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A mechatronic approach to smartphone failure analysis and sustainable maintenance solutions

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Abstract: In the context of sophisticated mechatronic technologies, this study explores the complex effects of smartphone repair services on the economy, society, and environment. The objective is to investigate the ways in which repair services support social inclusion, economic opportunity, and sustainability. The qualitative approach uses information from industry reports, case studies of nearby repair companies, scholarly literature, and community feedback and forums to gauge public opinion. According to research, the surge in smartphone manufacturing has raised environmental issues and e-waste. However, by encouraging sustainable use, prolonging equipment lifespans, and lowering the demand for new production, repair services help to minimize these problems. In terms of the economy, the repair industry creates jobs and offers chances to develop technical skills. Socially, it promotes digital inclusion by providing affordable technology, particularly in marginalized places. The incorporation of public opinion demonstrates considerable community support for repair activities and rising consumer knowledge of sustainability. Finally, smartphone repair services are critical for mitigating the negative externalities of mechatronic progress. The report proposes that politicians and industry stakeholders encourage and invest in repair services as part of a larger plan for long-term growth and social equality.
Keywords: *Advanced mechatronic device, Circular economy, Hardware, Smartphone, Software.*

1. Introduction

Smartphones now have unique qualities thanks to recent significant technological advances. Because numerous tasks are carried out by one component, such as integrated circuits, while a system is perceived to be complicated, there may be more issues now than there were a few years ago. Although some companies may have collapsed and others may have gained popularity in recent years, the majority of these manufacturers now provide products that are smartphones rather than just regular phones.

The article that will be discussed includes information on phone malfunctions in terms of hardware and software, and solutions using appropriate technology. Even though most countries now have a warranty that lasts for about two years or less, this does not mean that they do not require repair, because the frequency of damage does not dictate that replacement should only be done with new ones, only when a manufacturer fails, or the problems presented cannot be fixed. Thinking that this article is also helpful to businesses that are struggling with a certain occurrence or who may need to consider some internals or breakdowns based on the data that was gathered.

The application of the latest technology creates some problems because it involves the integration of many functions into a single module, which probably offers the main cost advantage. However, it also presents more problems and, in some ways, creates limits even for repairs. Often, repairs are not carried out because the investment is deemed not worth the rent burden. These issues will be included in the results, and some recommendations will be made.

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Such efforts can be helpful in the end-of-life management Process, particularly when reusing components that in some way increase the equipment's lifetime. Especially considering that recycling electronic waste contains hazardous materials and incurs high management costs in terms of technology as well as human resources, which must be qualified with relevant knowledge and experience. It is stated that in order to increase the lifespan of mobile phones, users' views on returning equipment for reuse and repair must change for the better [1]. E-waste is a severe issue for both society and the environment, and in the last five years, both its volume and rate of production have drastically increased [2, 3].

Smartphone repair itself fits into the circular economy concept in an urban setting, and related operations like restoration, reengineering, and recycling are environmentally friendly and support the objectives of sustainable development. Although it initially appears to be a complex technology to repair, this helps us understand that the majority of people who take repair courses can solve problems effectively [4].

1.1. Historical Changes to Mobile Phone Technology and Services

The origins of mobile phones depend on the technology used, but as it has evolved in terms of technology and services, substantial progress has been made in design. The primary goal of modern technology is to make life easier and more efficient, and smartphones play a significant role in that. Smartphones now serve as personal assistants, event organizers, communication devices, and entertainment media, as [5]. From a brick to a smartphone.

Figure 1.
From brick to smartphone
Source: Moss [1].

As a communication device, smartphone technology has emerged as the most fascinating modern phenomenon. Nonetheless, its application needs to be such that it promotes inventive advantages that advance society. Learning how to use technology should be the main focus, and access to smartphone technology should always come with a reward. The complexity of integrated circuits is expected to increase steadily over the next 18 months, as predicted by Moore; therefore, the technology behind smartphones will also continue to advance [6].

The technological aspect, as well as the design, varies from time to time, but regardless of model or technology, the phone is made up of several inseparable parts for the communication of this embedded or mechatronic device, such as LCD, charging port, microphone, PCB, sensors, flex cable, etc. This conclusion that there are similar parts does not imply that their servicing is also similar; previous experience only aids in understanding the operation of equipment and components, but there is a fundamental difference in repairs.

If the screen's aspect is the only factor considered, early technology used it as an output device. However, with the advent of the touchscreen and its integration into the layers, it has become both an output and an input device, changing not only the technology but also the size of the screen. There are variations in terms of repair because the first example used a technology in which the flex cable's connection to the PCB was established using tape and tiny pins. It frequently happened that the contact migrated during physical collision, but with intervention, it reverted to normal. For example, the first picture taken from the table reveals a Nokia 1100.

Figure 2.
The development of smartphone screens from [https://lucentlcd.com/introduction-to-the-history-of-lcd], last retrieved 23.3.2025.

With today's technology, unlike the previous one, which featured a touch screen, the front glass is almost exclusively protective and has no other purpose. Its benefit is that it still has a chance to be replaced by technology that is acceptable, as is the case with the LCD separator for mobile phones and the device that holds the glass using OCA, and then the screen using high pressure up to 8 bar. Another illustration is the loading ports, which have parts that are not attached simply because they were designed to be in that form, just with contact. Today, however, they are directly attached to the PCB or to the flex cable that is connected to the connector, as it has been emphasized that in the past we only understood the concept, while the repair is carried out differently, and there are other examples, such as air soldering equipment. The most significant change is most likely the significant improvement in sound quality with the microphone, which was once simple but is now an integrated circuit.

The technical issues that have arisen recently as a result of the addition of functions such as the home button, fingerprint, face ID, and so on are most likely problems that did not exist previously, but they have solutions and can be repaired using some of the technologies that have just been mentioned.

2. Related Work

The reuse of parts, which can extend the life of the device, is the most important point that can be fulfilled through the repair of electronic waste. It is even possible to anticipate environmental directives as a consequence of this. Repair, reduce, and recycle, as the three "RRRs" are known, for e-waste, many studies and scientific works have been conducted because it is one of the factors that has a significant impact on the environment. According to Ajaegbu et al. [7], their findings, China, despite being the largest producer of these devices, is also the most active in this field.

Despite the fact that the most recent years are not shown in Table 1, it is clear that data were gathered between 2002 and 2013. This does not imply, however, that there has been a major shift in the number of dangerous elements present in cell phones sold today [8].

According to "Figure 3," electronic devices account for the majority of 3.5%, but this does not imply that they are the only ones, as smartphones contain plastic and a variety of other materials. Most likely, it is also the section containing the majority of hazardous materials that require special recycling treatment. Many electronic industries rely on printed circuit boards (PCBs), which are high in heavy metals and toxic halogenated organic substances [9, 10].

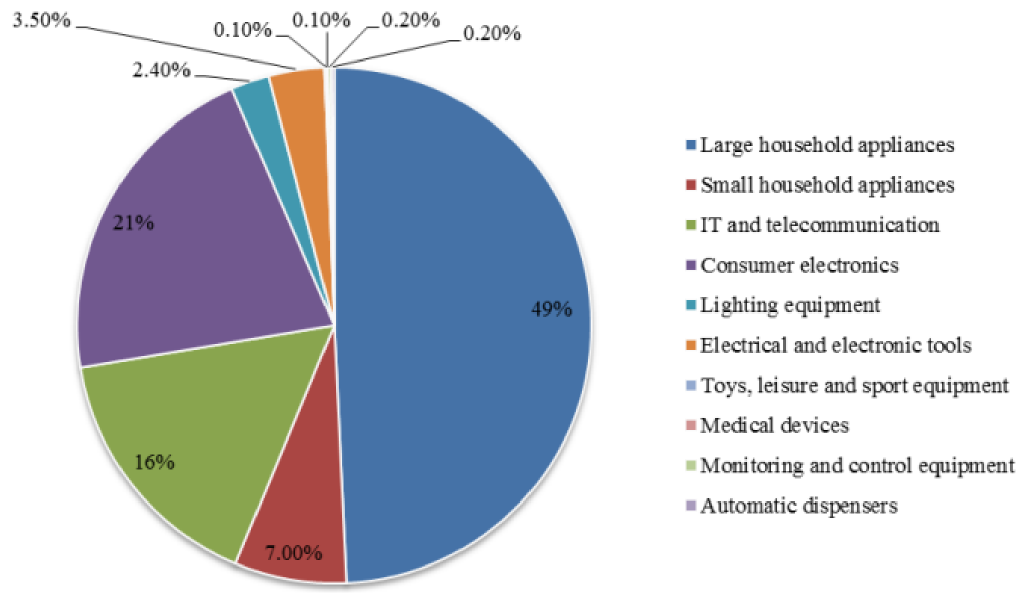

Figure 3.
Classification of WEEE.
Source: Ajaegbu et al. [7].

The company in question collects all damaged screens and PCBs, separates the parts that can be used again, and then agrees to send the materials back to be recycled in the most developed nations. This actually gives the company a direct financial benefit while also indirectly helping to protect the environment. It, in fact, consists of two modules or portions that are the most hazardous, using Excel [11] or other methods as the Synthetic Minority Oversampling Technique [12].

There should be such services that connect manufacturers and industries in every nation. Surprisingly, a large proportion of repairs are performed by consumers themselves. The main barrier is the higher price of low-cost jobs for new products, which is often the best value, contributing to the business's repair costs and low consumer motivation. Furthermore, because a skilled workforce is a major challenge for the repair industry, it is expected to grow in the coming years. As industry consumers agree that they are good products, this results in a significant increase in motivation and many profitable repairs. These findings have policy implications for extending product life through repairs, such as increased use and complaint recognition. "Fix your mobile phone within 30 minutes," asserts a Taiwanese mobile phone repair company.

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Table 1.
Leachates from waste mobile phones according to the Toxicity Characteristic Leaching Procedure (TCLP). Note: N.D.: not detected; concentrations in bold are above regulatory limits; a unit of measurement is mg/L.

Model / Year	Ag	As	Ba	Cd	Cr	Pb
MOTO V70 (2002)	2.23	N.D.	147.6	0.22	3.46	23.78
MOTO E398 (2004)	1.42	0.20	138.3	0.05	3.31	7.22
NOKIA 1100 (2005)	0.24	0.03	81.0	0.02	2.38	1.96
NOKIA 1110 (2005)	0.22	0.03	79.2	0.02	2.22	1.63
NOKIA 2310 (2006)	0.20	0.01	72.0	0.01	2.10	1.34
SAMSUNG E250 (2007)	0.17	N.D.	61.0	N.D.	1.99	1.12
SONY E200 (2008)	0.15	N.D.	59.0	N.D.	1.87	0.97
APPLE iPhone 3G (2009)	0.13	N.D.	50.0	N.D.	1.75	0.85
HTC Hero (2010)	0.11	N.D.	48.0	N.D.	1.65	0.72
SAMSUNG Galaxy S (2011)	0.10	N.D.	46.0	N.D.	1.54	0.60
NOKIA Lumia 800 (2012)	0.09	N.D.	45.0	N.D.	1.43	0.52
HTC One (2013)	0.08	N.D.	44.0	N.D.	1.43	0.45

Source: Abdelbasir et al. [8].

The fluctuation in heavy metal concentration across various phone models and production years is correctly and clearly shown in Table 1. According to the statistics, the concentration of lead (Pb) in more recent electronics has significantly decreased, which is indicative of better production techniques and adherence to environmental laws like RoHS. A precise comparison between measured values and regulatory thresholds is made possible by the incorporation of TCLP and detection limits.

In the established country, there are larger companies that are at the service of their clients, and, in the absence of alternatives, the clients are forced by these services, which are often less favorable in economic terms. Then, the companies frequently face problems regarding the coverage of the device's warranty because there are many defects that can arise as a result of not correctly defining what they send in the context. In the absence of repairs, its lifespan is determined by warranty coverage, which also contributes to the creation of profits from used phones. Well, it is more difficult to operate in these countries, both legally and due to the fatigue of large and small businesses, but also due to the fact that [13] stated during the study that, with these repair services in Europe, it is important to consider the rapid introduction of new phones each year. Consequently, a significant portion of these devices will eventually be used or replaced.

Mobile phone repair fits into the vision of a circular economy in an urban context [14] where small businesses provide a broader range of services than large businesses, such as in China, where half of the interviews indicated that manufacturers must find ways to reduce maintenance. The total expected risk of leakage affects both consumers and producers. To highlight, a manufacturer could lose $331 million over five years if they choose not to repair their cracked-screen handsets and instead switch to another brand [15]. This should probably be a concern for manufacturers, and cooperation alternatives such as control agreements and necessary training for quality repair should be decided to pursue. Following it like Sabbaghi and Behdad [16], who used phones for old people who know that many functions are not of interest to them or expect more, so that their layer is enough for you as well, is one of the benefits of both large and small companies. They appear to be innovations because they are out of date.

In terms of economics, any strategy or method for the logic of smartphone reuse and recycling may be required. There should be a sustainable system for recycling mobile phones, which are primarily used by those whose lifestyles have come to an end, where multidimensional benefits can be created, such as those who sell them and the company that buys them, and indirectly everyone benefits, but most importantly, the achievement of adequate recycling treatment to meet the directives WEEE. Customers' willingness to participate in recycling is promoted by purchase prices and convenience, as the research case of a UMP recycling system is improved by reusing the existing well-developed mobile phone sales network. The proposed model is an integrated optimization model that chooses optimal return prices, optimal collection points, and optimal deliveries to maximize the total profit of recycling UMPs [17]. The findings Wan and Yu [18] revealed that the majority of residents assigned much higher values to old mobile phones than their actual values, although only one-third of them stated that the latter amounts would impede their collection activities. Collection systems must be developed, and the assurance of the diagnostic nature of the information will also accelerate its collection because hesitation can frequently mean that they have the information, but that it will be misused.

Although the benefits may be personal, it is unreasonable to expect the small business initiative to be primary; however, economic interest must first be created in order to begin with genuine recycling. However, it should not be limited to their will and material benefits; there are other options as well [19]. Investigation demonstrates that people's intention to recycle is not influenced by their perception of recycling businesses or by the items that lead to them being compensated for the harm. Nevertheless, for things like control, subjectively positive rate, and the sensation of pain in personal recycling goals, it may be inferred that they are accountable to me from the outside for motivating them to make adjustments because they are unable to consider their own importance for an activity. It may also be made for the purpose of using and selling certain components of an economic seal [20], where the decrease in hazardous materials for environmental pollution has the other major effect.

Local repair shops and other services that need support from higher hierarchical entities to be more well-equipped for the provision of these services have opened as a result of the quick development of mobile phone technology. Houston demonstrates how regional practices are entangled with international knowledge networks using analysis from [21]. In doing so, it broadens the scope of observable activity, such as that of cell phone repairmen, and reframes the idea of action in this context.

Many projects in this field consistently support the notion of multifaceted benefits, and some of them have also mentioned the need for the development of professions, analyzing that technological equipment is increasing while the shortage of human resources in their maintenance is relatively small. There are comparisons between the effort that will be displayed in data gathering and the challenges and phenomena that accompany new technologies. One of the primary negative effects, in addition to issues with EoL, of recommending various forms and techniques of their recycling and reuse, is the development and rapid change of technology, which is leading to bigger issues. The explanation behind users seeking alternatives and frequently performing individual maintenance is that if such services are sufficient for them, they want cost-oriented solutions [22-25].

It is more cost-effective in the solution to the problem because recycling is given specific attention rather than the "inner circles" that deal with maintenance/repair and reuse. In this piece, they draw a circular economy connection between repairing smartphones, extending product life, and increasing the local economy. In Denmark, the number of local smartphone repairs has increased recently. These agreements not only increase the lifespan of smartphones as a whole, but they also have positive effects on the environment and the economy [26].

According to "Figure 4," the years may be older than the statement made in the article, but this picture supports all I know about how often repairs are needed, particularly if we look at the curve, which resembles an exponential equation in recent years. According to analyses from a review of the literature, Producers should consider the material, design, and other factors, as well as the maintenance aspect [27]. It is clear from "Figure 4" that the materials used to make the battery and the specific chemical components must either be replaced or strategies for their reduction must be developed, which subsequently constitutes a sustainable development [28] or energy reduction methods [29, 30].

The article examines effective organization and maintenance techniques. It introduces practices related to the operation of mechanisms within the field of maintenance to ensure task completion. The level of development of the maintenance management system is also discussed, emphasizing its specific role in maintenance jobs. Quality remains a prominent aspect of modern maintenance. Systems designed for logistics support will significantly aid logistics operations in the future. The logistics industry is evolving; buzzwords such as Industry 4.0, Smart Logistics, and the digitalization of transportation networks are already major trends [31].

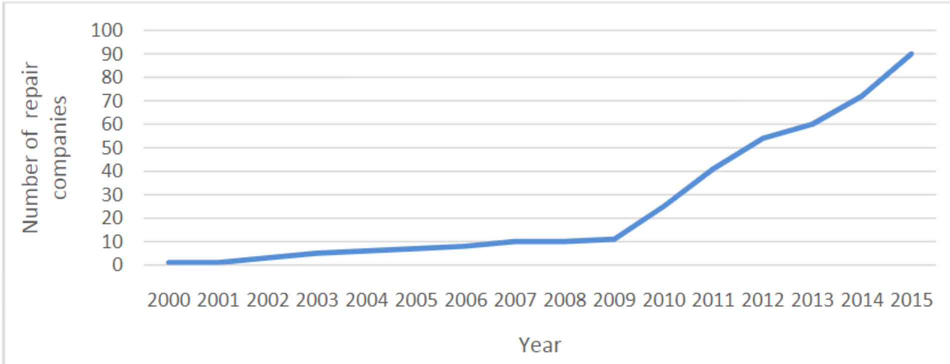

Figure 4.
Number of smartphone repairs in Denmark.
Source: Wilson et al. [27].

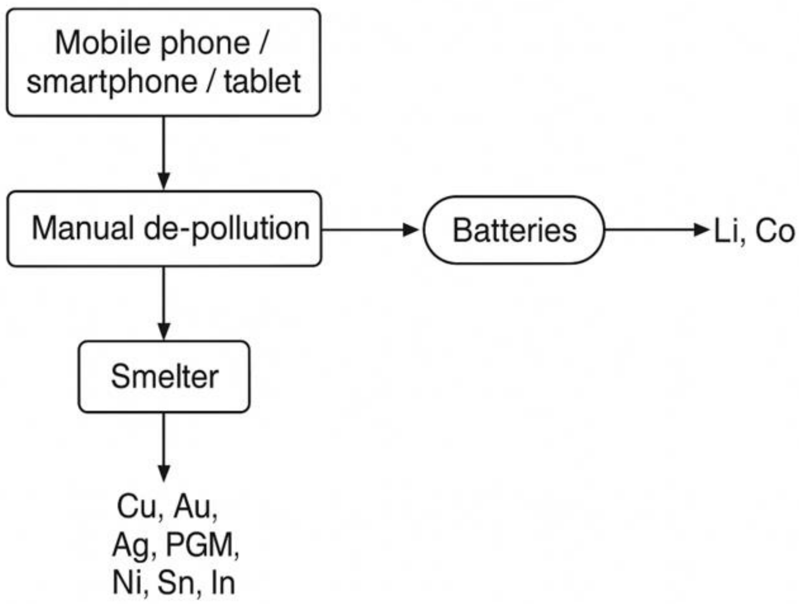

Figure 5.
End-of-life process for smartphones and tablets.
Source: Rakyta et al. [31].

The recycling procedure for cell phones, smartphones, and tablets is accurately and clearly depicted in Figure 1. The primary steps are depicted in the flowchart, which begins with manual de-pollution, separating batteries for additional recycling, and concludes with the recovery of important metals from the smelting process, including Cu, Au, Ag, PGM, Ni, Sn, and In. The recovery of Li and Co from the battery recycling stream is clearly shown in the diagram.

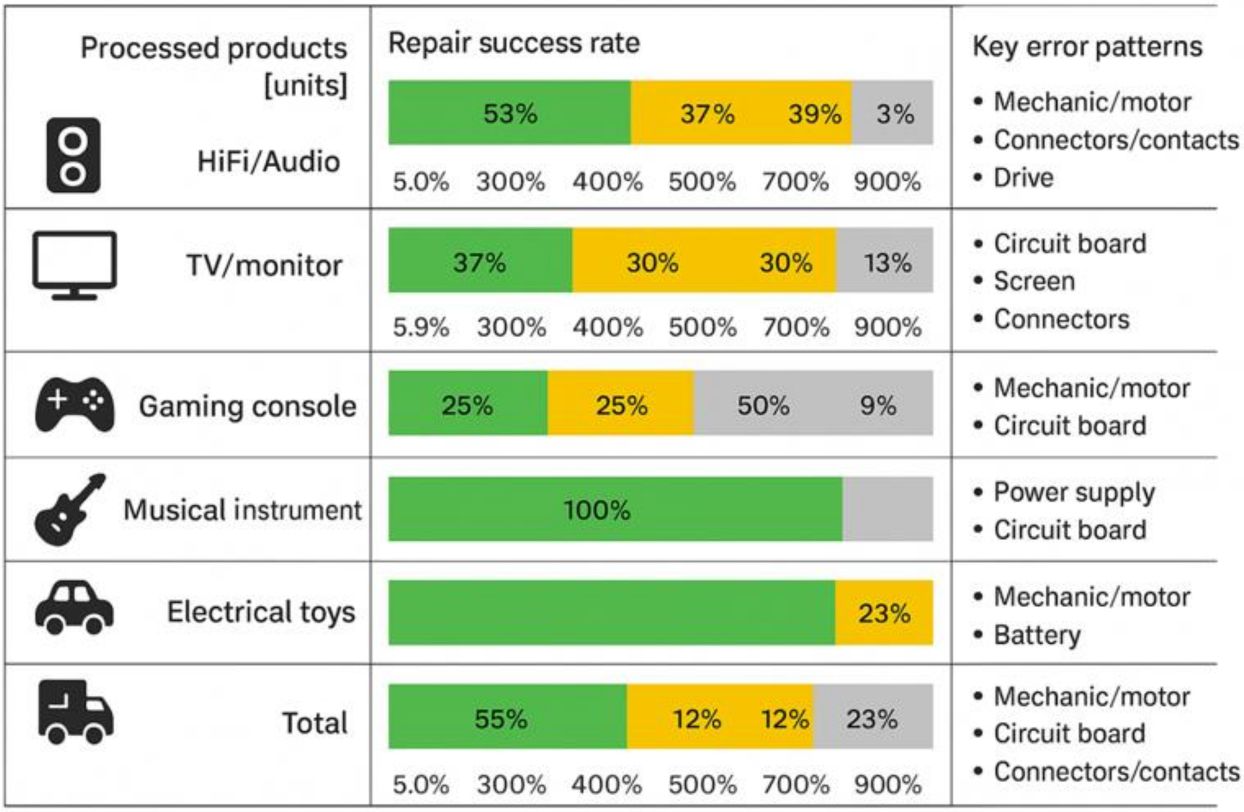

Figure 6.
Summary of processed product for repair.
Source: Rudolf, et al. [32].

Figure 6, error patterns and repair success rates for many categories of electrical products.
The repair performance of many product groups, such as HiFi/audio, TVs/monitors, gaming consoles, musical instruments, and others, is accurately and clearly depicted in Figure X. In an easy-to-understand visual format, the figure integrates quantitative (number of processed products, average repair time, repair success rate) and qualitative (key error patterns) data. In total, 55% of processed goods were successfully fixed, 36% could not be fixed, and 9% had no data at all. All categories combined had an average repair time of 5.5 hours. The image successfully illustrates how different product categories have different repair success rates, highlighting both the technical difficulty and the possibility of prolonging product lifetimes through repair efforts.

The logic of developing repairs and methods, as well as appropriate equipment, can also assist manufacturers in detecting errors in the PCB and other peripheral parts, as a [33] smartphone failure with an internationally recognized brand has been reported. In detail, after this number of smartphones was released to the market, they frequently experienced problems with scrambling or no display, necessitating recall and resulting in losses of nearly $4 million.

3. Methodology

A cross-sectional study will be undertaken to examine the consumer base of the company in a city of 70,000 residents based on the company's 21 years of experience. Using the bill evidence, the study will collect information from both B2C and B2B clients. The study's objectives are to understand the client base's demographics, purchasing patterns, and technological advancements. It is crucial to keep in mind that the study's findings could be indicative of the full population of the nation, given that the company operates in a community with 70,000 residents. Nonetheless, the survey will offer perceptions of the habits and patterns of the firm's clients in the specific city. The information was gathered with the company's permission and included customer age, brand, model, and faulty phone issues. Because a significant portion of the company's customers are compatriots living in developing countries, around 30%, the study is relevant to developing countries as well.

The data was gathered from 10.02.2025 to 15.03.2025 for working days, during which he did not work except on Sundays. All of this information was collected over 28 working days. A total of 562 smartphones will be used as a sample for analysis and study, which is sufficient because this trend has been identified through questions posed to the company owner and experience. These table dates will also be used for model divisions, average processing time, and other damage classifications; they will be classified with the model and amount for each model across nine issues classified as failures. Age classifications are under 50 years and over 50 years, determined directly by questions to the customer, and are noted in the bill of evidence. Additional data has also been collected for more detailed analysis, based on experience. This is close to the limit where people still understand new technology and maintenance, except in some specific cases.

Using Microsoft Excel will examine the data. The information from Table III-VII then computes several ratios, including the ratio of phone repairs, the average cost of repairs per customer, and the ratio of repairs for various phone models, which can help better understand the trends and patterns in phone repair and upkeep in our sample population with the assistance of these ratios. In order to graphically display the data and ratios, Excel will also be used to generate a number of diagrams, including bar charts, pie charts, and line graphs. With the help of these diagrams, we will be able to spot any anomalies or strange trends and clearly communicate our conclusions.

Will perform a statistical analysis to find any notable correlations or patterns in the data after calculating the ratios and making the diagrams. Standard deviations, confidence intervals, and, if necessary, ANOVA tests will all be performed as part of this study.

The study is limited by the possibility that some of the smartphones and tablets accepted for repair had underlying issues that weren't identified during the diagnostic procedure or lacked appropriate technology. Additionally, some new models are under warranty. The customer may incur additional charges as a result, or the device might be declared beyond repair. Furthermore, some clients might not have consented to pay for the extra expenses needed to address the underlying issues, which could have affected the analysis of repair costs.

Overall, by applying Excel to analyze the data, we will be able to present our findings in a straightforward and easy-to-understand manner and acquire a greater understanding of phone repair and maintenance in our sample population.

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Table 2.
Collected data within 28 days at "Mulaku Mobile Service".

Number of smartphones each day			Brand/pcs		
Day	**Date**	**Amount**	**iPhone**	**Samsung**	**Others**
1	10.2.2025	18	6	9	3
2	11.2.2025	22	4	14	4
3	13.2.2025	23	11	10	2
4	14.2.2025	27	9	13	5
5	15.2.2025	24	8	13	3
6	16.2.2025	16	9	6	1
7	18.2.2025	11	4	3	4
8	20.2.2025	23	7	14	2
9	21.2.2025	31	11	14	6
10	22.2.2025	24	8	11	5
11	23.2.2025	19	5	12	2
12	24.2.2025	13	6	5	2
13	25.2.2025	21	7	12	2
14	27.2.2025	24	9	13	2
15	28.2.2025	13	5	6	2
16	1.3.2025	13	6	5	2
17	2.3.2025	23	11	8	4
18	3.3.2025	29	11	12	6
19	4.3.2025	18	6	8	4
20	6.3.2025	22	9	11	2
21	7.3.2025	13	4	8	1
22	8.3.2025	21	11	9	1
23	9.3.2025	13	3	6	4
24	10.3.2025	18	8	8	2
25	11.3.2025	12	5	7	0
26	13.3.2025	26	6	11	9
27	14.3.2025	14	4	8	2
28	15.3.2025	11	3	7	1
Total		542	196	263	83
Average per day		18,07	6,53	8,77	2,77

Based on the dates indicated in the left column, Table 2 aggregates information about phones received for repair within a 28-day period. Furthermore, the overall amount has been decomposed to reveal the proportion of iPhones, Samsungs, and other brands. The average quantity of phones received for each brand and the total sum are computed in the last row.

Table 3.
Separated data for each model and classified by age per day for iPhone.

Amount by Model			**Model**														**Age**	
Day	***Date***	***iPhone***	***11***	***11 Pro***	***11 Pro Max***	***12***	***12 Mini***	***12 Pro***	***12 Pro Max***	***13***	***13 Pro***	***13 Pro Max***	***14***	***14 Pro***	***14max***	***14 Pro Max***	***up to 50***	***over 50***
1	10.2.2025	6	2					1	2				1				4	2
2	11.2.2025	4	1	1		1					1					1	3	1
3	13.2.2025	11	3		2			2	1	1				1		1	5	6
4	14.2.2025	9		2				2	3			2					6	3
5	15.2.2025	8	2					2	1			2	1				6	2
6	16.2.2025	9	1	3		1	1		2								7	2
7	18.2.2025	4	1					2				1					4	0
8	20.2.2025	7	2	2		1				1							5	2
9	21.2.2025	11	3		2			1	2			2				1	8	3
10	22.2.2025	8	1	2		2		1				1	1			1	3	5
11	23.2.2025	5	1					2	2								4	1
12	24.2.2025	6		1	2			2		1							5	1
13	25.2.2025	7			1				2	1		2				1	4	3
14	27.2.2025	9	3					1	2		1	1		1			5	4
15	28.2.2025	5			2					1			1			1	4	1
16	1.3.2025	6	2	1				1				1	1				6	0
17	2.3.2025	11	2	1	2	1			2			1				1	8	3
18	3.3.2025	11	1		3			2		1		1	1	1	1		9	2
19	4.3.2025	6	1						1			2		1		1	5	1
20	6.3.2025	9		2	1	1			2	1			1			1	7	2
21	7.3.2025	4			2				1				1				4	0
22	8.3.2025	11	2	1	1			2	1			1	2			1	7	4
23	9.3.2025	3				1					1	1					1	2
24	10.3.2025	8	2		1	1	1		1	1						1	6	2
25	11.3.2025	5		1				1		1		1	1				3	2
26	13.3.2025	6	2			2							1				5	1
27	14.3.2025	4				1			1			1	1			1	2	2
28	15.3.2025	3	1							1						1	3	0

Table 3 is derived from Table 2 and provides a more detailed breakdown of received iPhones by model. It also includes age data acquired using a questionnaire, which divides respondents into two age groups: under 50 and over 50 years old.

Table 4.
Separated data for each model and classified by age per day for Samsung

Amount by models			**Model X-Series**				**Age**	
Day	***Date***	***Samsung***	***A***	***F***	***M***	***S***	***up to 50***	***over 50***
1	10.2.2025	9	5		2	2	5	4
2	11.2.2025	14	8	2	2	2	9	5
3	13.2.2025	10	8	1		1	6	4
4	14.2.2025	13	10		2	1	11	2
5	15.2.2025	13	9		2	2	9	4
6	16.2.2025	6	4		2		4	2
7	18.2.2025	3	3				1	2
8	20.2.2025	14	8	2	2	2	11	3
9	21.2.2025	14	11		2	1	10	4
10	22.2.2025	11	7	1	1	2	8	3
11	23.2.2025	12	8	1	2	1	9	3
12	24.2.2025	5	4			1	2	3
13	25.2.2025	12	6	1	1	4	6	6
14	27.2.2025	13	7		3	3	9	4
15	28.2.2025	6	6				5	1
16	1.3.2025	5	3		1	1	4	1
17	2.3.2025	8	4	1	2	1	6	2
18	3.3.2025	12	8		1	3	11	1
19	4.3.2025	8	5		1	2	6	2
20	6.3.2025	11	6		3	2	8	3
21	7.3.2025	8	7			1	7	1
22	8.3.2025	9	5		2	2	6	3
23	9.3.2025	6	4	1		1	6	0
24	10.3.2025	8	5			3	7	1
25	11.3.2025	7	6			1	5	2
26	13.3.2025	11	7		1	3	9	2
27	14.3.2025	8	5		3		8	0
28	15.3.2025	7	5	1		1	6	1

Table 4 is derived from Table 2 and provides a more detailed breakdown of received Samsung by model. It also includes age data acquired using a questionnaire, which divides respondents into two age groups: under 50 and over 50 years old, as shown in Table 5 for other brands.

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Table 5.
Separated the data for each model and classified it by age per day for the other models.

Amount by models			Model								Age	
Day	**Date**	**Others**	**Huawei**	**Xiamo**	**LG**	**Oppo**	**Nokia**	**Htc**	**other**	**Tablet**	**up to 50**	**over 50**
1	10.2.2025	3	1							2	2	1
2	11.2.2025	4	1				1	1		1	4	0
3	13.2.2025	2	1		1						1	1
4	14.2.2025	5	1	2				1	1		5	0
5	15.2.2025	3		1			1			1	3	0
6	16.2.2025	1							1		1	0
7	18.2.2025	4	1	1			1			1	3	1
8	20.2.2025	2			1			1			2	0
9	21.2.2025	6		2			1		1	2	5	1
10	22.2.2025	5	2	1				2			4	1
11	23.2.2025	2		1						1	1	1
12	24.2.2025	2							2		0	2
13	25.2.2025	2				1	1				2	0
14	27.2.2025	2		1						1	2	0
15	28.2.2025	2		1			1				1	1
16	1.3.2025	2	1						1		2	0
17	2.3.2025	4	1		2				1		3	1
18	3.3.2025	6					2	1	3			6
19	4.3.2025	4				2			2		3	1
20	6.3.2025	2		1					1		2	0
21	7.3.2025	1								1	1	0
22	8.3.2025	1						1			0	1
23	9.3.2025	4	2	1						1	3	1
24	10.3.2025	2							1	1	2	0
25	11.3.2025	0										0
26	13.3.2025	9	1	4			1	1	2		7	2
27	14.3.2025	2		1					1		1	1
28	15.3.2025	1		1							0	1

Table 6.
Damage-based iPhone classification

Amount		**Failure by brand**	**11**	**11 Pro**	**11 Pro Max**	**12**	**12 Mini**	**12 Pro**	**12 Pro Max**	**13**	**13 Pro**	**13 Pro Max**	**14**	**14 Pro**	**14 max**	**14 Pro Max**
iPhone failure by category	32	LCD replacement or glass	8	4	5			2	3	2		3	2	1		2
	22	Back cover	4	2	3	1			2		2	3	2	1		2
	32	Charging connector	5	5	2	3		4	3	3		4	1	1		1
	9	Mic failure	1	2		2		1	1	1		1				
	25	Speaker failure	2	1		4		8	8				1	1		
	27	Battery change	3	1	6	2		2	3	3		3	1			3
	15	IC failure	3				1	1	2			3	3		1	2
	7	Other			1			1	1	1		2	1			
	27	Software issue	7	2	2	1	1	3	3		1	1	2			3

Table 7.
Damage-based classification of other models.

Failure by brand			Huawei	Xiamo	LG		Oppo	Nokia	Htc	other	Tablet
Others' failure by category	11	LCD replacement or glass LCD	3	4				2			2
	8	Back cover	1	2				2	2		1
	16	Charging connector	3	3	4		2	1		3	
	7	Mic failure	1	2			1	1	1	1	
	8	Speaker failure	2	3					2	1	
	13	Battery change							1	3	9
	6	IC failure	1					2	1	2	
	3	Other failure							1	2	
	11	Software issue	1	4				1		5	

Table 1.
Damage-based classification of Samsung models.

Failure by brand			A	F	M	S
Samsung failure by category	53	LCD replacement or glass LCD	27	3	9	14
	22	Back cover	9			13
	57	Charging connector	39	3	9	6
	12	Mic failure	8		2	2
	18	Speaker failure	16		2	
	36	Battery change	28	2	6	
	13	IC failure	9		2	2
	9	Other	5		2	2
	43	Software issue	33	3	3	4

Tables 6, 7, and 8 provide data classified by the most prevalent damages for further study. Based on these tables, we can deduce that certain models exhibit comparable forms of damage. This information enables us to identify common risks and provide preventive measures as recommendations for the design and manufacturing of future smartphone models.

4. Results

The literature has extensively acknowledged smartphones' significance in today's society. Due to the connectivity of numerous aspects, including communication, entertainment, and related activities, smartphones have become an essential component of people's lives. Studies on their preferences and practices have been the subject of numerous reviews. Unfortunately, the majority of this research relies on self-reports, which can have bias and other drawbacks. Prior to 542 units, our objective is to address these studies' ties to the reality of smartphone damage.

Past studies have emphasized the value of maintaining smartphones. Companies must comprehend consumer preferences and wants as the market becomes more competitive. The absence of smartphones must therefore be acknowledged. Customers, company image, and after-sales assistance, among others, can play a crucial role. This study aims to clarify these aspects by examining the variations between major brands, as well as the trend of brand loyalty. Additionally, it is necessary to examine Product life cycle forms, in line with time, waste management, or EoL, cost planning, and related factors.

The breakdown percentages of the Samsung and iPhone brands are shown in a diagram, while Table 6 lists the other brands. The diagram from “Figure 7,” which is based on data from Table 2, shows that the average number of pieces received per day is approximately 18.

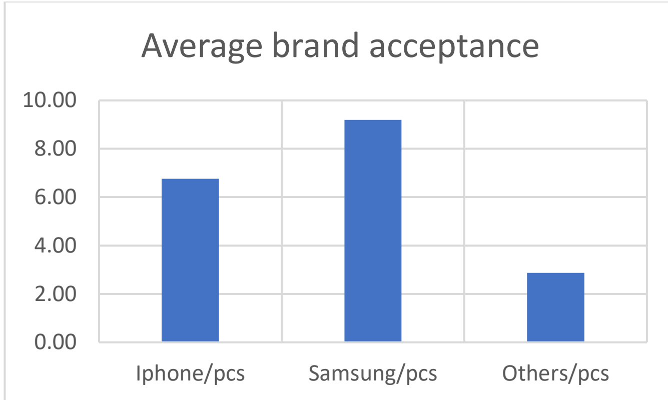

Figure 7.
Comparing brands.

The statistic shows that the Samsung brand has the highest number of repairs, but this does not imply that they have a higher percentage of faults overall, as the amount is about equal to that of the iPhone brand and other brands. This may also be a sign that Samsung is at the forefront of the broader transformation, as there is a product or service available for any level of income.

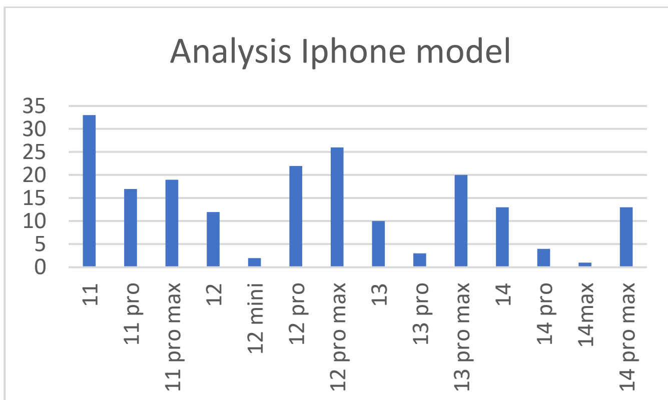

Figure 8.
Repairs on different iPhone models are compared.

From Table 3, "Figure 8" is omitted, highlighting which of the models have been repaired the most. From what is observed, the iPhone 11 is the most repaired, but this is due to it being less expensive and older compared to the others. This does not indicate any usual problem; it is at the end of its lifespan. We will also analyze the classification of breakdowns. The same arguments clearly do not apply to the iPhone 12 Pro and 12 Pro Max, but here, a possible factory error has been observed that will manifest after a while, which will also be discussed in the breakdown categorization analysis.

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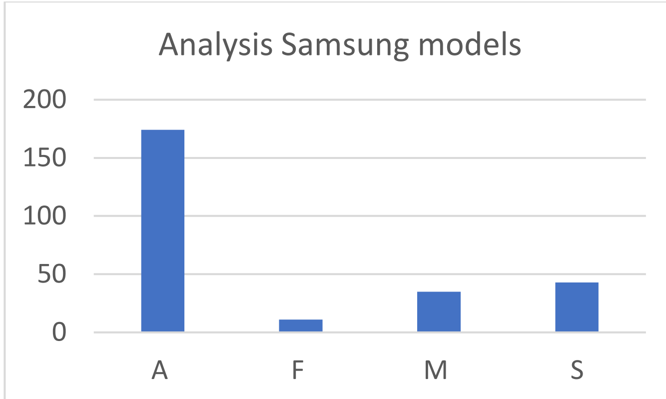

Figure 9.
Repairs on different Samsung models are compared.

Because of the wide variety of Samsung smartphones, even those in Table 4 and "Figure 8" are classified as Samsung brand subcategories. It is worth noting that the A series is also widely used because many models and economic segments produce fast series. Subcategory F is the least present due to the fact that it began producing several types in the last year; even for subcategory M, it is almost the same. Subcategory S is known as its premium and often follows the logic of competition with iPhone, Xiaomi, and so on. It is more visible in the F and M series because there have been several models in recent years, but this is not for the lower economic class.

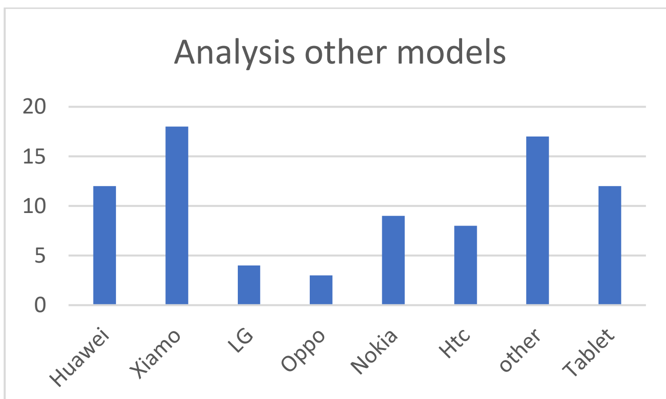

Figure 10.
Repairs on different Samsung models are compared.

From Table 4, it is extracted "Figure 5". As can be seen from the figure, the Huawei and Xiaomi brands are more noticeable. This is not because they have many issues, but rather because their use is growing. It was not possible to include models from each brand because, even when compared as a whole with the iPhone and Samsung, they represent less than one-fifth of the total.

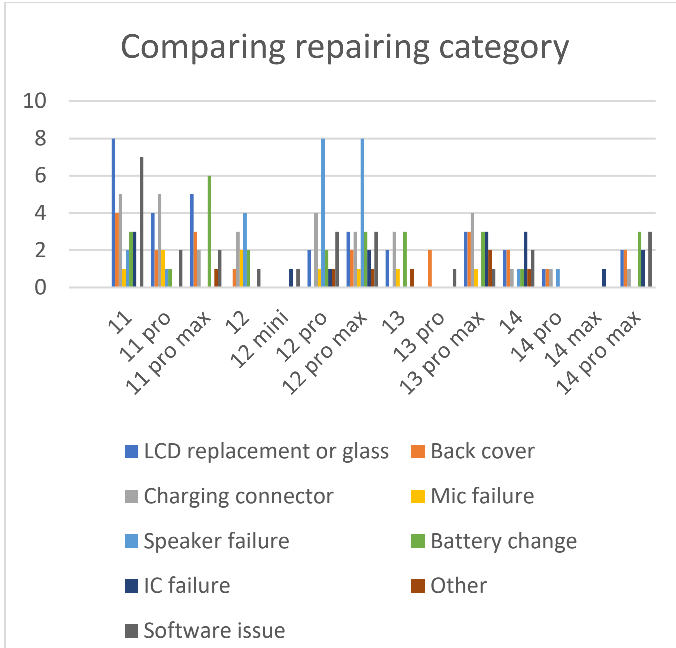

Figure 11.
iPhone models classified according to repairability.

Aside from the higher potential, the latest series of iPhones is observed to have lower participation because they are either under warranty, for example, or do not participate in many categories of repairs, such as battery replacement, etc. From this "Fig. 11" extracted from Table 5, it is worth emphasizing the participation in problems with the speaker of the iPhone 12, especially the 12 Pro and 12 Pro Max, because, as I previously stated, there are doubts that there is any release from the manufacturer. Many cases show no indication or interruption during consumer clarifications, but these issues occur momentarily, and then the device stops working. After conducting my research, I concluded that the voltage might become unstable or rise while it is being fed.

Under the iOS operating system, it is common that, while the owner's personal account offers a high level of security, if the customers forget this information, they will be unable to pass it on, rendering it useless.

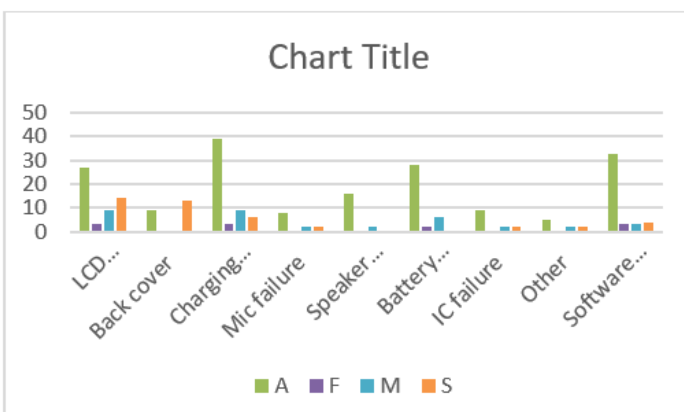

Figure 12.
Samsung models classified according to repairability.

In the Samsung brand, it is important to note that "Figure 12" shows that the leading category of issues is charging issues, which is due to the fact that, even though there are still some who wear out the micro charging connector and fill only one side, often until the damage occurs, it is somewhat distinguishable. However, the "C" type charging connector, even though this will be and for everyone in the near future, I think that is worth mentioning. Also, there is more concern from the software because the operating system permits the usage of untrusted sources and is unsafe, which comes with additional risks. It has these issues and requires a thorough reprogramming of the system. What increases the requirement for this category is forgetting the code, pattern lock, and account.

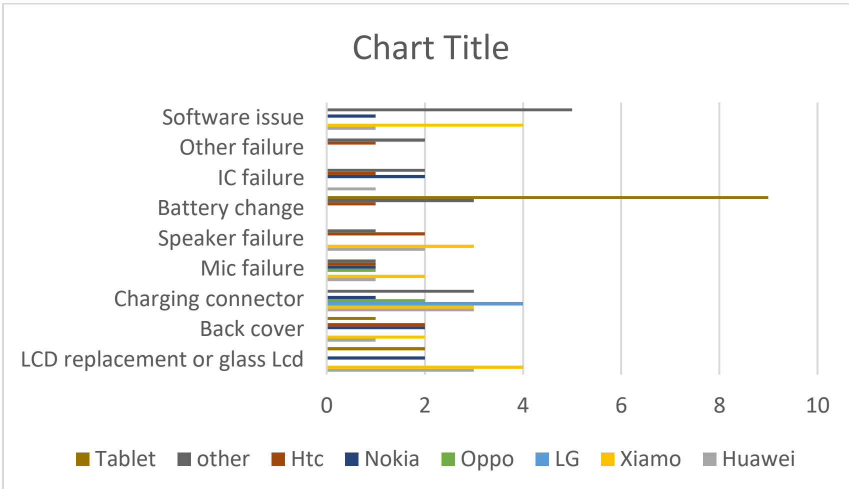

Figure 13.
Other models are classified according to repairability.

According to "Figure 13," it could be possible to conclude that Samsung, as well as these categories generally, experience higher rates of screen replacement. This is likely due to the fact that some of their models have sharp edges that can be broken by minor physical contact. The requirement for a new battery may be observed in other models; this is also due to the fact that the majority of the models are at least two years old.

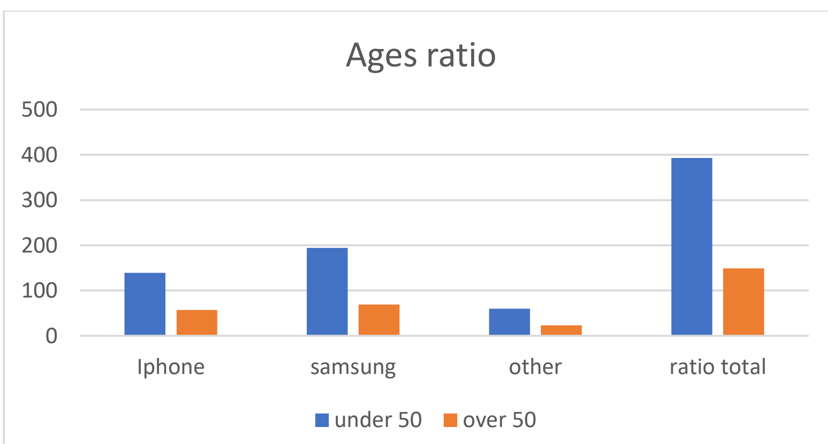

Figure 14.
Ratio between ages under and over 50 years old.

This threshold has been exceeded since, at a certain age, people tend to stop using it and believe it is too late to start learning. For this reason, I wanted to examine the issues that arise during repairs.

Regarding the breakdowns from this report, it is important to note that overall, there are fewer complaints due to the use of more packages as well as the fear of technology, and they try to respect the rules of maintenance. As can be seen, the ratio is 62 to 38, which in some ways represents the demography of the country. When they attempt to enter programs without understanding what they are doing and simply hit "accept" when a prompt appears, those in the second category of users carry iPhones more frequently than it appears to be less complicated, but they also have more software-related issues.

Overall, these are some of the technical aspect findings from these tables; however, it was discovered during the assessment of the literature that there is research on whether it is worthwhile to fix. To examine this, one must begin with some information like:

- Whether an insurance policy or a warranty will cover the harm
- risk harming the environment if I don't fix where I have to send it
- The phone's age
- How badly damaged it is
- How much time might it take to fix it
- The cost of replacing it versus repairing it
- How risky is it for them to get my data if I give it to them?

These are some of the quandaries that necessitate, sometimes, the optimal solution, and I wish to address them one by one.

Typically, warranties cover problems caused by the manufacturer, software issues, and minor damage that is not related to physical collision, water supply, or power problems, so the buyer would know what the warranty covers based on the damage. It is worth noting that there is a categorization of guarantees, but those that cover all damages are often not worth it due to the high price.

There should be a strategy and possibly motivation for organizations to make collection mandatory and to consider green equipment [34] If it is not repaired and there is no strategy in place for their collection, which is required as motivation after the reward, it may even find a way if it is not arranged to sell to local companies in such a way that some parts can be reused, and they find other ways after collection to send the other parts to the right destination. Such a way may be applied as with old TVs [35].

The point of how old the phone is for repair probably incorporates many questions, such as if it is fixed and does not support other applications, whether it is worth it, whether age plays a role, and the cost of repair as well.

The question of how much the phone is damaged should have been better than knowing if it can be fixed without problems in the near future. Secondly, if the phone is of the current generation by analyzing the 9 categories of damage, even if it has category nine damage, it does not reach the value of the smartphone, so it is worth investing.

The time required for repair is shorter than the time required for purchasing the phone or ordering online. No one in the nine categories mentioned exceeds the maximum waiting time of approximately 28.67 minutes, due to the fact that the company works 9 hours per day and 18.83 pieces on average need repairs each day. This can also be argued because the smartphone does not show when it is damaged, but this can happen by chance.

The question of whether the most frequently used data is at risk and is lost first should be understood, as a backup copy is always required. It is better not to hand over peripheral devices such as a SIM card and a micro memory card during repairs. Only software issues can lead to data loss; data may be lost in case of losing a smartphone as well [36].

When "Figure 15" is analyzed, it is clear that the replacement of the screen and the charging connector presented the biggest challenges. The causes of these issues are only known for the screen, but it should be noted that occasionally the design of phones causes them to become more sensitive, and for the charging port only, because it was previously discussed.

The findings of a single-factor ANOVA from "Table 9" with three groups (iPhone, Samsung, and Others) and a total of 28 observations are displayed in the accompanying ANOVA table. For each group, the summary table displays the count, total, average, and variance. There are 28 total observations, with a total sum of 542. The average value for iPhone is 7, for Samsung is 9.39, and for Others is 2.96. According to the F-test results and the ANOVA table, there is a significant difference between the three groups. The F-value of 101.50 is substantially higher than the critical F-value of 2.69 at the 0.05 significance level, which means the null hypothesis that there is no difference between the groups is rejected. Additionally, the p-value is extremely low (2.69E-31), indicating that the outcome is statistically significant. The between-group variation accounts for the majority of the total variation, leading to the conclusion that there is a substantial difference in the variable being assessed among the groups of iPhone, Samsung, and Others. With a significance level of 0.05, the critical F-value is 2.69, and the p-value confirms the statistical significance of the results, supporting the rejection of the null hypothesis.

The majority of the total sum of squares (4088.36) can be attributed to the source of variation between groups (Between Groups), whereas within-group variance (1450.07) explains a lesser fraction of the total sum of squares. The between-group variation accounted for the majority of the total variation, according to this ANOVA table, which concludes that there is a substantial difference in the variable being assessed between the groups of iPhone, Samsung, and Others.

The majority of the total sum of squares (4088.36) can be attributed to the source of variation between groups (Between Groups). In contrast, within-group variance (Within Groups) explains a lesser fraction of the total sum of squares (1450.07).

According to the ANOVA Table 10, x performed a single-factor ANOVA with one independent variable, the smartphone model. The number of smartphone failures for each model appears to be the dependent variable. The ANOVA table shows that the means of the groups (smartphone models) differ statistically significantly, with an F-statistic of 15.864 and a p-value of 1.1828E-28. This implies that the smartphone model substantially impacts the number of failures. Furthermore, the within-group variance (MS) is 71.791, while the between-group variance (MS) is 1138.909. This indicates that the variation in the number of failures between smartphone models is significantly greater than the variation within each model.

In summary, based on this ANOVA table, it appears that there are significant differences in the number of smartphone failures between different models and that the variance in the number of failures is larger between models than within models.

There are many local mobile shops operating in the municipality where the company is located, all of the same category, and working B2B. There are five such shops; Kosovo has 38 municipalities. If we take the weight data from the specifications of the iPhones, it can be calculated that the total weight for a year is 6950.77 kg from Table VIII. If we take the other two brands and multiply them by the average weight of iPhones, we get the following results: 19219.65 kg. Smartphones that are not repaired and end up as electronic waste can have a significant environmental impact. The amount of electronic waste generated by smartphones that are not repaired is 19219.77 kg per year, which contributes to the 3.5% [2] environmental impact of electronic waste. However, if we prioritize reasonable smartphone repair over disposal, we can reduce the amount of electronic waste generated and thus the negative impact on the environment. We can extend the life of smartphones and reduce the need for new ones by repairing them, conserving resources, and lowering carbon emissions [37-39]. Furthermore, reasonable smartphone repair can generate economic and social benefits. It has the potential to create job opportunities in the repair industry, lower the cost of smartphone ownership, and expand access to technology for those who cannot afford to buy new smartphones. In conclusion, prioritizing reasonable smartphone repair can benefit the environment by reducing electronic waste, conserving resources, and potentially creating economic and social benefits.

The company in question employs 3 people, and if we logically compute the number of employees generated, excluding those who operate exclusively in B2C, it means that only 5 companies out of 38 municipalities have more than 100 people overall. Customers have saved at least 20%, with some models of Samsung, maybe LCD, accounting for 80% of the total cost, because 102,980 cell phones have been fixed using the same rationale [40-42].

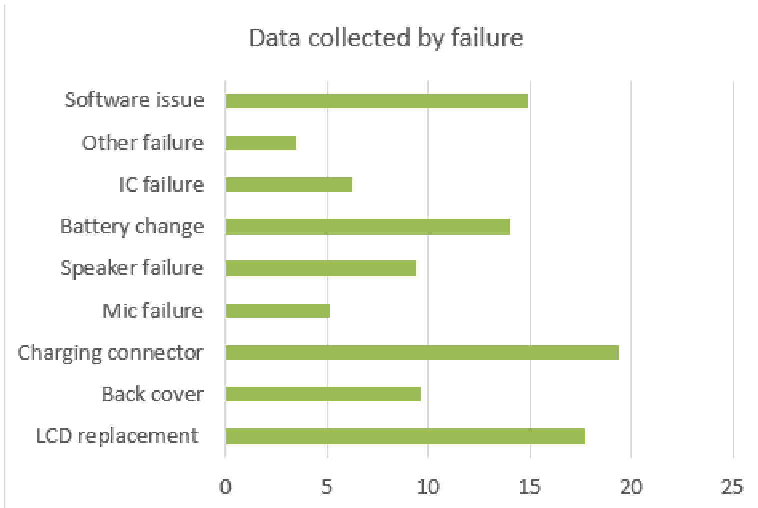

Figure 15.
Collected total smartphones with categorization.

Table 9.
Applying one-way ANOVA based on data from Table 3.

Summary						
Groups	**Count**	**Sum**	**Average**	**Variance**		
iPhone	28	196	7	6,814815		
Samsung	28	263	9,392857	9,876984		
Others	28	83	2,964286	3,813492		
Total	28	542	19,35714	33,20106		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4088,357	3	1362,786	101,499	2,69E-31	2,688691
Within Groups	1450,071	108	13,42659			
Total	5538,429	111				

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Table 10.
ANOVA applied to summary failure categories via smartphone models.

Summary						
Groups	**Count**	**Sum**	**Average**	**Variance**		
11	8	33	4.125	5.839286		
11 Pro	7	17	2.428571429	2.285714		
11 Pro Max	6	19	3.166666667	3.766667		
12	6	13	2.166666667	1.366667		
12 Mini	2	2	1	0		
12 Pro	8	22	2.75	5.642857		
12 Pro Max	9	26	2.888888889	4.361111		
13	5	10	2	1		
13 Pro	2	3	1.5	0.5		
13 Pro Max	8	20	2.5	1.142857		
14	8	13	1.625	0.553571		
14 Pro	4	4	1	0		
14 Max	1	1	1	#DIV/0!		
14 Pro Max	6	13	2.166666667	0,566667		
A	9	174	19.33333333	158.25		
F	4	11	2.75	0.25		
M	8	35	4.375	9.982143		
S	7	43	6.142857143	27.47619		
Huawei	7	12	1.714285714	0.904762		
Xiamo	6	18	3	0,8		
LG	1	4	4	#DIV/0!		
Oppo	2	3	1.5	0.5		
Nokia	6	9	1.5	0.3		
Htc	6	8	1.333333333	0.266667		
Other	7	17	2.428571429	1.952381		
Tablet	3	12	4	19		
Total	9	542	60.22222222	931.4444		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29611.63	26	1138.908711	15.86402	1.18E-28	0.582358
Within Groups	9189.367	128	71.79193018			
Total	38800.99	154				

Table 11.
Total weight for the year.

iPhone models					
Model	**Weight/g**	**Amount**	**Total Weight**	**Total in City**	**Total in country/kg**
iPhone 14 Pro Max	240	3	720	3600	136,8
iPhone 14 Plus	203	1	203	1015	38,57
iPhone 14 pr	206	4	824	4120	156,56
iPhone 14	172	13	2236	11180	424,84
iPhone 13 Pro Max	240	20	4800	24000	912
iPhone 13 Pro	204	3	612	3060	116,28
iPhone 13 Mini	141	10	1410	7050	267,9
iPhone 13	174	26	4524	22620	859,56
iPhone 12 Pro Max	228	22	5016	25080	953,04
iPhone 12 Pro	189	2	378	1890	71,82
iPhone 12	164	12	1968	9840	373,92
iPhone 11 Pro Max	226	19	4294	21470	815,86
iPhone 11 Pro	188	17	3196	15980	607,24
iPhone 11	194	33	6402	32010	1216,38
				Total/Kg	6950,77

5. Conclusion

Cost reduction, based on the data, indicates that there are opportunities to reduce the cost of smartphone repairs. Identifying this opportunity can result in increased profit and more jobs for repair shops, as well as benefits for the customer.

Time-oriented, the data suggests that there may be ways to streamline the repair process, which could lead to quicker repair times and higher levels of client satisfaction.

Environmental impact: repair shops can lessen the quantity of electronic waste that ends up in landfills by fixing smartphones rather than replacing them. This might benefit the environment and assist repair shops in establishing a reputation for being green enterprises.

Manufacturers Known: Analyzing repair data to provide insights into the performance of various smartphone manufacturers. This enables repair shops to make more informed recommendations to customers, resulting in increased customer trust.

Understanding brand trends in smartphones can help repair shops stay current on the latest technologies and features. This can assist repair shops in providing more relevant services to customers and positioning themselves as industry experts. Potential smartphone repair firms can better understand their customer base and their needs by analyzing the age distribution of their potential customers. For instance, a repair shop may want to choose the mosteconomical smartphone repair or reconditioned devices if they are encountering a high volume of repairs for older smartphones. In general, it implies that there is some multidimensional analysis for smartphone repairs and that there are advantages for repair shops to run their businesses.

5.1. Future Direction

The manufacturer may be able to grow their client base and sales by addressing the price difference between the iPhone 14 and iPhone 14 Pro/Max models, while also providing more inexpensive options to those who may not be able to buy the models that are much higher. Customers with low incomes saw that they had an iPhone 14 and that there wasn't much in the way of a 14 Pro and Max; therefore, it would be beneficial to provide categories with competitive pricing. Also, there were numerous speaker and buzzer issues with most iPhone 12 Pro and 12 Pro Max models. These issues need to be investigated to prevent future occurrences.

Proposed that it also include as many universal components as possible and not be specific to just one model, when the Samsung models in the category started to adopt various parts, such as the screen in some models.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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The company "Mulaku Mobile Service," which, without a doubt, made it possible for me to prepare all of this information, deserves my sincere gratitude.

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