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Sustainability via Extended Warranty Contracts: Design for a Consumer Electronics Retailer

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Abstract: Warranty is one of the most important attributes of any product, from both manufacturer and consumer points of view. Although the retailers connect manufacturers to customers by selling goods, traditionally, they have isolated themselves from warranty-related matters such as customer complaints and maintenance costs. However, recent trends in consumer behavior toward extended warranty contracts have changed this approach. While retailers have started to generate considerable revenue from the sale of these contracts, sustainability is also achieved by longer product life cycles. This study analyzed the failure behavior of different classes of cell phone products and their related costs through a chain of consumer electronics retailer operating in Türkiye. To compete on pricing and customer service, a novel policy was designed for the retailer to honor the contracts in house rather than underwriting to a third party insurer as the industry standard. The maintenance records of 328 previous failures were analyzed to plot a failure model. Failure mode and effects analysis was carried out to identify failure classes and the respective costs for extended warranty design for cell phones. The expected warranty costs for coverage of the third, fourth, and fifth years of operation were determined. The results show that the retailer may achieve the same level of profit by increasing customer satisfaction along with the sustainability of the product through repair actions.

Keywords: extended warranty; cell phone sustainability; warranty costs

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1. Introduction

Warranty can be defined as a legal and binding contract between a manufacturer and a consumer (buyer) that a given product (or service) is as advertised and free of defects. Warranty contracts usually have many specific terms related to duration, coverage, and remedies. The terms of such contracts also differ based on the product type, origin (country) of sale, ownership situation, etc. Despite these differences, the interpretation of a warranty from the stakeholder perspective is stable. One of the stakeholders, governments, overview these terms and regulate them to protect consumers against safety hazards, as well as to minimize the burden on the judicial system for legal actions taken for breach of contract. Consumers consider the warranty an important dimension of a product that assures them that the product will be reinstated to fully functional form (through repair or replacement) in the case of a failure. The third and last group of stakeholders, producers, perceive a warranty as an important cost item involving both pre- and postsale activities. The design of a product with warranty considerations involves many foreseeable and unforeseeable factors, such as product/part analysis, recalls, and loss of reputation.

As a special category, extended warranty contracts are receiving increased interest in sustainability-conscious industries such as in the automotive and durable products industries. This interest has arisen strongly from both parties in the retail equilibrium. Since manufacturer warranties are limited to 1 year in many countries, and to 2 years for some exceptions, consumers are willing to pay a premium for the extra peace of mind. More than one-quarter of car buyers and three-quarters of durable product buyers purchase such extended warranty options [1]. Additionally, producers that directly offer extended warranties (such as Apple) or retailers that offer them in the form of hidden insurance make

enormous profits from the sale of such contracts. Estimates put such revenues at more than 30% of the total operating income for companies [2]. Independent of the stakeholder view, the sustainability of the product sold/bought becomes the core of the decisions made in the handling of extended warranties.

The extended warranties that are offered have various characteristics. They can be offered directly by the manufacturer or through retailer-managed programs in geographic regions where the presale handling of the product is carried out by local distributors instead of the manufacturer [3]. The time of sale of the extended warranty is also important. While most are sold at the time of product sale, in some markets, warranties are offered during a grace period starting from the product's purchase up to several months. This kind of grace period is found to be especially important in terms of consumer psychology, where willingness to pay is affected by the touch and feel of the product [4]. In addition to this complex nature of extended contracts, their design and pricing also require a multiobjective approach, where tradeoffs between cost, length, and coverage exist [5].

In this study, a framework was structured for an electronics retailer to offer extended warranty contracts for various brands of cell phones sold through their sales channels (online or in store). Contrary to the widespread market practice, the retailer honors the extended warranty in house rather than offering it as a hidden insurance policy. The primary reason for this practice is to improve customer satisfaction, rather than increasing profits, as the industry-wide assessment of customer satisfaction during warranty processes was found to be critical [6]. This approach has wider value in terms of sustainability: as the number of extended warranties honored increases, so does the life expectancy of the products. According to customer feedback, the common practice of outsourcing extended warranty coverage to third-party service providers is a major source of dissatisfaction among buyers. Customers view the retailer as the first point of contact in the case of an extended warranty dispute. However, the legal counterpart becomes the third-party service provider or the insurer of the contract after the sale of the product. One-sided restrictions of the contract mandated by the insurer and written in a complicated format (which many of the customers do not read) hold up legally. According to sikayetvar.com, the largest online customer complaint and company solution platform in Türkiye, more than 2000 entries regarding extended warranties were present and unsolved in the last year. Such cases of unfulfilled warranty service results in unsustainable products, with dissatisfied customers blaming the retailer for a perceived deception [7].

This paper proposes a decision support system for retailers to honor extended warranty contracts in house rather than the classical execution through third-party insurance companies. The novelty of this study is that it bridges the gap from modeling implications to applicability in real life environment. Also,

- This is the first study in the extended warranty literature taking place specifically in Türkiye. The volatile macroeconomic factors in Türkiye (such as currency rates and inflation) have unforeseeable impact on warranty costs, thus making their pricing a challenging task for retailers (in terms of profitability and customer satisfaction).
- The product under consideration is the cell phone. Cell phones are the bestselling product in the consumer electronics domain in terms of both the number of units sold and the revenue generated [8]. Cell phones are also challenging from a sustainability perspective, since they constitute the top consumer electronics product category with the most "Replace" decisions taken for failed products under warranty. This study provides a unique approach for cell phones by considering all the failure modes and their associated cost schemes.

The next section presents the literature on the extended warranty domain and the impact of this domain on the sustainability of products. Then, the proposed framework is introduced by illustrating the pre- and postreflection on extended warranty schemes. An analysis of the data gathered from retailers based in Türkiye is provided to highlight the costs and lifetime benefits of honoring extended warranty contracts in house.

2. Literature Review

Although the provision of a warranty is one of the older practices in the trading world, limited attention had been given to its scientific foundations prior to the 2000s [9]. Since the cost of a warranty was included in the original sale price of the product, warranty cost analysis occupied the majority of such studies [10–12]. In the studies related to the design of extended warranty contracts, as a subcategory in this field, warranties have been considered collectively from the perspective of cost/price, maintenance type, and time horizon [13].

The mathematical modeling of extended warranty contracts is achieved with a decision support framework. Inherently, the cost domain is the primary objective of such domains. The maintenance costs incurred by both the buyer and producer during the product's lifecycle are modeled in an expected total cost approach [14]. This modeling is carried out in a pareto optimal manner so that the maximum extra cost the consumer should pay and the minimum price at which the manufacturer should sell the extended warranty can be identified in the decision domain. Preventive maintenance is also a key factor in the modeling of extended warranty contracts. In areas where the operational conditions of a repairable deteriorating product significantly differ, the classification of customers is crucial. Periodic and other types of maintenance efforts are optimized in a dual manner, with reliability and cost objectives balanced simultaneously [15]. Concerns regarding the preventive maintenance strategy decisions to be made under various warranty policy options are also crucial for sustainable supply chains for secondhand or remanufactured products [16]. Again, considered within the supply chain domain, the provision of an extended warranty has been analyzed from an optimal cost perspective comparing a manufacturer and the e-commerce platform [3], and among the manufacturer, retailer, or both [17]. Similar cost optimization schemes were also considered in the literature for replacement, repair, or hybrid repair/replace corrective actions in each of the discrete subwarranty domains [18]. Unfortunately, none of the modeling in the literature was conducted with a large real-world data set to highlight the practical implications.

In addition to modeling implications, extended warranty contract research has received a great deal of interest from consumer study groups. Consumer reasoning on how and why they buy such contracts has been analyzed in these studies. Product utility characteristics and retailer initiatives such as promotions were found to have an impact on contract purchase decisions [19]. Demographical characteristic such as sex and income level were also found to have interesting effects on decision making. Such contracts were also investigated in terms of the psychological ownership perception of consumers for tangible products [4]. Experimental data from 133 consumers in Canada indicated that touching the product can enhance both the psychological ownership of the product and the willingness to pay for a warranty. This study further investigated and found that allowing shoppers to touch both hedonic and utilitarian products would likely increase the demand for the latter, without negatively impacting the former.

As a special but momentum-gaining case, the effect of store-branded products on extended warranty was also investigated [20]. This kind of good, carrying the label and brand of the store in which it was sold, is usually a low-cost alternative to a specific product line. Since the brand and manufacturer of product are not same, quality is not a primary concern at the beginning of the product life cycle. This study shows that offering an extended warranty on such products and transferring a share of the profit made from such contracts to the manufacturer improves the quality of the product, thus benefiting all parties in terms of cost, time, and satisfaction.

Extended warranty initiatives seem to be more important than ever in an era where the circular-economy philosophy-driven sustainability is gaining momentum. The sustainability of such contracts involves either operational concerns or customer behavior issues. Longer life times are now an important objective in the design stage for the reparability of products [21]. The decisions made by the consumer, at the acquisition of the product, have a significant impact on the life expectancy and availability of the product as well [22].

In the analysis of consumer behavior for circular products, warranty length (including extended domain) was found to be significant, especially for the risk-averse demographic category [23]. While some initiatives such as "trade-in" during extended warranty may be attractive for consumers, the impact on the sustainability of the product and on all life cycle costs should be analyzed carefully [24]. As long as the market-driven environment and the consumption attitude of the consumers dominate such decisions, issues related to "throw-away society" and "product obsolescence perception" have subjective and incalculable impacts on the product's lifespan [25,26].

Pricing of the extended warranty service is a key element for both the service provider and consumer. The foremost challenge for service providers is the handling of price changes in terms of time, which is the service sold to the customer. Depending on the product type (associated expected warranty cost of the product) and marketing type of the extended warranty service, mix-and-match approaches can be developed [27]. While dynamic pricing of an extended warranty service usually creates a better profit margin for the provider, a two-way effect should be taken into account: As the repair learning ability increases, pricing positively affects the consumer. In other cases, consumer is not happy with the increasing price of the service [28]. "Free to consumer" (complimentary) extended warranty contracts are present on the market for some consumer product types. Although these are rare and only for brief time periods, they attract risk-averse consumer types [29].

According to [30], the average lifespan of smartphones in the USA had fallen from 3.01 years in 2018 to 2.65 years in 2022. This trend of diminishing usage durations is also reflected by the number of obsolete units in many countries. In Korea, 14.5 million mobile phones were retired annually between 2000 and 2007 [31]. China's numbers seem to be quite large: while only 11.7 million units were retired in 2000, this number increased to 781.1 million units by 2015 [32]. Iran was expecting 39 million retired mobile phones in 2014, of which 4.2 million could be reused [33].

The positive impact of sustainable cell phone usage with an extended lifespan also has a certain positive impact on waste management, recycling, and cleaner production. Many studies from developing and developed countries highlight the effect of the use of sustainable cell phones on the environment [34–36].

3. Extended Warranty—Classical Execution

A minimum of 2 years of government-enforced manufacturer (or distributor) warranty coverage is present for all products sold in Türkiye. This duration is higher than the median global coverage since, in most of the other countries, only a single year is mandated. While some companies offer longer terms (e.g., Korean automakers) for marketing purposes, electronic and durable home appliance firms have adopted 2 years as a market standard without many exceptions. Extended warranty contracts are then offered as additional production on the top of the mandated warranty in the form of 2 + 2 or 2 + 3 years of coverage. So, when a product fails within the first 2 years of operation, the consumer makes a claim on the warranty from the manufacturer's technical support channels by using a proof of sale date such as receipt or online product activation information. If the product fails beyond the 2 years of coverage, claims are brought to the extended warranty issuer by using the policy bought at the time of sale. In exceptional cases, the manufacturer may offer such contracts as well (e.g., AppleCare+ for Apple products (Cupertino, CA, USA)), which are restricted to certain markets. Manufacturer-offered contracts also have the flexibility of being purchased by the consumer during a grace period after the sale of the product. In Türkiye, some manufacturers of durable products such as refrigerators, washing machines, and small home products offer extended contracts in a similar fashion (e.g., companies such as Beko-Arçelik and Vestel (Istanbul, Türkiye)). Note that such manufacturers have a strong service and technical support network throughout the country.

Other than these cases, all contextual extended warranty contracts are honored through insurer rules and channels. In the case of a failure, consumers are directed to a third-party service center, with which the insurance company has an agreement. Usually, the contract's

policy and coverage are extensive enough. Some consumer-attractive policy benefits are the provision of service and technical support through a call center, on-site repair service for oversized products such as TVs and refrigerators, and limited repair of minor damages incurred by user, e.g., one screen change per policy.

However, in practice, claims are usually rejected because of the exclusions listed in the same contracts. Some of these are abuse, drop damage, viruses, unauthorized repair attempts, etc. Even if the claim is accepted, in many cases, the product cannot be repaired or replaced due to spare part shortages or obsolescence. In such cases, replacement of the product imposes a partial cost to the consumer. Insurance policies depreciate the value of the product due to the wear and tear incurred over time. A general scheme for such depreciation involves a refund of 60% for third-year, 50% for fourth-year, and 40% for fifth-year failures based on the original invoice price. There is no factory- or distributor-offered extended warranty policy for cell phones sold in Türkiye. Retailer-sold policies adopt these rules in a similar fashion.

4. Extended Warranty—Design for the Retailer

Although retailers have no legal attachment to extended warranty contracts, unsatisfied consumers develop a negative perception of these retailers as these products are marketed and sold via their channels. In order to improve customer satisfaction while keeping the profit level the same (or even higher), the retailer under investigation opts for honoring extended warranty contracts for cell phone products (almost all phones in the smart phone category) themselves. They make an exclusive agreement with a service center that provides maintenance and repair service for different brands. Previous failure data were also gathered from the same service center. The goal was to set a single premium selling price (cost + profit) of this extended warranty for the retailer. For marketing purposes, such price should not differ between brands and models, thus capturing all products.

The estimated extended warranty cost is a function of the reliability of the product in addition to the original 2-years warranty period (all products are assumed to be starting from this age). As the repair cost is borne by the retailer, the free repair warranty (FRW) modeling approach was adopted for the analysis [37,38]. The other model assumptions were as follows:

- Failures are statistically independent. If there are any, previous repairs have no impact on the failure mechanism of the extended warranty domain.
- Service time (downtime including assessment, procurement, and repair times) is neglected.
- The cost of each claim is a random variable.
- Replacement decisions are made with a fixed cost.

Under the FRW model, the length of an extended warranty period, w, is the period during which the retailer is obligated to repair failures free of charge to the consumer. The number of claims over the specified warranty period w can be shown as $N(w, a)$, where these claims occur according to a Poisson process with an intensity function $\Lambda(t)$ starting from the end of original warranty period of $a = 2$. The intensity function can also be described as the time-dependent failure rate of the item and can be shown as

$$\Lambda(t) = \frac{f(t)}{R(t)} \tag{1}$$

where $R(t)$ is the reliability of the item. Then, the expected number of claims is calculated using the following:

$$E[N(w,a)] = \int_a^{a+w} \Lambda(t)dt. \tag{2}$$

If the average warranty cost of each repair during period w is $\bar{c}$, then the expected warranty cost can be given as

$$E[c(w,a)] = \bar{c}\int_{a}^{a+w} \Lambda(t)dt. \quad (3)$$

In order to understand the failure and cost characteristics of the products failing beyond the original 2-years warranty period, an analysis of service data was carried out. The failure mode and effects analysis of smart phones indicated 5 general classes for failure mode, as illustrated in Table 1.

Table 1. FMEA summary.

Failure Mode	Cause	Effect on System	Detection Method	Service Level
Battery	Improper charge Over usage	Down Dissatisfied usage	System diagnosis	Reject
Casing	Abuse Drop damage	Dissatisfied usage	Inspection	Reject/Replace
External User Interface Components (EUIC)	Abuse Contamination	Partial function loss	Inspection	Repair
Mother Board (PCB)	Substandard material Insufficient design Drop damage Contamination	Down Partial function loss	System diagnosis	Repair/Replace
Screen	Drop damage	Down Dissatisfied usage Partial function loss	Inspection	Repair

While some failure modes are easier to detect and resolve, extensive diagnosis is required for claims involving complex components such as the motherboard of the phone. Claims regarding battery and casing are rejected due to the coverage exclusion of modes involving consumer misuse. Past data from a service center were classified with respect to these failure modes. Only the data with complete failure mode, system status, and cost information were considered. Table 2 provides the failure modes and respective costs of 328 such complete records that occurred within the calendar year of 2022. Out of 328 items, 41 were replaced, and partial refunds were issued.

Table 2. Extended warranty claim data.

Claim	Claim Time (Days)	Failure Mode	Cost ($)
1	1331	PCB	219
2	1196	Battery	0
3	855	Screen	99
4	1700	Screen	94
5	1443	EUIF	78
6	1298	Screen	117
7	1037	PCB	132
8	1225	Screen	105
9	1167	PCB	193
10	944	Casing	0
...	...	...	...
...	...	...	...
...	...	...	...
324	1589	Screen	102
325	1097	EUIF	79
326	989	EUIF	73
327	1263	PCB	293
328	1007	EUIF	91

Weibull is generally assumed as the underlying failure distribution for cases where aging effects are present, especially in the reliability modeling of hardware. Its flexibility in modeling the changing behavior of failure mechanisms is also quite high. The service data were fitted to a Weibull distribution both graphically (Figure 1) and statistically. Goodness-of-fit analysis through chi-squared and Anderson–Darling tests was conducted, with the latter giving a p-value of 0.208. The graphical fit and statistical significance evidence supported the Weibull fit of the data. Next, maximum likelihood (ML) estimation of the Weibull parameters was carried out. These parameters were estimated as follows: shape parameter—$\hat{\beta}$ = 1.635 and scale parameter—$\hat{\theta}$ = 976.5 days. Note that this is actually a 3-parameter Weibull distribution with a threshold value of 730 days, since the claim data only started 2 years of original warranty (used in the shifted form).

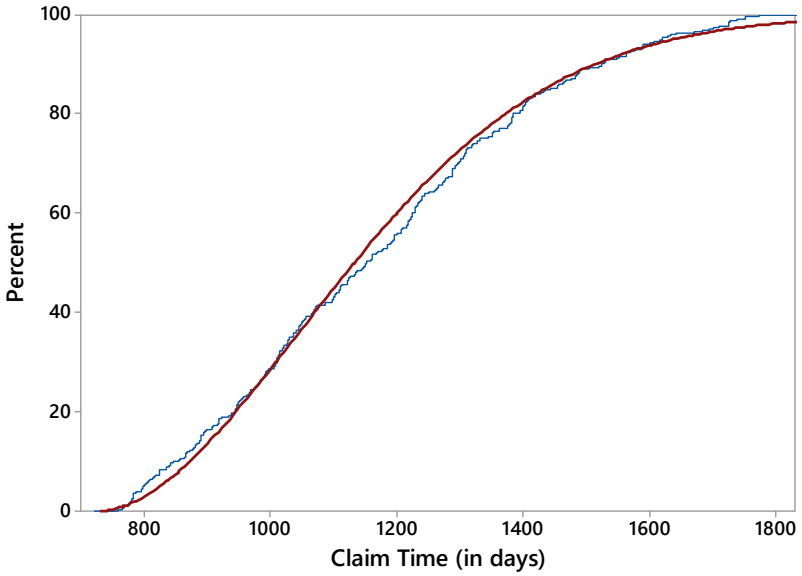

Figure 1. Weibull plot for claim data [true (red) vs. estimate (blue)].

In order to calculate the expected warranty payout, the $\Lambda(t)$ intensity was derived. The probability distribution of the number of failures during a warranty cycle could be approximated using nonhomogeneous Poisson process given as

$$\Lambda(t) = \frac{\beta}{\theta}\left(\frac{t}{\theta}\right)^{\beta-1} \text{ where } t, \beta, \theta > 0 \tag{4}$$

and can be utilized within Equation (3). Also known as the power law process, this intensity function can further be validated as the failure rate of the associated Weibull failure model.

By using the ML estimates of the shape and scale parameters on the intensity function, along with the average cost, $\bar{c}$, expected warranty payouts were calculated. The average cost, $\bar{c}$, was directly calculated from the service data and was found to be USD114. This led to the payout values summarized on Table 3 for the time horizon between 800 and 1800 days starting on the 730th day (considered the 3rd, 4th, and 5th years of extended warranty coverage).

Table 3. Expected warranty payout.

w (*days*)	800	900	1000	1100	1200	1300	1500	1600	1700	1800
E[$c(w,a)$] (USD)	82.6	100.1	118.9	138.9	160.1	182.5	230.5	256.1	282.7	310.4

Our analysis showed that the expected payout per claim for +1 year was USD 139, and close to USD 230 for 2+ years. The price of the service must be 20–30% higher than

these values if the retailer wishes to achieve a profit. These costs may be seen as high but considering the price of high-end smart phones in Türkiye (e.g., as of November 2023, the average suggested retail price for iPhone 15 Pro (Apple, Cupertino, CA, USA) was USD 2700 and USD 1600 for a Samsung S23 (Samsung Electronics Co., Ltd., Suwon-si, Republic of Korea)). The retailer preferred not to offer a warranty beyond 4 years, thus offering 2 + 1 and 2 + 2 years of extended warranty services separately. This seems practical, as consumers do not wish to pay a premium of more than 10–15% of the invoice price of the cell phone for an extended warranty.

5. Conclusions

5.1. Theoretical Implications

For the selected case study, real data collected over a year's time were used. To the best of the author's knowledge, this sample size (n = 328) is the largest one considered in the literature, with complete cost and failure mechanism data provided for each sample. There were two sources of data: warranty claims and service records. However, data were stored on simple spreadsheet applications without much contextual data analytics or attributes. The data were also rarely analyzed. In order to have a healthy decision support environment, data storage, analysis, and reporting tools should be part of the mainstream ERP software that is used in the retailer's day-to-day operations' management. Cost and repair actions must be updated as new data become available, as suggested by the flow proposed in Figure 2.

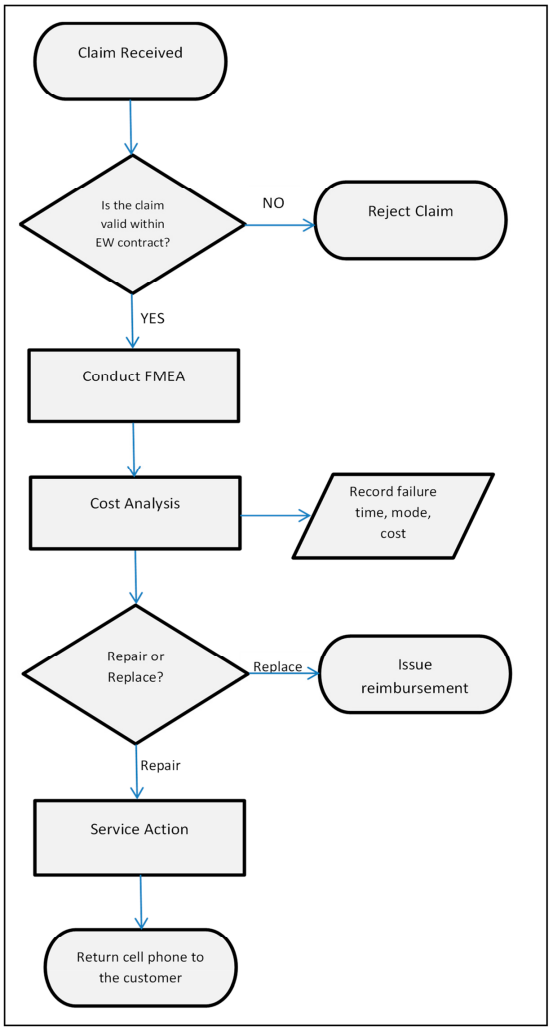

Figure 2. Flow chart for extended warranty claims.

Extended warranty policies are an invaluable tool for sustainability, especially from a circular economy point of view. Although they have long been considered as add-on services to create immediate profit without much hassle for retailers, their side benefits cannot be underestimated. Intuitively, when there is a failure or problem with a cell phones during the original warranty period, consumers wish for a replacement after the claim. In many instances, manufacturers also opt for this action as it is time-efficient, satisfies customer, and only incurs relatively higher costs considering the administrative and technical processes involved. Even after the original warranty period, manufacturers offer swaps by issuing partial refunds for used phones. Unfortunately, this approach makes the product unsustainable owing to the high turnover. Extended warranty contracts, with a "repair first" motto, aim to keep the product active and sustainable for extended durations.

The environmental impact of sustainable cell phones is also significant, as there is no recycling facility dedicated to this product in Türkiye. Cell phones cannot be exported to other countries for recycling as the tax laws prohibit such actions (IMEI numbers are registered with a government database).

5.2. Practical Implications

Honoring extended contracts in house is beneficial for the following practical reasons:

- Because of the higher-than-average inflation rates in recent years, repair costs have surpassed the partial replacement refund cost (replace decision) calculated using the original invoice price. For this reason, insurance companies almost always opt for the partial refund instead of the repair option, thus making the sustainability of the product impossible through an extended warranty. Such approach becomes even more financially unsustainable as the partial compensations counterpoise an even lower percentage of the substitute product available on the market (e.g., an iPhone Pro 13 lost its original value to USD 680 from 2021 to 2023 because of such macroeconomic reasons and only a refund of USD 408 was issued in case of an accepted claim in the third year of use).
- The proposed decision support system also works as a dynamic pricing and revenue control mechanism. As new brands and models are released on the market and sold, their cost impact may be gradually incorporated into the extended contracts as service information becomes available. The price of the contract(s) offered can be adjusted accordingly.
- Although retailers receive immediate profit from the sale of contracts offered by third parties, customer satisfaction levels are extremely low in the case of a claim. Handling claims locally has a positive impact on customer satisfaction as the consumer can deal directly with the retailer from which they purchased the policy in the first place. Loyalty programs reflect this positive trend.
- The policies offered by insurance companies almost always have a clause stating that the policy is terminated once a refund is made. This makes the policy useable only once in many instances. On the other hand, repairs are covered during the whole stated policy period.
- Retailers may further generate income by offering service on cell phones that are not covered by any means of a warranty policy. Notably, minor service requiring actions such as screen repairs may be carried out to generate revenue and improve customer loyalty.

5.3. Future Research

Further studies may be conducted to design and offer extended warranty contracts for tablets as well since their repair and brand compatibility are similar to those of cell phones. In-house-offered contracts seem to be logistically difficult and costly for durable-class consumer products. But other warranty models, such as cost-sharing and maintenance-applied models can be applied to durable-class products and can be considered as a substitute for insurance policies.

The effect of extended warranties on specific products should be compared and monitored to evaluate and understand the true impact on the circular economy. This may be carried out by analyzing the results for the same product class sold with and without extended warranties on a long time horizon by including whole life-cycle costs.

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