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The effect of reliability improvement actions and providing warranty policy type LIC and FRW/LSW on price range of used devices

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Abstract

Access to new products and also buyers' requirements to specific technologies have become more difficult because of the low purchasing power of some consumers, some sanctions and political issues in the world; these cases have caused noticing to second-hand market. Product warranty and performance guarantee are also the cases to attract customer and gain his/her trust. Buyers' hesitant on proper functioning of these products has encouraged vendors to perform reliability improvement actions and provide valid warranties to gain their confidence. The effect of reliability improvement actions and providing warranty policies limited on individual cost (LIC) and free replacement warranty /repair warranty/ lump sum warranty (FRW/LSW) on the price range of two types of used laboratory equipments of Mehr Abrar Company will be surveyed. This research is an applicable type that after consistency of failure rate function with exponential function has been used for estimation of warranty cost from available models in the literature. Warranty cost was also calculated after reliability improvement actions with hybrid approach of virtual life, minor-full repair; and then determined by using cost data of accounting department in price range of each device. Statistical society consists of all failure data of cell counter and biochemistry devices of Mehr Abrar Company in the period of four years.The results show that after performing reliability improvement actions, period warranty costs are reduced; and this affects on total costs and devices price per unit. For vendor, the cost of LIC policy is more than FRW/LSW warranty, this is because that a higher price ceiling has been considered. However, FRW/LSW policy in long-term and LIC policy in short-term can help the vendor to provide his/her product.

Keywords: Used product, warranty policy, free replacement warranty /repair warranty/lump sum warranty (FRW/LSW), reliability improvement operations, industrial management.

Introduction

Reusing products is one of the best ways to protect environment. While maintaining natural resources also saves the costs of new productions and prevents discarding the used products as wastes (Hobi *et al*, 2010). Besides, new products in markets with higher technology and better performance lead to increase longevity of products. As a result, sale of a new product is often an ongoing process and this has led to creation of used market. Second-hand product is a product which was used previously by one or several consumers and now is purchased by other consumer for specific reasons (Shafiee, 2010). On the other hand, sometimes because of the low purchasing power of some consumers, some sanctions and political issues in the world access to new products becomes more difficult. Previous studies on buying used products indicate two main results (Williams and Paduk, 2003): first, low purchasing power that has started from 80's causes the tendency toward purchase of these products, secondly, the specific and superior characteristics of some used products (like antique) and the existence of distinct purchasing and distribution canals such as charity bazaar , internet and etc creates a perception of some features in used products to make their re-production difficult or impossible (Gute and Rox, 2010).

During recent decades, used products have been traded internationally. This trade includes the most products in developing country (Dora PA, 2002; Lyne *et al.*, 2007). Poor performances, consecutive failures, lack of appropriate guarantee and in some cases theft or smuggling of used product make buyers

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doubtful about them. Vendors tried to restore all lost customers' confidence by providing written contract and valid warranties. By competition, more sophisticated technologies and reducing the purchase power of new products, more buyers turned to used markets and vendors adopted remanufacturing for buyers' satisfaction. Over time, governments and countries have welcomed this case and provided rules and regulations for remanufacturing of different devices and the conditions of providing warranty to second hand product. According to conducted researches, 85 percent of second hand parts are usable and the quality of remanufactured parts can be even known equal to new parts by reliability improvement actions (I Jumah, 2008).

Useful lifetime of used devices can be improved upgrading actions so; they can be appropriate alternatives to buy new products. The characteristics of a warranty can be expressed by looking at the articles (Jack and Ston,2000; Murthy and Djamaludin, 2002; Murthy and Blischke, 2005; Karim *et al*, 2005; Shafiee, 2011) as follows:

- A warranty agreement is a commitment, guarantee or trust from warranty provider (manufacturer or vendor) to buyer.
- This commitment results in warranty provider's responsibility towards product failure and its proper function.
- Warranty is offered for a specified period and conditions.
- Warranty is delivered to buyer during the sale in form of oral or written.
- The conditions for failures compensate and the kinds of responsibility are listed in warranty.

Quantitative studies on warranty of used products and their costs modeling have been conducted by researchers, among them Morti and Chattopadhay (2000,2001,2004); Pongpech *et al* (2006); Rahman and Chattopadhay (2006), Shafiee (2010) and Yeh *et al* (2010) can be mentioned. These researches rely more on costs modeling of different policies regarding warranty and most of them have been conducted with engineering view; they are following the optimal warranty policy for sale price and warranty period. However, it should not be forgotten that customer impacts on purchasing process and the optimality of studies has always been from seller's viewpoint. Bargain has high importance in competitive market and seller should provide the bests to customers. This research offers a price package by applicable use of models and policies which help managers to offer prices and conditions to customer with proper understanding of cost and profit rate of it; they are fully aware of future loss result from discounts.

This industry except from vehicle is used in heavy machinery, medical equipment industry and laboratory industry. In a market where buyers are looking for accuracy and exactness of devices, good quality and inexpensive articles should be used which result in proper results. Remanufacturing global number one used devices in addition to high quality results increase internal engineering ability of the country in repairing and designing similar products. Understanding buyers' doubtfulness in used product causes suppliers to attract customers in this market by doing improvement actions and providing reliable warranty. The research goal is to identify warranty costs for two types of used laboratory products of Mehr Abrar Company by using existing frameworks and model and investigate the impact of upgrading acts on them. For this purpose, two limit individual cost and compound policies (FRW/LIC) are surveyed. This research determines price range by calculating the costs before and after the sale and allows vendors to provide various options to the buyers and consider profit rate properly in each condition.

Research Questions

This study tries to answer the questions:

1- What are the effects of upgrading actions on the price range of used devices of Mehr Abrar Company?

2- Are the upgrading actions effective on estimating the costs of two types of warranty policies (LIC, FRW/LSW)?

Research Objectives

This study seeks to investigate the effect of upgrading actions on estimating the costs of two types of warranty policies (LIC, FRW/LSW) and the effect of upgrading actions on price range of used devices of Mehr Abrar Company.

Methodology

This research is applicable in regard to results, compound in research performance process, descriptive and then analytical in research goal.

After compatibility of failure rate function with exponential function in this research, the existing models in literature have been used for estimation of warranty cost. Statistical population including all failure data on two types of used laboratory devices " cell counter and biochemistry" of Mehr Abral Company which both are used for testing blood test results in period of four years. To determine the price range, first it is necessary to calculate the product cost per unit. These costs in-

clude the costs before and after the sale. The costs before the sales include device purchase costs, transportation, administrative and technical, human resources cost and reconstruction operations costs which prepare used devices for sale. When selling, also a warranty will be given to customer to ensure him/her from proper functioning of the device. This guarantee (warranty) itself requires costs that in future will be imposed to the company.

Theoretical basis of research

After management consulting in this study, two policies have been selected which can help services after the sale, they include:

1- FRW/LSW compound policies: Vendor will have two warranty periods in this policy, repair / replacement of parts and other expenses in the first period has no cost to buyer (FRW) but after that buyer will participate in cost with a fixed proportion (LSW).

2- Limit on individual cost: In this policy, each downtime cost is shared between vendor and buyer. Vendor deals with all failures during the warranty period, if repair/replacement of parts is less than a specified rate (c_1), the total cost will be obliged by vendor but if it is more, its marginal cost and c_1 rate should be paid by buyer.

Also, after consultation with technical and management part, combination approach to virtual life and minor/ full repair are used for upgrading actions which cover both characteristics of these approaches. Virtual life is a multiple of product current life which is effective on product current life if upgrading actions are efficient. The assumption in minor/full repair is that the percentages of used products are placed under full repair and the others under minor repair.

A - Estimation model for FRW/LSW compound warranty cost

It is assumed that warranty period is equal to fixed value *w* and starts immediately after the sale; and $N(w,a)$ is equal to the number of failure in second- hand product with life *a* in warranty period *w*. Also, Cumulative failure distribution of the item is as $F_T(t)$ and its Density function is equal to $f_T(t)=\frac{dF_T(t)}{dt}$. In this policy, vendor is responsible to repair all failures of used product freely in the time of w_f; and in time range of w_f to w with receiving the percentages of repair/replacement costs from consumer. Refund function in this policy is as follows (Shafiee, 2010):

$$R(t)=\begin{cases} c_r(a) & 0\le t<w_f \\ kc_r(a) & w_f\le t\le w \\ 0 & t>w \end{cases} \quad (1)$$

Accordingly, the average vendor cost in warranty period will be equal to:

$$E[c_d(w,a)]=c_r(a)\frac{F_1(w_f)}{1-F_1(w_f)}+kc_r(a)[F_1(w)-F_1(w_f)] \quad (2)$$

In which $c_r(a)$ is the average cost of replacement of defective part with a used part with life time *a*. This cost is obtained by the following equation in which c_r indicates the cost of replacement with a new item and L the expected lifetime of the new item.

$$c_r(a)=c_r\left[1-\frac{a}{L}\right] \quad (3)$$

B - Estimation model for warranty cost on the basis of limit on individual cost

If intensity function is equal to $\Lambda_T(t)=\frac{f_T(t)}{[1-F_T(t)]}$, the average number of product failures in warranty period will be equal to (Morti and Chattopadhay, 2000):

$$E[N(w,a)]=\int_a^{a+w}\Lambda_T(t)dt \quad (4)$$

The assumption is that: $\bar{c}_d$ is the average cost paid by vendor and $\bar{c}_b$ the average cost paid on individual cost by buyer. So, the average vendor costs in warranty period are equal to:

$$E[c_d(w,a)]=\bar{c}_d\int_a^{a+w}\Lambda_T(t)dt \quad (5)$$

Similarly, the average consumer's cost in warranty period is equal to:

$$E[c_b(w,a)]=\bar{c}_b\int_a^{a+w}\Lambda_T(t)dt \quad (6)$$

Individual cost can be considered as a fixed or random variable.

C- Warranty cost due to upgrading actions

Below, a model is selected that is a combination of two approaches to virtual lifetime and minor-full repair. If $E[N_w(a,u)]$ represents the number of compensation claims incurred in one used product with lifetime a and promotion level of u in warranty period w, therefore, it will be (Shafiee, 2010).

$$E[N_w(a,u)] = \frac{\theta_1}{\theta_1+\theta_2}\int_0^w \Lambda_T(t)dt + \frac{\theta_2}{\theta_1+\theta_2}\int_a^{a+w} \Lambda_T(t)dt \quad (7)$$

In which $\frac{\theta_1}{\theta_1+\theta_2}$ is total productivity coefficient for revival used devices. It means that θ_1 is the number of devices ready to sell after upgrading action and $\theta_1+\theta_2$ is total number of used devices. Thus, the average vendor cost for used product with longevity *a* in the condition of doing upgrading action in warranty period is equal to:

$$E[c_w(a,u)] = \bar{c}E[N_w(a,u)] \quad (8)$$

Statistical population includes failure rate data of all cell counter and biochemical devices of Mehr Abrar Company that 30 cell counter and 50 biochemical devices were analyzed from 2008 to 2011. Goodness-of-fit test was performed on both of these devices.

In cell counter devices, the rate of computational χ^2 was equal to 2.505 and also the critical value of χ^2 in the table in meaningful level of 5 percent and free degree of 4 equal to 9.487 which accordingly exponential assumption is not rejected. Failure rate of this device is equal to 0.244 per month. The rate of computational χ^2 in biochemical device was equal to 7.29 that the critical value of χ^2 in the table in meaningful level of 5 percent and free degree of 5 is equal to 11.075 which accordingly exponential assumption is not also rejected in this device. Failure rate in biochemical device is equal to 0.2014 per month. In the policy FRW/LSW, the company wants to improve all devices failures up to half the warranty period ($w_f = 0/5$) with free repair/replacement policy and then to the end of the warranty period with receiving half of the repair/replacement costs ($k = 0/5$) from buyer. The average cost of replacing each item in cell counter due to available documentations was considered $ 65.253 and in biochemical device $ 122.35; and then the cost of this policy calculated.

For policy LIC, due to analysis of cost data in these four years, cost of failure elimination may have been increased to $ 97.88 or $122.35 because of improper use of device, improper repair, applying unauthorized craftsmen or price increase on the items and other expenses. By negotiating with company managers, it is interpreted that the cost of $ 81.566 is the maximum extent that Mehr Abrar Company can incur to eliminate each failure. Also, this maximum cost has been considered $ 163.132 in biochemical device that for the reasons mentioned above can be increased to $ 187.602 - $ 203.915. Regarding the above costs, the costs imposed on buyer and seller are calculated. This cost is recalculated due to: combination approach of virtual lifetime and minor-full warranty cost. Documentations have been used to calculate total productivity coefficient for revival used devices. According to experts' and specialists' viewpoint in the engineering sector, productivity coefficient for revival in used product has been determined 0.75 for cell counter device and 0.60 for biochemical device in this study.

Three periods of one year, one year and half and two year warranties and devices previous longevity were chosen two, three and four years to calculate warranty costs for cell counter device. Also, four periods of one year, one year and half, two years, two and a half years have been considered for devices with three, four and five years previous longevity to calculate warranty costs in cell counter device. Previous longevity of devices was determined due to documentations and warranty period according to manager's and customers' viewpoints, so that the results reflected the facts.

Results

Computations associated with the policy FRW/LSW

As regards failure distribution function follows the exponential distribution, the average vendor costs (USD) have been obtained for cell counter and biochemical devices in the tables 1 and 2.

Table 1. Average annual vendor costs with the policy FRW/LSW for cell counter devices

Previous lifetime / Warranty period	a = 2	a=3	a=4
W=1	73.935	95.081	121.946
W=1.5	103.509	131.646	170.725
W=2	131.605	169.245	217.065

Table 2. Average annual vendor costs with the policy FRW/LSW for biochemical devices

Previous lifetime / Warranty period	a = 3	a=4	a=5
W=1	189.510	219.115	281.592
W=1.5	264.179	306.750	394.228
W=2	336.690	390.173	501.233
W= 2.5	397.971	460.141	591.343

As it is clear in this policy, average warranty costs are increased by increasing warranty period and product's previous lifetime.

Computations associated with limit on individual cost

Average vendor cost and average buyer cost for cell counter device were shown in table 3 and 4:

Table 3. Average annual vendor and buyer costs plus a cost equal to $ 16.313

Table of average annual vendor costs				Table of average annual buyer costs			
	a=2	a=3	a=4		a=2	a=3	a=4
W=1	141.304	180.352	230.192	W=1	19.963	25.480	32.542
W=1.5	162.610	203.263	254.078	W=1.5	28.261	36.071	46.039
W=2	178.025	227.222	290.013	W=2	356.901	45.445	58.003

Table 4. Calculation of annual vendor and buyer costs plus a cost equal to $ 40.783

Table of average annual vendor costs				Table of average annual buyer costs			
	a=2	a=3	a=4		a=2	a=3	a=4
W=1	141.304	180.352	230.192	W=1	49.909	63.700	81.452
W=1.5	162.610	203.263	254.078	W=1.5	70.652	90.176	115.097
W=2	178.025	227.222	290.013	W=2	89.012	113.611	145.007

Average vendor cost and average buyer cost for biochemical device have been shown in table 5 and 6:

Average costs in this policy as in previous policy are increased by increasing warranty period and product's previous lifetime for each device. The difference between this method and previous policy is that here a maximum is determined for undertaking the cost by the company, if for any reason the costs exceed this maximum; the remaining cost will be paid by customer. As it is clear in the above tables, whatever extra cost is more; the share of buyer cost goes higher. This issue is shown in the figure 1 and 2 for three-year devices.

Table 5. Calculation of annual vendor and buyer costs of biochemical device plus a cost equal to $ 24.47

Table of average annual vendor costs				Table of average annual buyer costs			
	a=3	a=4	a=5		a=3	a=4	a=5
W=1	282.687	328.241	421.861	W=1	42.403	49.237	63.279
W=1.5	395.762	459.550	590.604	W=1.5	59.364	68.932	88.591
W=2	503.183	584.285	750.911	W=2	75.477	87.643	112.637
W=2.5	593.643	689.325	885.908	W=2.5	89.046	103.399	132.886

Table 6. Calculation of annual vendor and buyer costs of biochemical device plus a cost equal to $ 40.783

Table of average annual vendor costs				Table of average annual buyer costs			
	a=3	a=4	a=5		a=3	a=4	a=5
W=1	282.687	328.241	421.861	W=1	69.965	81.241	104.410
W=1.5	395.762	459.550	590.604	W=1.5	97.951	113.738	146.175
W=2	503.183	584.285	750.911	W=2	124.538	144.610	185.850
W=2.5	593.643	689.325	885.908	W=2.5	146.927	170.608	219.262

Calculation of warranty cost according to reliability upgrading actions

Warranty costs after improving measures for cell counter and biochemical devices are shown in the tables 7 and 8.

In the figure 3 and 4, a comparison was done between the costs before and after warranty that indicate reduction in warranty costs after upgrading actions.

It should not be forgotten that improving measures will be effective when result in reduction of future costs.

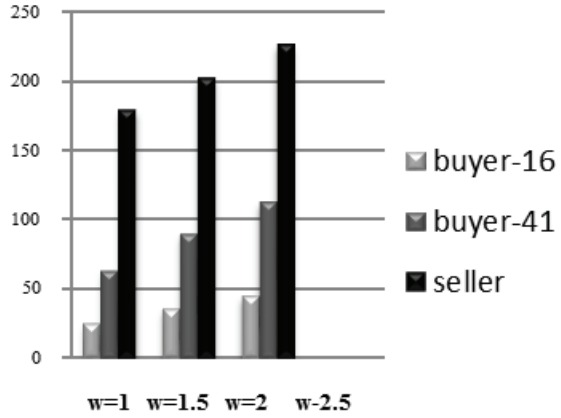

Figure 1. A comparison of buyer's cost in two extra cost conditions (Biochemical)

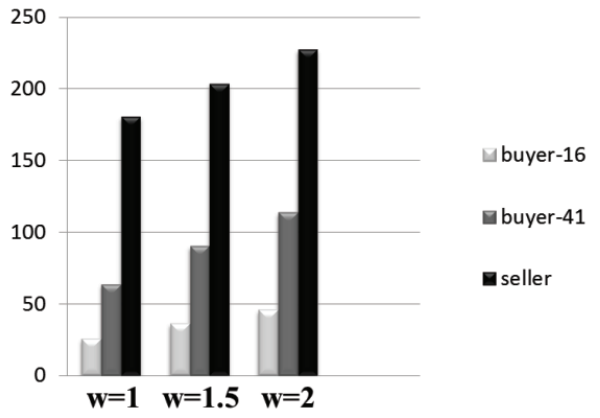

Figure 2. A comparison of buyer's cost in two extra cost conditions (Cell counter)

Table 7. Warranty cost (USD) after improving measures (cell counter)

Device type	Previous lifetime / Policy type	a=2			a=3			a=4		
		W=1	W=1.5	W=2	W=1	W=1.5	W=2	W=1	W=1.5	W=2
Cell counter	FRW/LSW	68.299	95.529	121.542	89.445	123.666	159.183	116.288	162.745	207.002
	LIC	133.324	167.96	248.441	172.372	197.626	217.159	156.973	222.212	279.950

Table 8. Warranty cost (dollar) after improvingmeasures in different warranty policies for biochemical devices

Device type	Policy type	a=3				a=4				a=5			
		W=1	W=1.5	W=2	W=2.5	W=1	W=1.5	W=2	W=2.5	W=1	W=1.5	W=2	W=2.5
Bio chemical	FRW/ LSW	145.073	202.235	257.743	304.654	167.737	234.823	298.685	352.248	215.564	301.790	383.704	452.685
	LIC	216.403	302.964	385.197	454.446	251.276	351.795	447.282	527.692	322.943	452.120	574.838	678.181

Determining the price range

To determine the price range, in addition to warranty cost after improving measures that was calculated; other related costs including purchase, transportation, manpower, administrative and other costs will also be calculated and placed as a base for determining the price range. Since the price has no limitation in the market; managers have decided to calculate prices per unit based on per unit costs and the considered profit percentage and also due to different conditions, therefore, vendors can receive different bid prices and are aware of discount rate they can give. This can help to consider appropriate fees for vendors. The prices for three-year cell counter and biochemical devices according to different conditions are shown in the tables 9 and 10. Price limitation for cell counter and biochemical devices are mentioned in the tables 11 and 12, respectively.

For simpler check on the prices, the numbers have been rounded in both tables. Note that these prices are all proposed and done in per unit-level of product. Other studies should be done to calculate profitability in organization and to review major purchases.

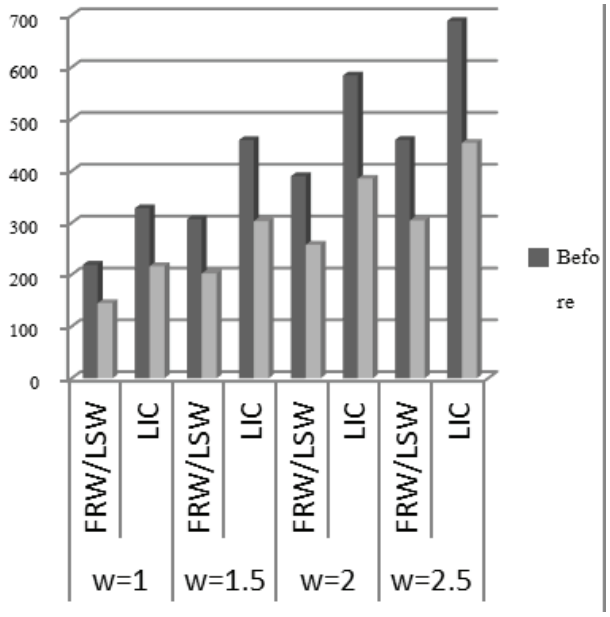

Figure 3. Comparison of costs before and after warranty (cell counter)

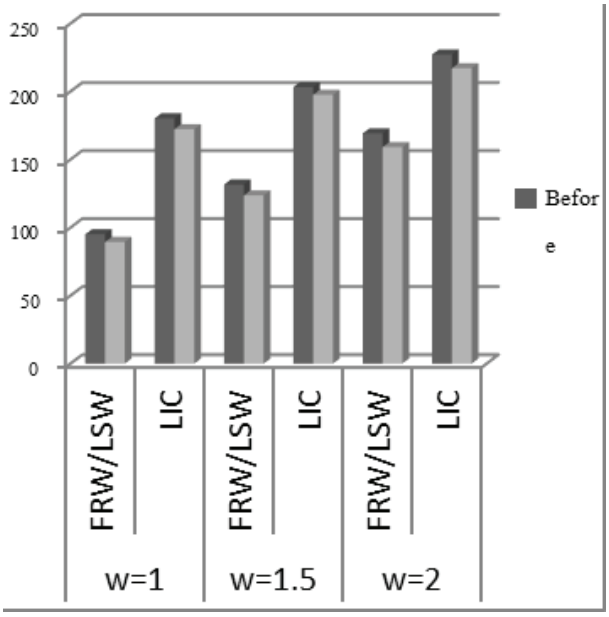

Figure 4. Comparison of costs before and after warranty (biochemical)

Table 9. Bid prices (USD) for cell counter device with three-year lifetime based on different profits

		Compound policy FRW/LSW	Limit on individual cost
10 percent profitability	W=1	12/235	12/398
	W=1/5	12/316	12/423
	W=2	12/349	12,480
15 percent profitability	W=1	12/830	12/887
	W=1/5	12/871	12/969
	W=2	12/887	13/051
20 percent profitability	W=1	13/377	13/458
	W=1/5	13/426	13/515
	W=2	13/458	13/622
25 percent profitability	W=1	13/866	14/029
	W=1/5	13/898	14/078
	W=2	14/029	14/111

Based on two above tables, the proposed price ranges for cell counter and biochemical devices have been presented in the tables 11 and 12.

Tables 9, 10, 11 and 12, each shows price limit of cell counter and biochemical devices. These tables provide an appropriate framework to managers that enable them with a proper look at the costs and optimal profitability rate to present a suitable price or discount to customer. Accordingly, managers or sale sectors have a framework to understand price limit and profitability rate properly in each price. In addition, customer can be directed to more lifetimes' warranty because of low price difference. Now, the company sells cell counter device in $ 13.866, so, data in above tables show 25 percent profit. The percentage that can be considered by company managers. Also, the current price of the device ($ 28.548) is based on the data in the tables above and the current profit on biochemical device sale is about 20 percent. In regard to the importance of devices, these numbers indicate that managers should not only rely on the sale price. While, the price of biochemical devices is almost double of cell counter devices, the current profit results from cell counter per unit is higher than other device that can be effective in long term. Numbers in the tables 9 to 12 help in determining the sale price and discount rate to customer. It can also be a basis for fees to vendors. Accordingly, managers can estimate fees rate paid to vendors based on the sale price and the discount that

vendors give to customers; and vendors also can provide appropriate options to customers with higher flexibility. Sale price under $12200 in cell counter device is as fewer than 10 percent profitability and sale price under $ 25000 in each biochemical device as fewer than 5 percent profitability, thus, giving huge discount regardless of profitability in long-term can create large-scale losses for the company. Looking at the price range of devices based on their profitability, company managers should understand that importance criteria of devices is not just their sale price because this study indicates that despite of twice price in biochemical devices, the current profit of cell counter device per unit is higher than other which can be effective in long term and in high-scale.

Table 10. Bid prices (USD) for biochemical device with four-year lifetime based on the percentage of different profits

		Compound policy FRW/LSW	Limit on individual cost
10 percent profitability	W=1	25/000	25/082
	W=1/5	25/082	25/204
	W=2	25/122	25/285
	W=2/5	25/204	25/392
15 percent profitability	W=1	26/207	26/297
	W=1/5	26/281	26/427
	W=2	26/346	26/509
	W=2/5	26/427	26/591
20 percent profitability	W=1	26/406	27/488
	W=1/5	27/488	27/569
	W=2	27/569	27/651
	W=2/5	27/651	27/732
25 percent profitability	W=1	28/548	28/711
	W=1/5	28/711	28/793
	W=2	28/752	28/915
	W=2/5	26/362	29/005

Table 11. The proposed price range for cell counter device with different warranty policies

	10 percent profit	15 percent profit	20 percent profit	25 percent profit
Price (USD)	12200-12500	12800-13100	13300-13600	Over 13800

Table 12. The proposed price range for biochemical device with different warranty policies

	5 percent profit	10 percent profit	15 percent profit	20 percent profit
Price (USD)	25000-25400	26000-26600	27400-27700	Over 28000

Conclusion

The results of this study shows that the cost of warranty policies is increased by increasing previous lifetime of the product and warranty period; this indicates that company managers should set warranty period and its conditions by proper understanding of costs and customers' expectations. The policy FRW/LSW is more suitable for conditions in which vendor offers monopolistic market or relative advantage than other products and also longer-term warranty period for customers' attraction. The costs of this policy in such condition help to maintain the customer and optimal profitability for longer period of time. It is necessary to note about this policy that the customer at first should be completely familiar with this policy to proper understanding of cost-

sharing payment. Limit on individual cost will be useful when the company seeks to resolve customers' disputes and complaints about the basic warranty. Sometimes, a cost beyond the usual cost is imposed on the company because of customer's negligence or extra manipulations. At this time, some companies claim that customer violated the warranty and should pay the money fully, in other hand, when the company is not very strong and should pay the price completely; the cost beyond the specified is imposed on company. Because the laboratory devices are large and bulky, they should be repaired in situ and the company is faced with many problems when receiving the cost; the future consequences can be avoided by using this policy and complete awareness of customer. To calculate vendor cost, the maximum cost has been considered higher than the average individual cost. So, it has higher warranty in comparison to another policy. When compound policy FRW/LSW is optimal that the company is going to have long-term connection with customer but the policy LIC can also resolve many customers' problems and dissatisfactions in short-term. Improving measures, with each goal is accomplished, will be useful when can reduce the cost in warranty period by influencing on failure rate of devices. Costs improvement rate in biochemical devices are far more significant than that in cell counter device which indicates the importance of upgrading actions in biochemical device.

The most important point in having price package is attendance at bargaining meetings. Having this framework, managers are well aware of costs and their profitability. They know what conditions should be announced that do not lead to their loss; and if customer is not satisfied with the proposed price, other available options with various prices and different conditions will be provided to him/her.

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