator on medical devices. The speed of technology progress is rapid. There is a large pressure on medical institutions to care the patient in best way in the lowest prices as well as reducing technologic gap between superior and underdeveloped equipment. To concern all issues above and to control waste, refurbish and remanufacture strategies introduces for medical devices to ensure customer on two dimension quality functionality and reliability (Anityasari et al (2007)).

The remanufacture of medical devices has recognized as a strong market and a growing market respectively in USA and Europe. In developing countries, third party do remanufacturing due to achieve financial and environmental opportunities (chenetal, 2014).

Remanufacture is the process of returning used device to better or original specification with warranty to match (Ijomah, 2007). The detailed description of remanufactured process could find in (Ijomah, 2007;Seitz and Wells, 2006;Sundinetal, 2005).

The remanufacture is greatly preferable because of economical and ecological advantages, and its potential to satisfy the customers' needs and profits, (Ijomahetal, 2007, chenetal, 2014, US. International Trade Commission, 2012).Despite many costs and work spend for manufacturing but the result is better quality product and a longer life in use(Hatcher, Ijomah and Windmill, 2011). Fortune Magazine reported that top ten firms among many industries(such as Honda, Goldman Sachs, Continental Airlines, etc) that use remanufactured strategies to carry out their environmental responsibility.

US as the largest producer, consumer and exporter in this field reported increasing in remanufacturing value of US by 15% to at least $43.0 billion between 2009- 2011, which support 180,000 full-time U.S. jobs. U.S. exports of remanufactured products totaled $11.7 billion in 2011(US. International Trade Commission, 2012, Japke and Onome 2009).

There are many research on remanufacturing, Charter and Gray (2008) works on remanufactureability that have an effect on the feasibility and profitability of this business strategy. Some research also focus on environmental effects of remanufactureability such as: Amaya et al., 2010; Gutowski et al., 2011, Lindahl et al., 2006;Nasr and Thurston, 2006). And other research wanted to know the effect of remanufacture on profit and price(Webster and Mitra, 2007, liang etal,2009, Subramoniam et al., 2009, Hatcher, Ijomah and Windmill, 2011, pakhorelliang, 2012, Xiongetal, 2013).

The remanufactured medical device sector is one of the triple parts of the extensive industry for pre-owned medical devices that divide into refurbished, remanufactured and no change categories (US International Trade Commission, 2012). Refurbished medical devices are consistent with the original product characteristics and service procedures and endure any upgrades. Refurbishment is determined as restoring a good to its original properties. Refurbished medical devices could have ranged from substitution of basic wear parts to a near complete end-to-end remanufacturing process (SCIRP insight, 2011).

In refurbished medical devices, the global market is expected to observe 14.0% rising from 2011 to 2016 and reach, $4.4bn in 2016 and US explain over 46% of total and the rest

of the world in about 29% of income in 2010. It is estimated that other countries (such as India, Russia, and Mexico) reported 35% of total income generated in 2016(SCIRP insight, 2011).

To ensure customers, some institution all over the world impel companies to do the specific steps (Healthcare IT Industry (COCIR, 2009), Global import regulation(2006), Japan IndustriesAssociation of Radiological Systems (JIRA), and Medical Imaging and Technology Alliance (MITA, 2012) and offer warranty to sell such products(See detailed process in SCRIP, 2011, pp 19).

As we considered the refurbished process, we could see that there are some research that cover this topic as"repair strategies, upgrading actions, maintenance models and recovery options". Shafiee and chukova(2013) , review all maintenance models that use for products with warranty. Shafiee etal (2011) review different kinds of upgrading strategies for used products as: replacement, minimal repair, imperfect repair and imperfect repair. Koh et al. [8] derived an optimal ordering and recovery policy for the reusable items (2002).Chattopadhya and Murthy (2004) provide optimal reliability improvement for used items sold with warranty. Shafiee et al (2011) introduce improvement factor approach that use in reliability improvement programs for second hand products.Saidietal(2010) introduce Modeling and analysis of effective ways for improving the reliability of second-hand products sold with warranty. In addition, Li and Tee (2012) present a Model for recovery options of e-waste.

To come back to our major concern, it is important to note that although the definitions of remanufacture and refurbishment are less strict in the USA, in EU, definition 'remanufacture' and 'refurbish' have different meaning when applied to medical devices.

When a medical device is refurbished, it is repaired, cleaned and updated to relevant safety standards. However, the remanufactured products are 'better' than a new device. The repair and upgrading in remanufacturing is beyond its original condition (SCRIP insight, 2011).

Such comparisons between strategies have been done in some researches, as Klausne and Wolfgang (1999) illustrated that the substitution of reconditioning with remanufacturing would result in a higher service level in product's repair (Urvashi, etal 2013). Contrast to previous investigations of durable goods markets that ignore the possibility of a retailer-profitable secondary market, Shulman and Coughlan(2007) show conditions under which the manufacturer would optimally choose to sell no new goods in the second period.

Shan etal(2012) compare the pre owned seating delivery to new one for children with disabilities, the results shows that there is an economic benefit to having a wheelchair recycling program as opposed to purchasing numerous new wheelchairs and equipment for children with disabilities.

Nenes et al(2010) compare alternative policies needs both new products and returns of used products by computing the expected cost of each policy and choosing the best policy. Chung and Wee (2011) by considering new technology evolution, studies the remanufacturing ratios and system's costs as a critical factors, which affect decision-making.

By considering the previous research, it seems that quantitative comparison between the effect of three strategies (selling new, refurbished and remanufactured products) on third parties companies is missing. Third party companies often work in developing countries to offer remanufactured or refurbished products which covered by warranty. Their focus is on

providing the best standard as well as lowest cost with that have potential opportunities for their financial and environmental savings. This paper tries to understand the real effects of strategies on profitability of such companies.

3. Methodology

In this paper, we aim to determine the effect of choosing remanufacturing and refurbished strategies on warranty cost and company's profitability. The warranty cost has estimated by existing model in literature and all products considered under FRW warranty policy. The company that we selected is a leading firm in IRAN that works as a third party or importer. This helps us to assess all factors related to buying, reconditioning and selling products. For this purpose, the failure data of 60 medical devices of a leading company has analyzed from 2012 to 2013. For each strategy (remanufacturing, refurbished and new products), 20 devices were selected and monitored over a year. The selected products were similar in usage to minimal the impact of function differences.

First step to calculate the profitability of each device is to compute costs before and after sales. The costs of new, refurbished and remanufactured products are different for Third Party Company; however, all products have the same fixed costs. The table 1 shows the item costs related to remanufacturing and refurbished process. Table 2 indicate the related costs which provided by accounting department to compute profitability. Table 3, present the result of warranty costs after upgrading actions calculated by applying Shafiee model(2011). Finally, weshow the profitability of each item in table 4.

Table 1 shows the item costs for remanufacturing and refurbished process. In our analysis, we use the total cost of items as a remanufacturing and refurbished cost. These

items was considered as literaturereview(SCRIP insight, 2011, Healthcare IT Industry (COCIR), Japan Industries Association of Radiological Systems (JIRA), and Medical Imaging and Technology Alliance (MITA), 2012) and the repair/ service manual of products. These items help us to computing remanufacturing and refurbished process cost which indicate in table 4.

Table1: the item costs for remanufacturing and refurbished process

Remanufacture	Refurbish
• Cost of skilled labor-engineers; • Cosmetic change; • Material for complete repair; • Cost related to replacement of critical parts with new one; • Adding enhance features/new parts	• Cost of unskilled labor- technicians; • Cosmetic change; • Materials for cleaning and minimal repair; • Costs related to control the function of critical parts.

As we considered before, customer are uncertain about functionality and reliability of used products although they know some upgrading actionshas taken on products. Offering warranty provides assurance to customers, that is the signals for product reliability. For estimating warranty cost for new products we use Chadopadhay and Murthy model (2000).For estimating warranty cost, we use model existing literatures that help us to add the cost of remanufactured and refurbished costs to warranty costs (Shafiee, 2011, saidietal 2010).

To estimating warranty cost for used products with age x sold under FRW, we have (shafiee and Chukova, 2011):

$$E[c_w(x,p)] = \overline{c}\, E[N_w(x,p)] \quad (1)$$

Where $\overline{c}$ is the expected cost of each repair strategies over the warranty period, and

$E[c_w(x,p)]$ is the expected number of claims over the warranty period given by

$$E[N_w(x,p)] = p \int_0^w \lambda(t)dt + (1-p) \int_0^w \lambda(t+x)dt$$
(2)

Where we have warranty period of [0, w] on which $\lambda(t)$ is for remanufactured process (upgrade perfectly) and $\lambda(t+x)$ is for refurbishedone (upgraded minimally).

The expected profit (EP) consider the remanufactured/refurbished costs $(c_p(x))$, the warranty cost $(E[N_w(x,p)]$, fixedcost (F), cost of buying used products (C_x) and the sale price(S) given by :

$$EP = S - C_x - c_p(x) - F - E[N_w(x,p)]$$
(3)

In the following tables, we review the results: Table 2 represent the parameters for calculating warranty costs after upgrading actions. In Table 3, we estimate warranty costs for new, refurbished and remanufactures products. In addition, Figure 1 shows an illustrative comparison between warranty costs of three options.

Table 2: the parameters for calculating warranty costs after upgrading actions:

	1. new	**2.refurbished**	**3.remanufactured**
Warranty policies	FRW	FRW	FRW
Terms of warranty	W=1, 1.5 , 2	W=1, 1.5 , 2	W=1, 1.5 , 2
Past age	0	x= 2, 3,4	x=2, 3,4
Parameters of the weibull distribution	$\beta = 1 , \lambda = 0.3125$	$\beta = 2 , \lambda = 0.188$	$\beta = 1.5 , \lambda = 0.370$

Table 3: Estimating warranty costs for new, refurbished and remanufactures products:

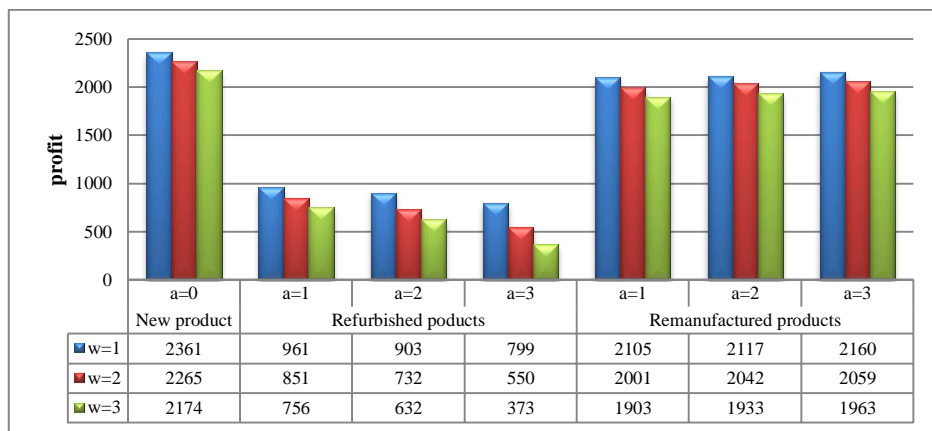| Warranty period	New product	Refurbished products			Remanufactured products		
		a=1	**a=2**	**a=3**	**a=1**	**a=2**	**a=3**
w=1	239	289.2	347	451.1	274.9	262.9	220
w=2	335	398.7	518.2	699.6	378.6	338.4	321
w=3	426	494.2	617.7	877.1	477.1	447.3	417
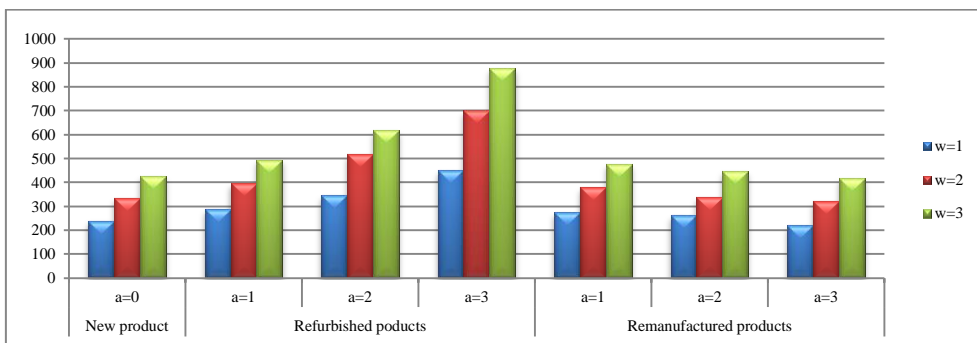
Figure 1: illustrative comparison between warranty costs of three options

Table 4 shows the other costs related to products that help us to compute profitability. The accounting department of company analysis the item costs and provides the total cost of each item to our studies. As we considered the cost of upgrading action, (remanufactured and refurbished process) is the total cost of items presented in table 4.

Finally, we calculated the profitability for each device. With the aid of table 3 and table 4, we represented profits. Figure 2 shows a summary of profitability results. In the next part, we discuss more about these figures.

Table 4. Other costs related to three options ($)

Item costs	1. New	2. Refurbished	3. Remanufactured
Fixed costs	800	800	800
Cost of advertising	500	700	700
Cost of buying products(new or used)	6100	4000	4000
cost of refurbishing process	0	250	250
Cost of remanufacturing process	0	0	370
Total cost	7400	5750	6120
Sale price	10000	7000	8500

	a=0 New product	a=1	a=2 Refurbished poducts	a=3	a=1	a=2 Remanufactured products	a=3
w=1	2361	961	903	799	2105	2117	2160
w=2	2265	851	732	550	2001	2042	2059
w=3	2174	756	632	373	1903	1933	1963

Figure2: profitability results

4. Discussion

In this paper, we aim to comparing the result of profitability between used and new products under three strategies (buying new, performing refurbish process and do remanufacturing upgrade). In our studies, we choose a third-party/importer company to have thoroughly knowledgeable about all obstacles and costs of used products in developing countries. As we noted before, one way to fill the technological gap between developed and developing countries in medical technology is to apply engineering methods and upgrading actions to provide patient with the best services as well as reasonable cost

According to Figure 1, regardless of choosing which strategy, warranty costs increased by rising the warranty period. This indicates the importance of selecting warranty period wisely because it has a direct impact on total costs and profitability. Table1 shows insignificant differences between warranty costs of new and remanufactured. As we said in part 2, the remanufactured products attempt to offer "like new" functionality that means it cause reducing failure rate that effects on reliability improvement, total costs and profitability.

As outline by the table 2, the warranty costs of refurbished products have significant increase in products with age three. This displays that although warranty costs of refurbished products with the one-year past age increase about 20 percent, when the past age rise to three, we could observe increasing in cost about 60 percent. This emphasizes that in used products with higher past age; companies should imply stronger upgrade strategies such as remanufactured.

Table 4 shows a list of other costs related to products, which have effects on profitability. The fix cost for all products are the same, these costs contains administrative, warehouse, rent, depreciation, utilities, taxes and others. The accounting department was responsible for computing theses costs and has given to us to use in our analyses. What needs to more discussion here is advertising costs. The current strategy of company is to perform more advertisement and promotion for used products, as we mentioned in section 1, some customers are uncertain about the quality and history of used products. Therefore, to enjoy the advantages of used products companied should spend more money on advertising of used products to attend customers and satisfied their needs.

Figure 2 summarized the result of calculating profit. Based on figure 2, the refurbished products have the least profitability. This is due to the higher costs of these products that increase by rising past age. The important concern here is the comparable profits in remanufactured products and new products. As figure 2 indicates there is insignificant differences between the profitability of new and remanufactured products. This approve the literature claim that remanufactured has economical advantages. The reason for the good profitability of remanufactured products is performing standard upgrading action which help used products to have the same function as new one. In the last part, we conclude our studies and try to show our limitation as well as some point that help manager to make proper decision.

One way that companies could increase their benefits as well as preventing e-waste is to employing modern strategies for used products. Among the broad industry for used medical devices we had a comparative view between two upgrading strategies named refurbished, remanufactured. We wanted to understand the different economical benefits that choosing three strategies (buying new, performing refurbished or do remanufacturing)could have for third-party/importer companies. For this purpose, all technical and financial dataof 60 medical devices of a leading company has studied in a year (2012-2013). The similar products selected to decrease the functional differences.

The results demonstrate no specific differences between warranty costs of new and remanufactured products which means the remanufactured products could offer "like new" functionality that ensure customer about quality and reliability of products. The outcomes also reveal that the warranty costs of refurbished productshave significant increase

by increasing past age of used product. Management should be aware that in such situation they should employ better upgrading strategies like remanufacturing, if not, it could suffer their profit in a long time.

Our results also imply no significant differences between the profitability of new and remanufactured products. This could have important contribution for companies that face difficulties such as shortage of capital. Companied in developing countries can apply used products while performing upgrading strategies as well as skilled workers to attract customers and benefit from economical profits. This is necessary,specially,for medical field to provide the best services that help national health and welfare.

Our paper works on medical devices and filed that other researches could assess the benefits andeffects of these upgrading strategies on other industries. In addition, we study a third –party/importer Company in a developing countries. Other researcher could examine the impact of these approaches on developed and underdeveloped countries to understand more about this market. Furthermore, they could offer someanalyses in otherperspectives (customer and manufacture) to fullyrecognize the advantages and disadvantages of employing such products. Other studies could observe the effects of marketing on customer attraction. Finally,otherscould consideradditional costs such as lost opportunity costs to determine the risk parameters and enter them to the existing models.

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