

**EU ECODESIGN REQUIREMENTS FOR SMARTPHONES: A SUFFICIENT  
INITIATIVE TO EXTEND THE USER SERVICE TIME OF SMARTPHONES?**

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A QUANTITATIVE STUDY AMONG EUROPEAN CONSUMERS

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**Dissertation written under the supervision of Professor Augusto Sales**

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## Resumo

**Título:** Requisitos de Ecodesign da UE para smartphones: Uma iniciativa suficiente para estender o tempo de serviço do usuário de smartphones? Um estudo quantitativo entre consumidores europeus.

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**Objetivo:** Este estudo está alinhado com os objetivos do Pacto Verde da UE para 2050, focando especificamente nas regulamentações de Ecodesign para smartphones, que visam prolongar o tempo de serviço do usuário através do aumento da durabilidade. O objetivo desta pesquisa é determinar se os principais componentes destacados nessas disposições legais têm um impacto significativo no tempo de serviço do usuário de smartphones.

**Metodologia:** O estudo utiliza uma pesquisa quantitativa para entender por que os consumidores substituíram seus smartphones anteriores e se os fatores de confiabilidade e reparabilidade afetam significativamente o tempo de serviço do usuário de smartphone. Um modelo de regressão múltipla foi empregado para analisar a influência desses fatores e controlar outros potencialmente importantes durante todo o ciclo de consumo.

**Resultados:** Os resultados revelaram que a substituição de smartphones e o tempo de serviço do usuário são influenciados por uma interação complexa de fatores, não sendo apenas a confiabilidade e a frequência de reparo. De modo significativo, as características do consumidor, o comportamento de cuidado e certos motivos de substituição do dispositivo emergiram como determinantes críticos da vida útil do usuário.

**Implicações:** Embora os requisitos de Ecodesign propostos possam impactar positivamente a durabilidade do smartphone, a atitude e o cuidado do consumidor também são cruciais. Portanto, iniciativas mais abrangentes, incluindo educação do consumidor e promoção de atitudes pró-ambientais devem ser implementadas juntamente com medidas legais. Pesquisas adicionais são essenciais para determinar o impacto exato das medidas propostas e fornecer estudos aprofundados sobre como influenciar positivamente as atitudes e o cuidado do consumidor.

**Palavras-chave:** Regulamentações da UE sobre eletrônicos, Requisitos de Ecodesign, Substituição de smartphones, Longevidade de smartphones

## Abstract

**Title:** EU Ecodesign requirements for smartphones: A sufficient initiative to extend the user service time of smartphones? – A quantitative study among European consumers

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**Purpose:** This study aligns with the objectives of the EU Green Deal 2050, focusing specifically, on the Ecodesign regulations for smartphones, which aim to prolong the user service time through increased durability. The goal of this research is to determine if the key components highlighted in these legal provisions, have a significant impact on the length of user service time of smartphones.

**Methodology:** The study applies a quantitative survey to understand why consumers replaced their previous smartphones and whether the factors of reliability and repairability significantly affect the length of smartphone user service time. A multiple regression model was employed to analyze the influence of these factors and control other potentially significant factors during the entire consumption cycle.

**Findings:** The findings revealed that smartphone replacement and user service time are influenced by a complex interplay of factors rather than being solely dictated by reliability and repair frequency. Significantly, consumer characteristics and care behavior emerged as critical determinants of user service life, along with certain reasons for device replacement.

**Implications:** While the proposed Ecodesign requirements can positively impact smartphone durability, the consumer's attitude and care for the device play a crucial role in the timing of replacement. Therefore, broader initiatives, including consumer education and the promotion of pro-environmental attitudes, need to be implemented alongside legal measures. Further research should be conducted to determine the exact impact of the proposed measures and to provide in-depth studies on how consumer attitudes and care can be positively influenced.

**Keywords:** EU regulations on electronics, Ecodesign requirements, Smartphone replacement, Longevity of smartphones

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## List of Abbreviations

CE	Circular Economy
CEAP	Circular Economy Action Plan
EC	European Commission
EU	European Union
GVIF	Generalized Variance Inflation Factor
IT	Information Technology
Log	Logarithm
OLS	Ordinary Least Squares
VIF	Variance Inflation Factor

# 1 Introduction

## 1.1 Contextualization

The production and consumption of electronics have a strong impact on sustainability. This includes mining damage by extraction of rare earth, emissions of greenhouse gases, and the increasing amount of electronic waste, as one of the fast-growing waste streams. If consumers and industry do not change their practices, waste will increase by more than twice the current amount by 2050 (Baldé et al., 2022; Klinger, 2018). Compared to other information technology (IT) products, the smartphone has a relatively small environmental footprint. However, due to its short usage cycles and widespread use among the population, the smartphone is a relevant factor influencing the environment. (Proske et al., 2020). Recycling is an essential measure of limiting these negative impacts. Unfortunately, minerals mainly exist in small quantities in the products, making recycling difficult and costly (Sabbaghi & Behdad, 2018; Vanegas et al., 2018). Therefore, it is essential to try to lengthen products' lifetimes before recycling. The proposed strategies in the Circular Economy (CE) literature are refurbishment (Wallner et al., 2022) or remanufacturing (Jensen et al., 2019). Yet, recording the chance of many products neither being resold nor entering the circuits of refurbishment/remanufacturing/recycling (Poppelaars et al., 2020), much value can be obtained by tackling this issue at an early stage.

An apparent approach is to try to extend the period of the first owners' usage. Slowing down the time until a first replacement, can significantly reduce the overall pace of consumption (Sinha et al., 2016). A recent study researched that using a smartphone for five instead of three years could reduce the phone's annual carbon footprint by 31% (Sánchez et al., 2022).

The EU has recognized that extending the service life of smartphones can be a component of achieving the goals of the European Green Deal. As part of the Circular Economy Action Plan (CEAP), they released a preliminary draft legislation in August 2022 called "Ecodesign requirements for mobile phones, cordless phones, and tablets." The draft's main objective is to promote durability to extend the user service time (European Commission, 2021).

From an engineering perspective, the durability of smartphones can be pursued by improving the reliability of the device (i.e., reducing the likelihood of failure) or its repairability (i.e., facilitating its restoration in case of failure) (Cordella et al., 2021). These engineering resources of increasing the service life lengths are mentioned in the draft legislation explicitly.

This study attempts to answer whether the overarching concepts addressed in the EU draft legislation, have the most significant impact on user service time indeed. Consequently,

the author will analyze whether other characteristics during the consumption cycle are comparatively more significant. Such findings can be beneficial in developing future legislation or initiatives. Thus, this study addresses the following research questions.

**RQ1:** Do the draft laws promoting durability, in the form of reliability and repairability, address the critical factors influencing the user service time of smartphones?

**RQ2:** Which additional factors affect the user service time of smartphones during their replacement cycle significantly?

Ensuring this work's narrow and goal-oriented focus requires delineating a clear scope.

Firstly, the study will focus specifically on smartphones. Therefore, other devices mentioned in the law, such as mobile phones, cordless phones, or tablets, will not be further addressed.

Secondly, the study refers exclusively to the period from the receipt of the smartphone until its replacement. Although the draft law also addresses the reuse issue, it will not be further addressed in this paper.

Thirdly, this study does not examine how consumers evaluate the draft law in detail. Instead, the objective is to determine if consumers are replacing smartphones early due to a lack of durability, reliability, and repairability or if other relevant factors lead to short replacement cycles.

## **1.2 Theoretical Relevance**

Sim Van der Ryn and Stuart Cowan popularized the term ecological design in 1996 through their book "Ecological Design" (2013). Its frequency of mention has increased since the publication of the European Ecodesign Directive of 2005 (EU, 2015). Since then, there has also been an increase in specialist literature on the subject of ecodesign in relation to consumer electronics (Li et al., 2015; Manjunatheshwara & Vinodh, 2021). There is also a rich body of literature specifically on the subject of mobile phones and ecodesign, addressing topics such as disposal routes and recycling of mobile phones (Andrae et al., 2016; Jang & Kim, 2010; Wilson et al., 2017). Even more specifically, researchers have examined the consumer perspective on replacement reasons and the factors contributing to the lack of repair of mobile phones (Jaeger-Erben et al., 2021; Magnier & Mugge, 2022; Wieser & Tröger, 2018). Some of the mentioned

studies targeted mobile phones and compared mobile phones with other electronic devices such as washing machines or hoovers (Jaeger-Erben et al., 2021; Magnier & Mugge, 2022).

In the study conducted by Jaeger-Erben et al. (2021), similar hypotheses are investigated, such as whether repair behavior extends the use time of products or if replacement behavior due to functionality impacts use time. Due to the inclusion of a comparison between washing machines and smartphones, which broadens the scope of the questionnaire used for analysis, the emphasis of the study shifts to a more general context. Concerning the described hypotheses below, sufficient evidence could not be found for any of them.

The study by Wieser & Tröger (2018), which partly forms the basis of this paper, also specifically examines the influence of various factors during consumption on user service time. In contrast to this dissertation, the paper also addresses other types of mobile phones, such as feature phones. The analysis employed a non-parametric statistical method which allowed the consideration of only two groups/variables separately. Consequently, the analysis did not fully capture the relationships among the different independent variables.

To the author's knowledge, this study is the first to exclusively focus on smartphones and analyze simultaneously multiple factors that could impact user service time.

### **1.3 Legal Relevance**

This dissertation centers on the core concepts presented in the preliminary EU draft named "Ecodesign Requirements for Mobile Phones, Cordless Phones, and Tablets."

Although the law will most likely not be enacted at this dissertation's release, the consultation period has already concluded (European Commission, 2021). It should be noted that the dissertation does currently not impact the discussed draft law. Still, the results may provide valuable insights for future legislative drafts and initiatives. For example, the draft law will primarily shift the brands' responsibility for a longer smartphone user service time to brands such as Apple or Samsung. To achieve the goals of the Green Deal in 2050, it can also be insightful to look at many different perspectives and factors of the consumption cycle and see where there are opportunities for intervention or influence on different parties, such as the consumer.

## **1.4 Dissertation Structure**

The dissertation is structured as follows. Initially, the topic's relevance, the associated research question, and the theoretical and legal relevance are outlined. The literature review discusses fundamental concepts and findings from the relevant fields. First, it deals with the European Green Deal and the replacement cycle. Then it goes into more specific detail on the European initiative "Ecodesign requirements for mobile phones, cordless phones, and tablets" and the findings of other studies concerning the replacement cycle of the smartphone. During the process, the hypotheses of the paper are developed.

After describing the methodology, the relevant results of the multiple regression are applied to answer the research question and hypotheses. Subsequently, these are discussed in the context of the existing literature, and the legal implications are derived. In addition, the limitations and future research questions are explained. In the end, a conclusion is drawn.

## **2 Literature Review**

### **2.1 European Green Deal**

The European Green Deal was approved in 2020 and includes a set of policy initiatives by the European Commission to make the EU climate neutral by 2050. The aim is to review existing legislation from a climate perspective and introduce new legislation concerning CE, building renovation, biodiversity, farming, and innovation (Council of the European Union, 2022).

In order to further advance the green transition and achieve the goals of the Green Deal, the new CEAP was presented in March 2020 (European Commission, 2020b). According to the Ellen MacArthur Foundation (2015), the central tenet of the CE is the regenerative utilization of resources, whereby raw materials are not treated as disposable waste. The concrete definition from the CEAP is the following: "In a CE, the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value" (European Commission, 2015).

Ecodesign is a methodology of CE that enables the integration of environmental considerations into the design and development of products to minimize the environmental impact of a product over its entire life cycle.

This approach entails assessing a product's environmental footprint from the extraction of raw materials to its final disposal or recycling. A significant lever on the environmental footprint is the time of product replacement. (Knight & Jenkins, 2009).

### **2.2 Replacement Cycle**

Within the literature on smartphone life cycle and lifetime, different terminologies have been used by various authors. For this thesis, a clear distinction will be made between the terms "user service time" and "device service lifetime." The former refers to the duration of a single-user service cycle, while the latter represents the total duration of all user service times. Therefore, this dissertation will focus on the user service time, defined as the period of active use of a device and the associated retention mechanisms, e.g., repair, that can prolong it. Mechanisms of reuse, e.g., passing the device on to a subsequent user, are not discussed further (Bieser et al., 2022; Thiébaud -Müller et al., 2018).

A product's duration of user service time results from its intrinsic features and consumers' maintenance habits, as Cox et al. (2013) noted. More specifically, a product's lifespan is influenced by its reliability, repairability and the extent to which consumers tend to retain and maintain it (Poppelaars et al., 2020; Wilson et al., 2017).

With a long time of ownership, the willingness to maintain and care for the product decreases. Consumers mentally adjust to an expected lifespan, often lower than the possible technical lifespan (Echegaray, 2016). Even if the device's functionality remains stable, mental devaluation continues to increase. This mental devaluation of products over time is a limiting factor for their actual lifespan (Hou et al., 2020).

When considering product replacement, consumers engage in a value trade-off between the value provided by the currently owned product and the expected value and costs associated with a potential new product (van Nes & Cramer, 2005).

Durable goods, such as smartphones, are subject to both forced and unforced replacement, with consumer attitudes playing a significant role in determining the replacement timing (Bayus, 1988; Grewal et al., 2004). Obsolescence, defined as losing a device's functionality, value, or usability over time, is a primary driver of replacement behavior (Mellal, 2020; Packard, 1960). This interpretation of obsolescence remains vague, with varying distinctions made between different types of obsolescence (Mellal, 2020).

Further, it can be categorized into material (e.g., physical degradation), functional (e.g., lack of compatibility), psychological (e.g., outdated fashion), and economic (e.g., costly repairs vs. new product) types (Cooper, 2010; Malinauskaite & Erdem, 2021; Proske et al., 2016).

Planned obsolescence is an additional form of obsolescence that has gained attention in the context of smartphones. It refers to a strategy of developing products with a limited lifespan to encourage consumers to buy a newer version (van Nes & Cramer, 2005).

### **2.3 European Ecodesign Requirements for Durability, Reliability, and Repair**

In order to understand the terms used in this thesis and by the EU, the definitions used below are those, established by the European Technical Committee in response to Mandate 543, which focuses on the assessment of material efficiency (European Standards, 2020a, 2020b)

Firstly, durability is the "ability to function as required, under defined conditions of use, maintenance, and repair, until a limiting state is reached." This limiting state could be reached due to various technical reasons, such as time or number of cycles. The durability of a product

depends on two key factors: its resistance to external stressors and degradation (reliability) and its ability to be restored to a functional state once it reaches a limiting state (repairability) (European Standards, 2020a).

Reliability refers to the "probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event." It represents the product's ability to resist malfunctions or failures, ensuring its performance consistency (European Standards, 2020a).

Repair is the "process of returning a faulty product to a condition where it can fulfill its intended use" (European Standards, 2020b).

A product remains functional until it encounters a limiting event that prevents it from performing the required functions. At this point, the product enters a limited state where it can no longer function as intended. Then, the product can be restored to a functional state by taking repair measures. A device's limited functionality or defectiveness may be due to various factors, including external stress factors, improper use, internal technical problems, or aging (Cordella et al., 2021).

The European initiative called "Ecodesign requirements for mobile phones, cordless phones, and tablets" was planned under the CEAP; additionally, it is based on the EU Ecodesign Directive 2009/125/EC. As stated by the EU, the Ecodesign directive is supposed to promote product durability, reliability, reparability, and recyclability. In addition, the European Commission (EC) seeks to address the concerns surrounding the relatively short lifespan of smartphones. Various studies in different countries have reported an average smartphone user service time of around 2 to 3 years. (Glöser-Chahoud et al., 2019; Jaeger-Erben et al., 2021; Thiébaud -Müller et al., 2018; Wieser & Tröger, 2018; Zhilyaev et al., 2021).

This phenomenon of short lifespan is driven by a range of factors, including the desire for the latest models, limitations in the availability of spare parts and updated versions of the operating system, as well as considerations related to cost, ease of repair, and diminished battery endurance over time (European Commission, 2020a).

In August 2022, the European Commission (EC) released a preliminary version of the regulation (European Commission, 2022b), which was partly based on a preparatory study conducted by the Fraunhofer Institute for Reliability and Microintegration (IZM) and Vito (Durand, 2022). Following a consultation period during which non-governmental organizations could provide feedback from August 31, 2022, to September 28, 2022, the Commission's next step will be to adopt the regulation (European Commission, 2021). The Parliament, Council, and Commission will then convene to negotiate an agreement. (European Union, 2023).

Since this work is primarily concerned with smartphone regulations, only smartphones are considered in the following analysis. The proposed regulation on ecodesign requirements for smartphones encompasses three objectives:

- Energy efficiency and durability
- Ease of repair, upgrade, and maintenance
- Facilitation of reuse and recycling of devices (European Commission, 2021)

The subsequent section will concentrate on the primary regulations that extend users' service time. All affected parties must implement the provisions outlined in the regulation within a period of 12 to 18 months after the regulation becomes effective. Although the requirements specified in the regulation are mandatory for manufacturers, importers, or authorized representatives, for brevity, only the term "manufacturer" will be used hereafter to refer to these entities.

#### **Design for reliability:**

The EU draft law takes a two-pronged approach to enhance the reliability of smartphones. It aims to improve both the physical resistance and the software. In order to make smartphones more resistant to accidental drops, manufacturers are required to ensure that their devices can withstand 100 falls from a height of one meter.

The smartphone must pass level four on the Mohs hardness scale regarding scratch resistance. Additionally, it has to be protected from dust and water (IP44) so that it is safeguarded against objects of size larger than 1 millimeter and splashing water. To set this into relation, an iPhone 14 is already rated with IP68, meaning it is dust-tight and protected at a maximum depth of 6 meters up to 30 minutes (Apple, 2022a; IEC, 2018).

Moreover, it is required that the smartphone's battery must achieve at least 500 cycles at 80% remaining capacity. Moreover, the manufacturer must provide users with instructions on how to maintain the battery, such as the impact of elevated temperatures and turning off functions like Wi-Fi, Bluetooth, or other features on the battery's lifetime.

In terms of software, manufacturers are required to provide security updates to the operating system for at least five years and functionality updates for at least three years without adversely affecting the device's performance. Further, the regulation requires that users are given the option to restore the operating system version that was available for their model on the date of the end of placement or any earlier version (European Commission, 2022a).

**Design for repair:**

An essential requirement outlined in the design of repair of the regulation is the provision of spare parts to professional repairers for five years following the end of placement of the smartphone on the market.

This requirement comprises a range of 15 different spare parts, including displays, speakers, and other components. Following the regulation, five of the 15 spare parts must be made available to end consumers, including components such as the battery and back cover. The provision of spare batteries to end consumers is mandatory only if the battery is capable of achieving a minimum of 500/1000 complete charge cycles. After this threshold is reached, the battery must have a remaining capacity of at least 83 % / 80 % of its rated capacity when fully charged (European Commission, 2022a). For comparison, Apple's standard battery is expected to maintain up to 80% of its original capacity after 500 complete charge cycles (Apple, 2022b). Furthermore, the regulation mandates that manufacturers publicly disclose information on how to order spare parts and how to use them to repair the device. The extent of information depends on whether the spare part is intended for use by professional repairers, end consumers, or both. In addition, the regulation stipulates that spare parts should be delivered within a maximum of five working days, and the manufacturer must provide an expected maximum pre-tax price for both professional repairers and end-users.

Moreover, the regulation includes disassembly requirements, such as the use of removable or reusable fasteners, to enable faster and more accessible repairs. Finally, if the manufacturer cannot meet the aforementioned requirements and is thus compelled to provide spare batteries, the battery replacement process must be feasible using either basic tools or tools supplied with the product, and it must be feasible for a layperson (European Commission, 2022a).

## 2.4 Durability, Reliability, and Repair impacting Smartphone Replacement Cycle

A comprehensive examination of existing research reveals that restricted functionality or defects often serve as the primary reasons for smartphone replacement (Magnier & Mugge, 2022; OCU, 2019; Watson et al., 2017; Wieser & Tröger, 2018). Wieser and Tröger (2018) reported that one in three replacements occurs due to these factors. Common problems leading to these replacements include battery issues, mechanical or technical failures, software glitches, and physical damages such as broken screens or casings. Incidents like dropping a smartphone, contact with water, or dust ingress contribute to these malfunctions (Watson et al., 2017).

These findings suggest that increasing the reliability of smartphones can extend their lifespan and resilience to incidents, which supports the legislator's proposal to improve product design for reliability. However, there is a notable lack of studies investigating whether defects or limited functionality led to the earlier replacement of smartphones and shorter service times for users compared to other replacement triggers. Based on the above, the following hypothesis is proposed:

**Hypothesis 1:** Smartphones replaced due to defective conditions or restricted functionality have a shorter user service time.

The option of repair appears to be an essential strategy for extending the product life of the smartphone. Various barriers, including product design, consumer behavior, business practices, and the comparatively high cost of new products, often discourage consumers from opting for repair (Jaeger-Erben et al., 2021). Other barriers from a product design perspective include difficulties in diagnosing faults and disassembling products (De Fazio et al., 2021; Pozo Arcos et al., 2020). Consumer hesitation to repair is also influenced by perceived behavioral and financial costs, including high repair costs and limited availability of repair infrastructure and spare parts (Laitala et al., 2021; Tecchio et al., 2019). Furthermore, consumer interest in smartphone repair decreases over time, regardless of how easy the device is to repair (Jaeger-Erben et al., 2021). Perceptions of obsolescence also affect decisions, as consumers believe that repair will not significantly extend the life of the device (Wieser & Tröger, 2018). Value depreciation has led to a culture of non-repair, where consumers prefer replacement to repair. A survey commissioned by the vzbv and conducted by forsa found that 47% of smartphone owners who had a defect in their device within the last 24 months chose not to repair it (vzbv,

2022). Another study showed that 75% of respondents have never repaired their smartphones (Jaeger-Erben et al., 2021).

Most smartphone users decide against repairing their devices and cite high repair costs as the main reason (vzbv, 2022; Jaeger-Erben et al., 2021). The EU draft law aims to improve and remedy the points mentioned above in the user's interest, such as easier repair, while criticisms such as high costs are not addressed. Although repairs seem to be a logical choice to extend smartphone lifespan, research has not been able to prove a statistically significant correlation between repair behavior and longer user service time (Jaeger-Erben et al., 2021). Therefore, a second hypothesis was derived:

**Hypothesis 2:** Smartphones undergoing repair(s) have an extended user service time.

## **2.5 Additional Factors impacting Smartphone Replacement Cycle**

In addition to durability, reliability, and repair, the literature shows various other influencing factors during the lifecycle, such as usage practice, smartphone relations, or demographic characteristics, that can affect the user service time.

When looking at demographic factors, Wieser & Tröger (2018) have found that older consumers keep their phones longer than younger consumers. The underlying paper explains that this observation is related to the fact that older people are more careful with their devices and less inclined to look for novelty. Besides age, the above-mentioned authors concluded that other socio-demographic factors such as salary, education, or gender have only a small or no relevant influence on the duration of use. W. Wilhelm et al. (2011), on the other hand, came to the conclusion that families with higher incomes tend to change their phones more often. Also, the authors noted that men and women have different replacement reasons, which lead to different lengths of replacement cycles.

Other studies have identified that the procurement type and the conditions in which the user receives the device can influence future usage time. For instance, smartphones tied to a contract are, on average, more likely to be replaced earlier. This is because consumers often receive an offer for a discounted new device after the contract expires (Magnier & Mugge, 2022; W. B. Wilhelm, 2012).

Another relevant factor is the personal attitude of the consumer and the relation to the smartphone. Studies on other products have shown that an emotional attachment to a product can delay the replacement of this object. At the same time, it leads to consumers being more

careful with the product (Schifferstein & Zwartkruis-Pelgrim, 2008). As a result, the device is dropped less often, has fewer scratches, and generally remains in better condition. This, in turn, can lead to a longer lifecycle, as defects occur less frequently or later and therefore need replacement (Evans & Cooper, 2016; Gregson et al., 2009).

Product care can be further strengthened by taking measures such as using screen protectors and external cases. They help reduce limiting states caused by drops or other mechanical stresses (Cordella et al., 2021). Research has found that applying an external protective case can decrease the frequency of breakage by up to 50% (Wertgarantie, 2017).

Furthermore, the expected product lifetime of the device can be a decisive factor during the consumption process. Consumers with low lifetime expectations tend to replace their devices because they believe repairing them would not yield enough additional years to pay off. Contrary, a highly extended lifetime could lead to the consumer being careful with the device, as they expect to use it for many years to come (Wieser et al., 2015).

One effect that can negatively impact the device's service life is the intensity of use. There is a close connection between wear and tear and, for example, the device's battery. Intensive use leads to frequent charging and discharging of the battery, which shortens the battery's lifetime, as it was only built for a certain number of charging cycles (Ercan et al., 2016).

Finally, when considering why consumers replace their smartphones, there are various reasons besides restricted functionality. For instance, Wieser and Tröger (2018) also revealed that mobile phones that are replaced due to new model versions, have a significantly shorter lifespan. Often, however, a minor perceived damage to the device is used to depreciate the perceived value and, thus, to justify the replacement (Makov & Fitzpatrick, 2021). This mindset allows consumers also to rationalize upgrading their phones to keep up with social practices and to fulfill novelty seeking, which is seen in the literature as a socially supported threat to longevity. Consequently, the combination of various reasons and an internal chain of reasoning often leads to the replacement of the device (Cooper, 2010; Jaeger-Erben et al., 2021). For completeness, there are unpredictable events on which the consumer has only limited influence, which can shorten the replacement cycle, such as gifts, changing life circumstances, and loss or theft (Wieser & Tröger, 2018).

All the above-mentioned influencing factors are considered for further analysis, regarding the second research question of whether other factors, durability, reliability, and repair should also be considered for the draft law.

## **3 Methods**

### **3.1 Research Design**

The methodology employed in this study adopts a quantitative consumer-based approach to address the research question (Chrysochou, 2017). It follows a deductive and explanatory approach, where hypotheses are derived from the EU draft under investigation and are supported by existing theories. These hypotheses are subsequently tested, providing a foundation for future research. To ensure the reliability, validity, and generalizability of the findings, a quantitative mono-method is utilized in the form of multiple regression analysis. This statistical analysis technique allows the rigorous testing of the formulated hypotheses and facilitates the generation of robust and meaningful insights (Saunders et al., 2009).

### **3.2 Data Collection**

The current study utilized a mixed sampling approach, applying both random and snowball sampling techniques to ensure the inclusion of a sizable and diverse participant sample within the constraints of the study timeframe (Goodman, 1961). The data collection phase involved administering an online survey using the Qualtrics platform, which was made available to respondents from April 23 to May 3, 2023. The survey was distributed through various channels, including social media platforms and direct messaging. It was presented in German and English to accommodate a broader range of participants. A screening question was implemented to restrict participation to individuals of European nationalities. In the context of this study, which primarily examines the user service time of smartphones, participants were provided with the opportunity to indicate the exact year and month of receiving their previous smartphone and the subsequent replacement date. It is worth noting that respondents were given the option to select "I don't know" if they were uncertain about these dates, thereby ensuring that the analysis exclusively considers data from participants who clearly remember their user service time. The survey deliberately addresses the previous mobile phone in order to be able to analyze an entire user service time.

### **3.3 Data Sample**

A total of 232 responses were gathered, out of which 27 were excluded due to incomplete or invalid responses, resulting in 205 valid responses. As the study's focus is to investigate the impact of various factors on the user service time, an additional 42 observations were removed as participants in these cases were uncertain about the dates of when they received and replaced

their smartphones. This led to a final sample size of 163 observations. Furthermore, it is essential to note that all participants indicated that their previous device was a smartphone. Appendix A offers a table that presents a comprehensive breakdown of the participants' socio-demographic characteristics, encompassing gender, age, nationality, highest level of education, and total household income before taxes. The target population for this study consisted of adult European Smartphone consumers aged between 18 and 64. The sample was almost evenly distributed by gender, with 77 female and 86 male participants. Half of the participants were aged 25-34, while 23% were aged 18-24. Most participants were of German nationality, accounting for 81% of the sample. The sample exhibits a relatively high level of education, with 66% of participants holding at least a bachelor's degree.

### **3.4 Procedure**

The main body of the questionnaire was adapted from Wieser and Tröger (2018) and inquired with 19 questions (see Appendix B) about the different phases of smartphone consumption. This research aims to comprehensively capture the entire user service time of smartphones, considering both the potential influences that occurred during usage and covariates such as demographics. All questionnaire items specifically focused on participants' previous smartphones, allowing for an examination of the complete consumption cycle. The observed variables were derived from the law draft, and the control variables from the literature review.

*Dependent Variable:* The dependent variable in this study is the user service time of smartphones. It is quantified as the difference, in months, between the date of smartphone receipt and the date of smartphone replacement. Respondents were instructed to provide these dates in the month and year format. The primary aim of this research is to investigate the impact of durability in the form of reliability and repair on the user service time of smartphones using this dependent variable.

*Independent Variables:* The variables under investigation in this study are the occurrence of a defective device or restricted functionality as the reason for replacing the previous smartphone and the frequency of repairs performed on the same device.

If consumers indicate limited functionality or defect as the reason for replacement, the replacement could probably have been prevented by higher reliability as promoted by the draft

law. Therefore, based on this variable, it can be assessed whether the draft law addresses the right reasons responsible for smartphones' relatively short user service time.

Regarding repair, participants were asked to indicate the number of times they repaired their previous smartphone. The hypothesis is that repair behavior can potentially extend the user service time of smartphones.

*Control Variables:* Including moderating variables in the analysis allows controlling additional factors that may concurrently influence the dependent variable (Wooldridge, 2020). In this study, several such variables were derived from similar studies to include their influence on user service time in the analysis.

*Consumer socio-demographics:* The group of socio-demographic variables includes gender, age, education, nationality, and income. Previous research has, for instance, shown a positive association between age and the replacement cycle (Jang & Kim, 2010; Wieser & Tröger, 2018). However, it should be noted that several socio-demographic variables were not included in the models because they may be correlated. For example, age is inherently associated with income, employment, and education. Typically, younger individuals tend to have lower education and income levels than older individuals. Since literature has shown that age is a significant determinant in explaining the user service time by socio-demographics, the variables of income, employment, and education were omitted.

*Time of acquisition:* At the time of smartphone acquisition, several factors emerge that potentially influence the user service time. These factors encompass the device's condition, such as whether it was acquired as new or used, and the mode of acquisition, including scenarios where the device is received as a gift, provided by an employer, or purchased directly by the consumer. Additionally, the contractual aspect of the acquisition, such as whether the smartphone is obtained with a SIM-lock contract or without any contractual obligations, may also be of relevance (Magnier & Mugge, 2022; Wieser & Tröger, 2018; W. B. Wilhelm, 2012).

*Personal attitude:* The model considered two dimensions that capture the relationship between consumers and their previous smartphones and may potentially influence smartphone replacement timing. To assess the level of this relationship, two items per dimension, based on the work of Wieser and Tröger (2018), were included in the survey. Participants were asked to

rate their agreement with each item on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The first dimension, care of use, pertains to treating the smartphone's hardware and has been previously associated with replacement cycles in other product categories (Evans & Cooper, 2016).

The second dimension focused on emotional attachment to the previous smartphone. Numerous studies have highlighted the connection between emotional attachment to a product, the tendency to handle it with care, and the inclination to prolong its replacement (Haines-Gadd et al., 2018; Van Den Berge et al., 2021).

Another variable is the natural algorithm of the expected lifetime in months, as the literature has also shown here that it can affect the behavior during the consumption cycle (Wieser et al., 2015).

*Period of use:* Increased daily usage may contribute to a shorter user service time, as the device may experience a more rapid decline in functionality (Ercan et al., 2016).

During smartphone usage, users may undertake measures that can positively impact the performance and condition of the device. Such measures may include the utilization of screen protectors and protection covers to safeguard against damage, regular updates to ensure optimal functioning, and adherence to care tips specifically aimed at maintaining the battery's performance. These user-initiated actions can contribute to an extended user service time by mitigating potential issues and preserving the overall functionality and condition of the smartphone (Cordella et al., 2021).

*Moment of replacement:* The reasons behind consumers' decisions to replace their previous smartphones can also play a role in determining the user service time. Various factors, such as a desire for a new phone, insufficient memory, or a stolen phone, may influence when individuals choose to replace their devices. In the survey conducted for this study, participants were allowed to select multiple reasons for replacing their previous smartphones, and each reason was represented as a dummy variable in the analysis. Additionally, a dummy variable for every year of replacement was added to control for time-specific macroeconomic or political trends that could have influenced consumer behavior (Wooldridge, 2020).

### 3.5 Sample modification and assumptions

After exporting the data set from Qualtrics, it was further edited in Microsoft Excel before it was imported into RStudio for subsequent statistical analysis. This section elaborates on how the sample was modified.

First, the user service time was calculated in total months by subtracting the date of receipt from the date of replacement. Afterward, the dependent variable was checked for outliers. Although the user service time was considerably longer or shorter in some cases, none of the observations appeared conspicuously unrealistic. Therefore, no outliers were removed from the data set. Subsequently, the natural logarithm was applied to the continuous variables of user service time and expected lifetime to ensure a normal distribution without skewness (Wooldridge, 2020). To ensure the reliability of the consumer relationship control variables, Cronbach's alpha coefficient was calculated for each dimension. The obtained values exceeded 0.6, indicating an acceptable internal consistency (Nunnally & Bernstein, 1995). Consequently, the two items within each dimension were merged.

Figure 1: Cronbach's alpha items

Constructs and items	Mean Value	(std. deviation)	Cronbach's a
<i>Care of use</i>	<b>3.02</b>	<b>1.18</b>	<b>0.75</b>
The phone had a lot of scratches	2.74	1.29	
The phone dropped on the ground many times	3.29	1.35	
<i>Emotional attachment</i>	<b>2.58</b>	<b>1.10</b>	<b>0.67</b>
The phone was worth a lot to me	2.61	1.27	
I really disliked replacing the phone	2.55	1.26	

Note: 1 = strongly disagree and 5 = strongly agree.

The application of the selected method of multiple linear regression involves adhering to the five Gauss-Markov assumptions, which include: (1) maintaining linearity between the dependent and independent variables, (2) ensuring random sampling, (3) avoiding perfect collinearity among the independent variables, (4) assuming a zero conditional mean for the error term, and (5) assuming homoscedasticity of the error term (Wooldridge, 2020).

### 3.6 Statistical Analysis

#### 3.6.1 Empirical methodology

In order to examine the research question and investigate the factors influencing the user service life of smartphones, this study utilizes three different regression models. These models are designed to explore the entire cycle of user service time and consider a comprehensive set of variables that may impact the user service time of smartphone usage. By employing these

regression models, the study aims to provide a comprehensive understanding of the factors contributing to smartphone user service time.

**Regression (1):**  $(\log) \text{ user service time}_i = \beta_0 + \beta_1 \text{ defective/restricted functionality}_i + \varepsilon$

**Regression (2):**  $(\log) \text{ user service time}_i = \beta_0 + \beta_2 \text{ number of repairs}_i + \varepsilon$

**Regression (3):**  $(\log) \text{ user service time}_i = \beta_0 + \beta_1 \text{ defective/restricted functionality}_i$   
 $+ \beta_2 \text{ number of repairs}_i + \beta_3 \text{ control}_i + \varepsilon$

The regression models in this study utilize the natural logarithm of the user service time as the dependent variable. Three regression models are employed to investigate the hypotheses and research questions.

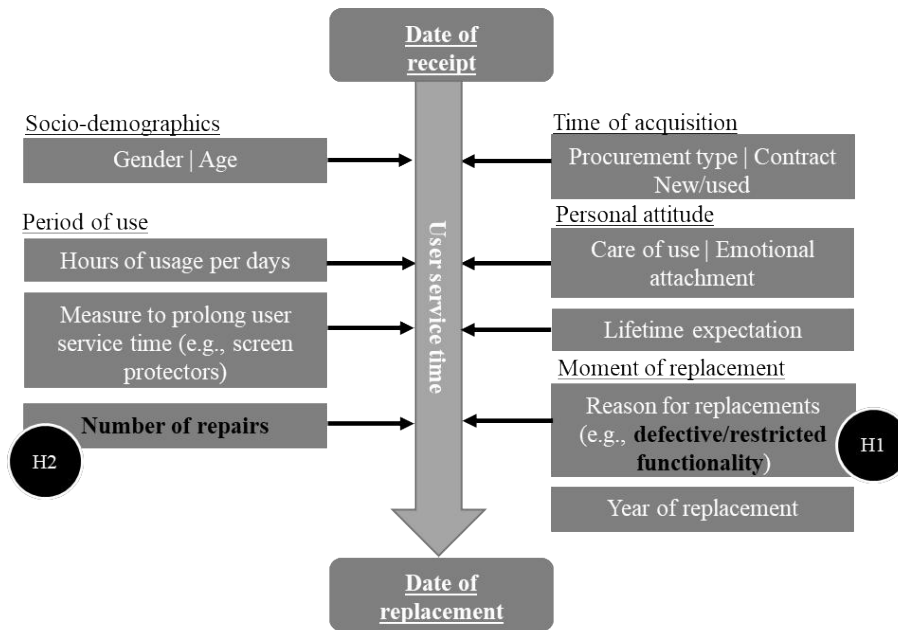
Regression 1 is a linear regression that includes only the dummy variable for defective/restricted functionality as a reason for smartphone replacement. Regression 2 includes only the number of repairs of the previous smartphone. These models aim to examine the individual effects of these variables on the user service time without any other control variables.

Regression 3 incorporates the control variables identified from previous research. These control variables are expected to impact the user service time and aid in its explanation.

This paper considers the recommended 5% significance level for studies to reject the null hypothesis (Wooldridge, 2020).

Regular ordinary least squares (OLS) regression is used in all the regression equations to analyze the effect of individual variables on the numeric outcome, which is the natural logarithm of the user service time. The investigated variables corresponding to the tested hypotheses are represented by coefficients  $\beta_1$  and  $\beta_2$ . The control variables that may influence the user service time and contribute to its explanation are represented by the coefficient  $\beta_3$ . The intercept of the models is represented by  $\beta_0$ , and the error term  $\varepsilon$  accounts for all unobserved effects, including those potentially caused by omitted variables (Wooldridge, 2020). To provide additional clarity, Appendix C presents a comprehensive overview of all variables incorporated in the regression analyses. Figure 2 illustrates the empirical framework and the various factors that can potentially influence the user service time through the cycle of consumption.

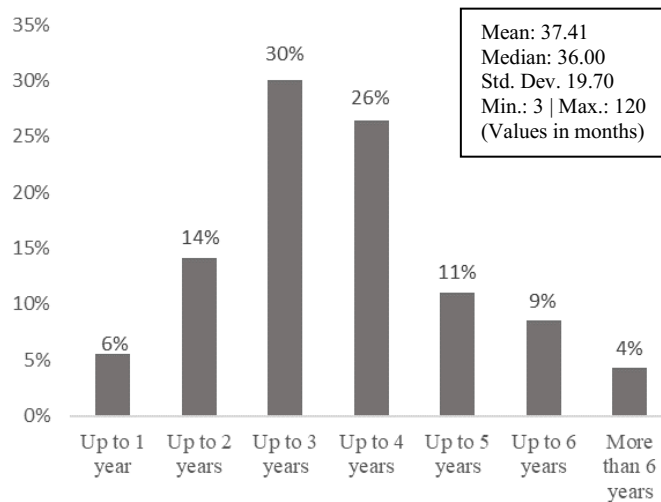
Figure 2: Empirical framework



### 3.6.2 Descriptive statistics

Based on the dataset comprising 163 observations, it was found that the average replacement cycle for smartphones is 37.41 months (equivalent to 3.12 years), with a median of 36.00 months (3.00 years). Furthermore, the shortest user service time recorded was three months, while the longest was 120 months (10 years). Remarkably, it was observed that only approximately 20% of respondents kept their smartphones for less than two years.

Figure 3: User service time



Regarding procurement type, most consumers (70%) purchased their smartphones, while 17% received them from their service providers, 9% received them as gifts, and only 4% received them from their employers.

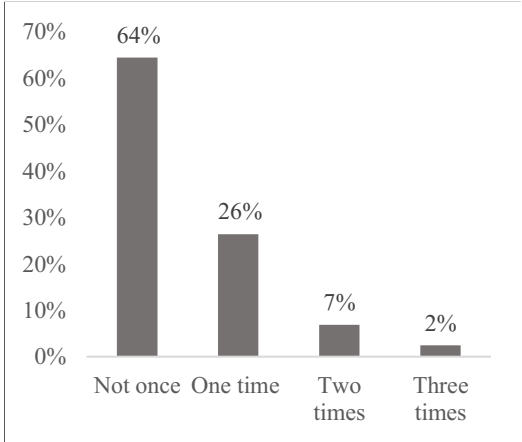
Regarding contract arrangements, approximately 47% of participants stated that their smartphones were not tied to any contractual obligations. In comparison, 27% had locked contracts (SIM-lock) with minimum contract periods, and 26% had contracts with minimum contract periods without SIM-lock. Additionally, 18% of the smartphones in the dataset were previously used before being received by the participants. Apple devices accounted for most smartphones (72%), followed by Samsung devices at 17%.

Concerning patterns of smartphone utilization, the average duration of smartphone usage per day was found to be 4.12 hours, with 81% of participants reporting usage durations of less than 5 hours. Regarding measures taken to prolong the user service time, it was observed that 65% of participants always used a screen protector, and an even higher percentage (80%) used a protective cover for their smartphones. Additionally, 80% of respondents indicated that they regularly updated their smartphones. However, adherence to care tips for battery maintenance was relatively low, with only 25% of participants stating that they always followed such tips, such as avoiding extreme ambient temperatures and utilizing automatic battery health management features.

Table 1: Measures to prolong user service time

	Yes, always	Sometimes	No
Screen protector	65 %	15 %	20 %
Protection cover	80 %	10 %	10 %
Regular updates	80 %	20 %	0 %
Follow care tips for battery	25 %	45 %	29 %

Figure 4: Number of repairs



Regarding smartphone repairs, 36% of participants reported repairing their previous smartphones, 7% reported having undergone two repairs, and 2% reported three repairs. When examining consumers' attitudes towards care of use and emotional attachment, the average score for care of use is 3.02 on a scale of 1 to 5 (with 5 indicating strong agreement). This suggests a neutral stance among consumers, indicating neither high nor low levels of care. Similarly, the mean value for emotional attachment is 2.58, which falls below the midpoint of 3. The data lead to the suggestion that, on average, consumers feel relatively less emotionally attached to their smartphones.

Examining the stated expected lifetime of smartphones, it was found that the average duration desired by consumers was 44.39 months, which is approximately equivalent to 3.70 years. This is about seven months longer compared to the average user service time of the previous smartphone. The median desired lifetime, representing the midpoint of the responses, was 40.00 months, or 3.33 years.

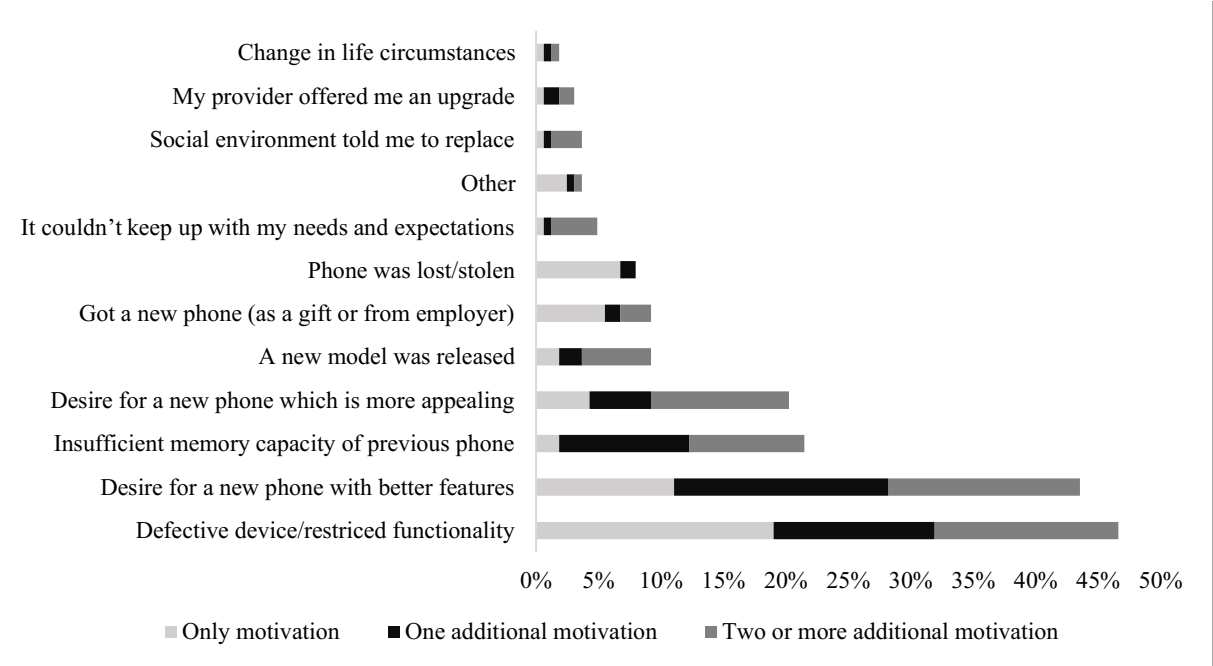
Analyzing the year of smartphone replacement, the results present that the majority of smartphones (87%) were replaced from 2020 onwards. The earliest recorded replacement year in the dataset is 2016. Additionally, 12% of the replacements occurred in the current year, 2023.

Evidence from the analysis indicates that in only 55% of cases, smartphone replacements were attributed to a single reason. The most commonly cited reason for replacement was the device being defective or functioning restrictedly.

This was the sole reason for 19% of the participants, while 13% reported an additional motivation, and 14% reported two or more additional motivations, resulting in 47% overall. Conversely, this means that 53% of smartphones were replaced not because of their condition but due to other motivations.

The explained data indicate that smartphone replacement is often driven by a combination of factors, including not only the device's condition but also the desire for a new device with improved features (44%) or a more appealing design (20%). Another reason mentioned was insufficient memory capacity, although it was the sole driver in only 2% of the cases. Reasons for replacement beyond the customer's control, such as theft or loss of the phone, were mentioned by 8%.

Figure 5: Underlying replacement motivation



## 4 Results

Two initial regression models were conducted to assess the isolated impact of the variables under investigation on the user service time.

The first model focused solely on the dummy variable "defective device/restricted functionality" as a reason for smartphone replacement. Results indicate this variable is statistically significant at the 5% level ( $p < 0.05$ ). However, the adjusted R-squared value of 0.033 suggests a relatively low explanatory power, indicating that only approximately 3.3% of the variation in the dependent variable can be explained by this variable in itself.

The second model explored the isolated effect of the variable "number of repairs" on the dependent variable. Results indicate a significant relationship at the 5% level, but the R-squared value of 0.025 is relatively low, as well.

Given the limited explanatory power of these two models, the subsequent third model incorporated all control variables as identified in the methodology to enhance the overall explanatory power and capture additional factors that may influence the dependent variable.

As the third model is a multiple regression, multicollinearity was examined. Since several variables, such as replacement year, have multiple dimensions, the Generalized Variance Inflation Factor (GVIF) is applied instead of the classical Variance Inflation Factor (VIF). To make the GVIFs of the individual variables comparable across dimensions,  $GVIF^{1/(2 \cdot Df)}$  is used. As for the VIF, the value five can also be used as a threshold for multicollinearity in this case (Fox & Monette, 1992). The discussed third model did not reach the threshold of 5; thus, there is no multicollinearity in the model (see Appendix D). A Breusch-Pagan was performed on all three models to test for the presence of heteroskedasticity. All p-values are greater than 0.05; thus, there is no evidence of heteroscedasticity (Wooldridge, 2020). All tests are illustrated in Appendix E.

Due to the imbalanced distribution of nationalities in the sample, with 81% of the respondents being German, it was deemed inappropriate to include nationality as a variable in the analysis. Similarly, the variable "brand" was not considered further due to the high prevalence of Apple smartphones (72%) among the respondents. The limited representation of other nationalities/brands would make it difficult to draw meaningful conclusions about the effects of different brands on the dependent variable (Wooldridge, 2020).

In the third model, including control variables significantly improved the explanatory power of the regression. The higher adjusted R-squared value of 0.263 indicates that 26.3% of the variation in the dependent variable can be explained. Notably, the variables "defective

device/restricted functionality" and "number of repairs" have lost their significance after controlling other factors.

Upon examining the control variables in relation to their significance level of 5%, it is evident that age significantly impacts the user service time. All age categories, except for the 35-44 range, exhibit statistical significance. Notably, there is an increasing trend in the coefficients for all age ranges, indicating that consumers tend to use their smartphones longer as their age increases. However, the influence of gender on user service time cannot be confirmed from the results.

The method of obtaining the smartphone, whether through purchase or as a gift, does not yield statistically significant results.

The variable indicating whether the device is used or new proves to be significant, with a negative impact on user service time. This suggests that previously used smartphones have a shorter lifespan than brand new ones.

The smartphone's contractual status, whether locked to a contract or not, does not display statistical significance. Similarly, most of the measures taken to prolong the user services time, such as using screen protectors, do not yield significant results at the 5% level. Additionally, the usage time per day does not significantly influence user service time.

Among the reasons for smartphone replacement, only device theft and insufficient memory storage significantly correlate with a shorter user service time.

The year a smartphone was replaced does not demonstrate statistical significance, indicating that external economic factors or temporal events do not play a significant role in user service time.

On the other hand, the expected device lifetime and the consumer's care of use exhibit significance at the 5% level. This suggests that individuals who express longer expected lifetimes of their smartphones and exhibit more excellent care in their usage tend to have longer user service time. It also fits into this pattern: consumers who sometimes use a protection cover, replace their smartphones later.

Lastly, emotional connection with the device does not prove to be a significant factor influencing user service time.

*Hypothesis 1: Smartphones replaced due to defective conditions or restricted functionality have a shorter user service time.*

In the first model, the variable "defective device/restricted functionality" is significant at the 5% level with a positive coefficient. This initially suggests that smartphones replaced due to "defective device/restricted functionality" may have, on average, a longer user service time. In model 3 with control variables, the variable "defective device/restricted functionality" still has a positive coefficient but is not statistically significant at the 5% level. Thus, there is inadequate evidence to support hypothesis 1.

*Hypothesis 2: Smartphones undergoing repair(s) have an extended user service time.*

The second model reveals that the variable "number of repairs" is statistically significant at the 5% level, indicating a positive coefficient. This suggests that smartphones with a higher number of repairs may, on average, have a longer user service time. However, in model 3, where control variables were added, the "number of repairs" no longer maintains statistical significance at the 5% level. This indicates that there is insufficient evidence to consistently support hypothesis 2 across these models. Based on the results obtained from the different models, it remains inconclusive whether smartphones with a higher number of repairs indeed have a longer user service time.

Table 2: Regression results

	Dependent Variable = User Service Time (natural log)		
	Model (1) Defective/restricted functionality only	Model (2) Number of repairs only	Model (3) All variables
<b>Variables examined</b>			
Defective device/restricted functionality (=1 if reason for replacement is defective device/restricted functionality)	0.234** (0.091)		
Number of repairs (0 – 3 times)		0.150** (0.066)	
<b>Socio-demographics dummies</b>			
Gender male			-0.072 (0.099)
Age 25 - 34			0.245** (0.111)
Age 35 – 44			0.231 (0.267)
Age 45 – 54			0.460** (0.188)
Age 55 - 64			0.488*** (0.156)
<b>Time of acquisition dummies</b>			
Mode of acquisition: Gift			0.350 (0.287)
Mode of acquisition: Provider			-0.171 (0.275)
Mode of acquisition: Purchase			-0.108 (0.253)
State of phone used/new (1=if used)			-0.299** (0.127)

Contract: Locked to a contract (SIM-lock)			0.009 (0.127)
Contract: No contract with a minimum period			0.141 (0.121)
<i>Hours of usage per day (natural log, continuous variable)</i>			-0.018 (0.019)
<b>Measures to prolong User Service Time Dummies</b>			
Screen Protector Sometimes			-0.018 (0.173)
Screen Protector Yes, always			0.003 (0.143)
Protection Cover Sometimes			0.451** (0.220)
Protection Cover Yes, always.			0.326* (0.185)
Regular Updates Cover Yes, always.			0.085 (0.119)
Batterie Care Tipps Sometimes			-0.053 (0.111)
Batterie Care Tipps Yes, always			-0.004 (0.134)
<b>Personal attitude</b>			
Care of Use (Max: 5, Min: 1)			0.150*** (0.047)
Emotional Attachment (Max: 5, Min: 1)			0.050 (0.047)
Expected lifetime (natural log, continuous)			0.228** (0.094)
<b>Year of replacement Dummies</b>			
2017			0.040 (0.515)
2018			0.010 (0.553)
2019			-0.132 (0.443)
2020			0.112 (0.443)
2021			0.200 (0.428)
2022			-0.068 (0.430)
2023			-0.060 (0.447)
<b>Reasons for Replacement Dummies</b>			
Desire for a new phone which is more appealing			0.012 (0.122)
Desire for a new phone with better features			0.025 (0.106)
Insufficient memory capacity of previous phone			0.255** (0.114)
Social environment told me to replace			0.016 (0.247)
Got a new phone			0.058 (0.179)
My provider offered me an upgrade			-0.223 (0.258)
It couldn't keep up with my needs and expectations			-0.069 (0.211)
A new model was released			-0.112 (0.171)
Change in life circumstances			0.358 (0.335)
Phone was lost/stolen			-0.481** (0.191)
Other			-0.092 (0.276)
Constant	3.364*** (0.062)	3.409*** (0.054)	1.550** (0.685)
Observations	163	163	163
R2	0.039	0.031	0.454
Adjusted R2	0.033	0.025	0.263
Note: *p<0.1; **p<0.05; ***p<0.01			

## 5 Main Findings and Discussion

The average replacement cycle determined in this study, which is 3.12 years, is consistent with findings from comparable studies, providing support for the validity of the results (Jaeger-Erben et al., 2021; Thiébaud -Müller et al., 2018). The descriptive analysis conducted in this thesis revealed that the most cited reason for smartphone replacement is the limited condition of the device. The results also indicate that a majority of respondents (53%) did not replace their smartphones due to a defect or restricted functionality. This suggests the presence of various underlying reasons for smartphone replacement. The second finding from the descriptive statistics that 36% of participants had repaired their previous smartphone at least once, indicates that repair was a common practice among study participants.

In the following, the author focuses on the key findings of the multiple regression:

### **Smartphone replacement patterns are not solely driven by functionality and the number of repairs**

To determine whether the "Ecodesign Requirements for Mobile Phones, Cordless Phones and Tablets" apply the right levers that have a significant impact on the user service time of smartphones, a multiple regression analysis was conducted. As a representative of reliability, it was tested if smartphones are replaced early due to defective/restricted functionality. As a proxy for repairability, it was determined whether repair(s) prolong the user service time.

Consistent with the results of the study conducted by Magnier and Mugge (2022), the hypotheses examined in this dissertation were not confirmed. Although the first two models indicated the significance of the variables analyzed, the significance dropped with the addition of the control variables. This indicates that the control variables explain the relationship between the independent variable and the dependent variable. The results of this study indicate that the factors influencing the user service life of smartphones are complex and varied.

### **The length of the user service life depends strongly on the characteristics and behavior of the consumer**

The results provide insights into the second research question, which focusses on other factors having a significant influence on user service time. The variables that proved to be

significant are age, condition of the phone at purchase, use of protective cover, expected lifetime, and certain reasons for replacement, such as theft, loss, or insufficient storage capacity.

Other findings indicating that used smartphones have a shorter user service time could be due to various reasons. It may result from the actual condition that the device is worn out by its previous user and thus has a higher likelihood of malfunctions (Ercan et al., 2016). Another reason could be the general perception that second-hand devices last shorter than new ones (Van Weelden et al., 2016). The different reasons for an earlier replacement could be discussed in further research. It should be noted that the implementation of this variable was relevant for answering the research question, as it has an influence on the variables under investigation. Yet this factor has not always been considered in other studies and the analysis of smartphones user service time (Wieser & Tröger, 2018).

Among the various reasons for smartphone replacement, two reasons have emerged as significant: theft/loss and insufficient memory capacity. Smartphones replaced due to insufficient memory capacity have a positive coefficient, suggesting that they tend to have a longer user service time. It is worth noting that the relevance of insufficient memory as a replacement reason may diminish in the future. With the increasing availability of cloud storage options, users may rely less on device storage to store their data. Consequently, this replacement ground could resolve itself without further legal intervention. The replacement reason theft/loss can also not be influenced by an ecodesign law perspective.

Despite previous studies attributed importance to certain reasons for smartphone replacement, such as early replacement due to the release of new devices, desire for a better design or enhanced functions (Jaeger-Erben et al., 2021; Okada, 2006), no evidence of their importance was found in this dissertation. It is possible that certain control variables in the regression had a stronger explanatory power for the user service time and thus overshadowed the significant effect of the reasons mentioned above. To develop a deeper understanding of the factors that influence these reasons for substitution, further research could analyze these replacement reasons as dependent variables.

The significance of the age variable and its increasing coefficients per older category indicates that younger consumers tend to replace their smartphones earlier than older individuals. This finding aligns with the conclusion drawn by Wieser & Tröger (2018). Their analysis suggests that older people exhibit greater care in terms of their devices and are less driven by the desire for novelty. The significance of consumers' age indicates the importance of consumers' behavior rather than the durability of the device.

The analysis also reveals the relevance of two variables related to consumer behavior with the care of use and the use of a protection cover. These findings emphasize the importance of how individuals handle and protect their smartphones. Both behaviors can prevent reaching a defective state (Cordella et al., 2021). The significant impact and higher coefficient associated with the "sometimes" use of the protection cover, compared to the "always" use, raises suspicion that an unaccounted variable may be influencing this factor. Further analysis is needed to investigate this result.

Evidence from the analysis confirms the significance of the expected lifetime on the user service time. A previous study has shown that consumers who expect a longer lifetime tend to take better care of their devices, as they expect to use them for many years to come (Wieser et al., 2015).

## **6 Conclusion**

### **6.1 Legal Implications**

The findings of this dissertation did not provide evidence to support the notion that lack of durability is the primary driver of early smartphone replacement. As a result, alternative approaches should be considered for future EU legislation or initiatives.

The findings reveal that a significant portion of smartphones were not replaced due to defects and remained in functional condition. However, there is a prevailing sense of skepticism among citizens regarding the durability of smartphones, driven by media and political debates surrounding issues like planned obsolescence. This perception often leads consumers to justify upgrading their phones prematurely (Makov & Fitzpatrick, 2021). To tackle this skepticism, policymakers should focus on increasing awareness of the extended lifespan potential of smartphones and reshape the narrative surrounding their long-term performance.

An effective strategy could involve introducing lifetime labels, which would serve as reference points for consumers (Van Den Berge et al., 2021). This would be particularly impactful, considering the significant influence of expected lifetime on user service time, as demonstrated in the study. The expectation of a long service life could ensure that the consumer automatically handles the device more carefully.

To advance the transition from a throwaway culture to a more sustainable one, awareness campaigns can play a vital role by emphasizing the environmental benefits of prolonging the lifespan of smartphones by each additional year. This could convey to consumers that their actions have a direct impact on the environment and contribute to stopping climate change.

Additionally, it is crucial to cultivate pro-environmental attitudes among young people, particularly within educational settings. Schools can integrate teachings on appliance repair, equipping children with the skills and knowledge to fix their own devices. Beyond educational contexts, the establishment of repair cafés equipped with the necessary tools and connections can further encourage individuals to engage in self-repair practices (Moalem & Mosgaard, 2021). One of the findings of the study were different replacement cycle between younger and older generations. Repair cafés could become a meeting place for young and old, where appreciation for repairs and enthusiasm towards a culture of sustainability could be rediscovered and passed on from the older generation to the younger generation.

## **6.2 Limitations and further research**

One limitation of the methodology, which considers an entire consumption cycle, is that the previous smartphone must be considered for the cycle to be complete. Since the last replacement may already be several years ago, the underlying data may not reflect current consumer behavior. In addition, answering the question required a lot of memory, as evidenced by the fact that a relevant proportion of respondents could not remember the date of purchase or replacement and were therefore excluded from the analysis. Consequently, a long-term study including mainly consumers who have recently replaced their smartphones could yield even more valid results (Wieser & Tröger, 2018).

Another weakness of the study was the imbalanced sample in terms of nationality and brand. As a result, these two factors were excluded from the analysis and could not be further examined. Additionally, the distribution of other demographic factors, such as age, was not representative. While the findings regarding age were consistent with previous studies, there remains a risk of biased results (Wooldridge, 2020). Future research would benefit from incorporating more diverse samples to mitigate these limitations and enhance the generalizability of the findings. Furthermore, even as the R-squared value of 0.263 is above 0.26 and considered substantial (Cohen, 1992), there is still the possibility of uncaptured external effects, commonly known as omitted variable bias (Wooldridge, 2020).

Moreover, the study is focused on the reasons that lead to a replacement but not on the exact analysis of what could have a positive effect on a longer user service time, according to the opinion of the consumer. Future work could therefore be a survey that analyses how, according to the consumer, the proposals from the draft law, as well as other suggestions from literature, could have an impact on the user service time.

Besides, the exact measures of the law draft were not compared to the exact defects of the consumer to see if the most important points were added. The same with reasons that prevent consumers from repairing and whether these are addressed in the law. These two points would be a further opportunity to deepen this work.

Finally, future research could broaden the scope by conducting similar studies on other devices, such as tablets, that are also covered by the proposed legislation. Similarly, exploring the topic of reuse, which is addressed in the draft legislation, could provide valuable insights.

### **6.3 Conclusion**

In conclusion, the results of the study demonstrate that the smartphone user service time is not solely dependent on the durability, reliability, and repairability addressed in the ecodesign law draft. Rather, it is a complex interplay of various factors that have a significant impact on user service time, including the age of the consumer, the condition of the phone at the time of purchase, the care of use, the use of protective cases, the expected life of the device, and certain reasons for replacement such as theft, loss, or insufficient storage capacity.

While the drafted "Ecodesign requirements for mobile phones, cordless phones, and tablets" adopt a product-centric approach focusing on engineering, this research suggests that these measures alone may not sufficiently extend smartphone replacement cycles. It highlights the critical role of consumer characteristics, durability attitudes, and device care practices in determining user service time.

To enable change towards longer smartphone use, regulatory initiatives need to be complemented by targeted consumer education and efforts to promote sustainable behavior, especially among younger users. The findings of this dissertation underscore the need for comprehensive measures that go beyond a purely product-oriented approach.

If the EU aims to address urgent issues such as mining damage, electronic waste, and greenhouse gas emissions, which are compounded by short replacement cycles, a holistic strategy that involves both manufacturers and consumers in responsible practices is crucial. Therefore, the future of sustainable smartphone usage requires an integrated and multifaceted approach that considers both product-related and user-centric factors.

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## Appendix

### Appendix A: Socio-demographics

Table 3: Socio-demographics

Category	n	%
<i>Gender</i>		
Female	77	47.24%
Male	86	52.76%
<i>Age</i>		
0	0	0.00%
18 - 24	38	23.31%
25 - 34	81	49.69%
35 - 44	5	3.07%
45 - 54	12	7.36%
55 - 64	27	16.56%
<i>Nationality</i>		
Germany	132	80.98%
Italy	7	4.29%
Portugal	5	3.07%
Other	19	11.66%
<i>Highest level of education</i>		
Completed Primary Education	2	1.23%
Completed Secondary	17	10.43%
Vocational or Similar	36	22.09%
University Bachelors degree or similar	69	42.33%
University Masters degree or similar	36	22.09%
PhD	3	1.84%
<i>Total household income</i>		
Less than 25,000 €	56	34.36%
25,000 - 49,999 €	37	22.70%
50,000 - 99,999 €	33	20.25%
100,000 - 199,999 €	21	12.88%
More than 200,000 €	7	4.29%
Prefer not to say	9	5.52%
<i>Employment Status</i>		
Working full-time	69	42.33%
Working part-time	25	15.34%
Unemployed and looking for work	4	2.45%
A homemaker or stay-at-home parent	0	0.00%
Student	60	36.81%
Retired	3	1.84%
Other	2	1.23%

## Appendix B: Survey Structure

Intro

Dear participant,

I would like to thank you in advance for your time and participation in this survey. This research is being done under a Master's Thesis in International Management, by FGV EBAPÉ and Universidade Católica Portuguesa; every data collected will be treated anonymously and only used for research purposes.

This survey will take you 8 - 10 minutes to complete and it is important to answer all questions as honestly as possible, after reading each question carefully. There are no right or wrong answers.

If you have any questions or interest in knowing the final results of this study, please contact: s-mkleinlanghorst@ucp.pt

Thank you very much!  
Max Kleinlanghorst

End of Block: Intro

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Start of Block: Demographics

Q1: How do you describe yourself?

- Male (1)
  - Female (2)
  - Non-binary / third gender (3)
  - Prefer to self-describe (4)
- 

- Prefer not to say (5)
- 

Q2: Where are you from?

▼ Austria (1) ... Sweden (26)

---

Q3 How old are you?

- 18 - 24 (2)
  - 25 - 34 (3)
  - 35 - 44 (4)
  - 45 - 54 (5)
  - 55 - 64 (6)
- 

Q4 What best describes your employment status over the last three months?

- Working full-time (1)
  - Working part-time (2)
  - Unemployed and looking for work (3)
  - A homemaker or stay-at-home parent (4)
  - Student (5)
  - Retired (6)
  - Other (7)
-

Q5 What is the highest level of education you have completed?

- Completed Primary Education (2)
  - Completed Secondary (3)
  - Vocational or Similar (4)
  - University Bachelors degree or similar (6)
  - University Masters degree or similar (7)
  - PhD (10)
  - Prefer not to say (8)
- 

Q6 What was your total household income before taxes during the past 12 months per year in Euros?

- Less than 25,000 € (1)
- 25,000 - 49,999 € (2)
- 50,000 - 99,999 € (3)
- 100,000 - 199,999 € (4)
- More than 200,000 € (5)
- Prefer not to say (6)

**End of Block: Demographics**

**Start of Block: Previous Phone**

**For the following questions, please refer to the mobile phone you used BEFORE your current mobile phone.**

---

Q7 Into which category fell your previous mobile phone?

- Smartphone (phone with regular touch screen) (1)
  - Feature phone (basic functions) (2)
  - Foldable smartphone (3)
  - Other (4)
- 

Q8 What was the brand of your previous mobile phone?

- Samsung (1)
  - Apple (2)
  - Xiamoi (3)
  - Huawei (4)
  - Oppo (5)
  - Motorola (6)
  - OnePlus (7)
  - Other (8)
-

Q9 How did you get your previous mobile phone?

- Purchase (new) (1)
  - Purchase (used) (2)
  - Purchase from provider with discount as part of a contract (13)
  - Gift from provider (3)
  - Gift (new) (4)
  - Gift (used) (5)
  - From employer (new) (6)
  - From employer (used) (7)
  - Other (8) \_\_\_\_\_
  - Don't know anymore (9)
- 

Q10 When did you get your previous mobile phone?

Year (1)

Month (2)

▼ I don't know (1) ... 2023 ~ 05 (177)

---

Q11 Which of the following options applied to your previous mobile phone?

- Locked to a contract (SIM-lock) with a minimum contract period (1)
- Contract with provider without SIM-lock (without tying the device to a specific mobile operator) (2)
- No contract with a minimum contract period (3)

Q12 Thinking about your previous mobile phone, to what extent do you agree with the following statements

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
I really disliked replacing the phone (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The phone was worth a lot to me (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The phone had a lot of scratches (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The phone dropped on the ground many times (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q13 Have you taken measures to extend the longevity of your previous mobile phone?

	Yes, always (1)	Sometimes (2)	No (3)
Screen protector (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Protection cover (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regular updates (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Follow care tips for battery (e.g., avoid extreme ambient temperatures, automatic battery health management) (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q14 How many hours did you use your previous mobile phone on average per day? (Insert a number)

Hours (1)

▼ 1 (1) ... 24 ~ 60 (1464)

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Q15 How often have you had your previous mobile phone repaired or repaired it yourself?

- Not once, but it was never defect (1)
  - Not once (2)
  - One time (3)
  - Two times (4)
  - Three times (5)
  - More than three times (6)
- 

Q16 What was the state of your previous phone when it was replaced?

- Working well (no significant problems with functionality) (1)
  - Partly malfunctioning (product could perform its main function, but it also suffered loss in functionality) (2)
  - Broken (product could not perform its main function anymore) (3)
-

Q17 Why did you replace your previous mobile phone? (multiple answers)

- Defective device/restricted functionality (Broken screen, weak battery, slowly reacting, no updates, etc.) (1)
  - Desire for a new phone which is more appealing (appealing design, easier to use, etc.) (2)
  - Desire for a new phone with better features (improved performance, camera resolution, etc.) (3)
  - Insufficient memory capacity of previous phone (4)
  - Social environment told me to replace (5)
  - Got a new phone (as a gift or from employer) (6)
  - My provider offered me an upgrade (7)
  - It couldn't keep up with my needs and expectations (8)
  - A new model was released (9)
  - Change in life circumstances (10)
  - Phone was lost/stolen (11)
  - Other (12) \_\_\_\_\_
- 

Q18 When did you replace your previous mobile phone with your current mobile phone?

Year (1)

Month (2)

▼ I don't know (keine Angabe) (1) ... 2023 ~ 05 (177)

End of Block: Previous Phone

---

Start of Block: Expectations

Q19 How long do you currently estimate the expected lifetime of a mobile phone? (in months)

End of Block: Expectations

## Appendix C: Variable Overview

Table 4: Variable overview

Variable R	Description	Characteristics	Type
<i>gender</i>	Gender	Male Female	Dummy
<i>age</i>	Age	Age 18 - 24 Age 25 - 34 Age 45 - 54 Age 55 - 64	Dummy
<i>purchase_way2</i>	Mode of aquisition	Gift Provider Purchase Employer	Dummy
<i>used_new</i>	State of phone	New = 0 Used = 1	Dummy
<i>contract</i>	Type of contract	Locked to a contract (SIM-lock) Contract with provider without SIM-lock No contract with a minimum period	Dummy
<i>screen_protector2</i>	Screen protector	Yes, always Sometimes No	Dummy
<i>protection_cover2</i>	Protection Cover	Yes, always Sometimes No	Dummy
<i>regular_updates_2</i>	Regular Updates	Yes, always Sometimes No	Dummy
<i>care_tipps_2</i>	Battery care tipps	Yes, always Sometimes No	Dummy
<i>usage_per_day</i>	Phone usage per day in hours	0 - 24	Continuous
<i>amount_of_repair</i>	Amount of repairs	0 - 3	Continuous
<i>as.factor(replacement_year)</i>	Year of replacement	2016 - 2023	Dummy
<i>log(lifetime_expectation)</i>	Lifetime expectation in months	0 - 160	Continuous
<i>care_of_use</i>	Care of use	1 - 5	Continuous
<i>emo</i>	Emotional attachement	1 - 5	Continuous
<i>defective_device</i>	Defective device/restriced functionality	0, 1	Dummy
<i>desire_design</i>	Desire for a new phone which is more appealing	0, 1	Dummy
<i>desire_better_features</i>	Desire for a new phone with better features	0, 1	Dummy
<i>insufficient_memory</i>	Insufficient memory capacity of previous phone	0, 1	Dummy
<i>social_environment</i>	Social environment told me to replace	0, 1	Dummy
<i>gift_employer</i>	Got a new phone (as a gift or from employer)	0, 1	Dummy
<i>upgrade</i>	My provider offered me an upgrade	0, 1	Dummy
<i>couldnt_expectations</i>	It couldn't keep up with my needs and expectations	0, 1	Dummy
<i>new_model</i>	A new model was released	0, 1	Dummy
<i>change_in_life</i>	Change in life circumstances	0, 1	Dummy
<i>phone_stolen</i>	Phone was lost/stolen	0, 1	Dummy
<i>other</i>	Other	0, 1	Dummy

## Appendix D: GVIF Test

Table 5: GVIF test model 3

	GVIF	Df	GVIF <sup>1/(2*Df)</sup>
gender	1.537756	1	1.240063
age	2.901418	4	1.142421
purchase_way2	4.387825	3	1.279504
used_new	1.497716	1	1.223812
contract	2.183958	2	1.215657
screen_protector2	2.558070	2	1.264673
protection_cover2	2.729128	2	1.285304
regular_updates_2	1.444213	1	1.201754
care_tips_2	2.113155	2	1.205682
usage_per_day	1.386765	1	1.177610
amount_of_repair	1.520367	1	1.233032
as.factor(replacement_year)	6.640879	7	1.144802
log(lifetime_expectation)	1.504141	1	1.226434
care_of_use	1.962828	1	1.401010
emo	1.641612	1	1.281254
defective_device	2.058323	1	1.434686
desire_design	1.509437	1	1.228592
desire_better_features	1.755400	1	1.324915
insufficient_memory	1.382546	1	1.175817
social_environment	1.371545	1	1.171130
gift_employer	1.684061	1	1.297714
upgrade	1.254696	1	1.120132
couldnt_expectations	1.308914	1	1.144078
new_model	1.548241	1	1.244283
change_in_life	1.277132	1	1.130103
phone_stolen	1.696348	1	1.302439
other	1.426175	1	1.194226

## Appendix E: Breusch-Pagan Tests

Table 6: Breusch-Pagan test model 1

```

studentized Breusch-Pagan test

data: lm_independent
BP = 0.34676, df = 1, p-value = 0.556

```

Table 7: Breusch-Pagan test model 2

```

studentized Breusch-Pagan test

data: lm_independent2
BP = 1.7483, df = 1, p-value = 0.1861

```

Table 8: Breusch-Pagan test model 3

```

studentized Breusch-Pagan test

data: lm_backward_2
BP = 50.75, df = 42, p-value = 0.1668

```