SUITABLE PRACTICES OF DESIGN AND REPAIRMENT FOR REDUCING THE ENVIRONMENTAL IMPACT OF SMARTPHONES

PERULA A.[1*]

[1]CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas), Avda. Complutense, 40 - 28040 Madrid, Spain

*corresponding author:
e-mail: alberto.perula@ciemat.es

Abstract. Nowadays, smartphones are one of the most common devices in developed countries, as most citizens are owners of at least one. However, smartphone's average lifetime is reported to be between 2 and 3 years by many studies, and the environmental impact of manufacturing, using and disposing of these products may grow to be a global issue in the years to come. This calls for a reformulation of our relationship with these devices, both from the user and design perspective, that allow us to extend their lives. With that purpose in mind, we first need to take a look at how this new way of thinking can greatly improve the sustainability of smartphones. This work shows how a change on new different kind of behaviors and habits can be a potential new path for diminishing the environmental impact of smartphones. It also reveals how easily, when faced with a component malfunction, consumers tend to replace their smartphone against the alternative of repairing them and what cost this has from a GWP perspective for the case of battery and/or display malfunctions. Finally, it estimates an average lifetime for every component and an average extended lifetime for every phone repaired.

Keywords: Smartphone, Life Cycle Assessment, environment, behavior, electronics

1. Introduction

Consumption habits of mobile phones have changed substantially since the introduction of smartphones 14 years ago. Almost every person in developed countries owns at least one smartphone (adult German citizens own an average of 3.22 phones per capita [1]), and many studies show that smartphone's lifetime is set between 2 and 3 years. German users seem to have used their last smartphone for an average of roughly 2 years [2], while Austrian citizens used their own for a mean average of 2.97 years [3] but a median average of 2.13 years. Most people seemed to have replaced their phone because of malfunctioning: 37% [2] and more than 30% [3] of respondents stated defective components of their phone as the main reason for replacing it. However, the same surveys determined that only less than a 50% of the people that claimed malfunction of a component tried to repair it before obtaining a new device. Despite this, when asked about how much time smartphones should last, users answered up to 4 years [2] and 5.2 years [4]. This may show there really is an interest in long lasting devices, but also that most people find repairment too of a complicated or expensive process for them to take the risk. To prevent this kind of obsolescence and facilitate repairment, Fairphone has launched two modular smartphones that isolate their main components in independent parts (or modules). Every one of these modules can be accessed and replaced by their users in a time period of merely minutes. However, it remains to be seen how much of a difference this kind of design and policy will have on consumer's behavior.

On the other hand, with climate change already knocking on the door and the whole of the scientist community warning about the more harmful RCP (Representative Concentration Pathway) scenarios we are globally heading to, measuring all kind of industry or services-related emissions has become one of the major tasks we face on the XXI century. The Life Cycle Assessment (LCA) methodology achieves this goal by analyzing the GWP (Global Warming Potential) from cradle to grave of products and estimating their related CO2e emissions (carbon dioxide equivalent, the sum of all greenhouse gases emissions). This tool has been applied in some occasions to calculate the CO2e emissions of smartphones production, use and end of life, like the Xperia Z5 [5] and Fairphone 2 [6] LCAs.

The aim of the present work is the study of consumption habits to promote suitable practices for reducing the global warming impact of smartphones. With this in mind, we launched an online survey in the fall of 2019 meant for all kind of Spanish citizens. Its results, along with those provided by the beforementioned LCAs, allowed us to present some scenarios of how different decision-making has an impact on the environment.

2. Methodology

2.1. Survey

This online survey was focused on the last smartphone owned by each respondent. The sample size resulted of 672 residents in Spain, between the age of 14 and 72 years old. Further characterization is detailed in Table 1.

Table 1. Characterization of the sample.

	Category	n	%
Gender			
	Male	210	31.25
	Female	447	66.52
	Non-conforming	15	2.23
Age			
	14 - 19	18	2.68
	20 - 29	266	39.58
	30 - 39	112	16.67
	40 - 49	98	14.58
	50 - 59	112	16.67
	60 - 72	66	9.82
Household income (€/month)			
	Up to 499	11	1.64
	500 - 999	42	6.25
	1000 - 1499	105	15.63
	1500 – 1999	102	15.18
	2000 – 2499	114	16.96
	2500 – 2999	87	12.95
	3000 – 4999	159	23.66

2.2. Model

In order to build scenarios for comparing different environmental impacts, some variables needed to be established. The first step we took was the estimation of a mean average for the lifetime of the surveyed people's smartphones. For all the respondents who had sold their smartphones, we estimated a "previous use time" from their response; this lifetime would be later added to that of the second handed smartphones to obtain a measure of the whole life of every smartphone, whether they had been used previously or not.

For every surveyed user who had repaired one single component of his/her smartphone in its life, we chose to estimate the extra life that resulted from this operation by subtracting the malfunction time of this component to the whole life he/she had given to his/her smartphone, minus the time lapse between this malfunction and the moment of repairment. With this, we managed to obtain the mean average "extra lifetime" that every smartphone with specific component issues could achieve by repairing

added in case of repairment as the lesser one of the extra lifetimes associated to those components.

On the other hand, for properly understanding the global warming impact caused by any replace/repair choice, we used the Xperia Z5 LCA. This study calculated the GWP for "the assessed smartphone…to 57 kg CO2e for an assumed operating lifetime of 3 years, excluding the network usage" [5]. Some clarifications should be made:

- Usually, LCAs of smartphones neglect the environmental impact of the network usage when presenting this kind of results because it doesn't serve the purpose of comparing and understanding the GWP caused by the device itself, since emissions produced by mobile and data networks are dependent of every country's phone operator companies infrastructure.

- The Xperia Z5 has a 7.2 kg CO2e emission associated to its 3 years average use. If, for example, we were to define a new functional unit of 6 years of use, this quantity would be doubled as well with this lifetime, but all the production/transport/end-of-life associated GWP would not be altered at all. We assigned a base quantity of 49.8 kg CO2e for all stages except the use one: 57 kg CO2e minus 7.2 kg CO2e for the use-stage on a functional unit of 3 years. To this value we would later add 2.4 kg CO2e for every year of lifetime:

  $$(1)\quad GWP_i(kg\ CO2e) = 49.8 + 2.4 * i;\ i = 1,2,3\ ...$$

  where i equals the number of years of use.

For the repair-scenario estimated GWP, we looked at the isolated GWP of the display and battery components as seen in the LCA in order to calculate the GWP that would take to repair each component. The production and internal transportation stage of the LCA of the smartphone reported a GWP of 3.5 kg CO2e for the screen and 1.4 kg CO2e for the battery. For the final transportation, since the LCA only studied the environmental impact of the final distribution of the final product and no information is available about how official repair centers are distributed among regions, countries or cities, we weighted the LCA results for final deliveries of the final product with the weight (grams) values of battery/display and delivery package, as follows:

$$(2)\quad Bat_{DelGWP} = \frac{Bat_W + Pack_W}{FP_W} \times FP_{DelGWP}$$

$$(3)\quad Dis_{DelGWP} = \frac{Dis_W + Pack_W}{FP_W} \times FP_{DelGWP}$$

them. Whenever 2 or more components were malfunctioning, we chose to consider the extra lifetime where Bat_{DelGWP}, Dis_{DelGWP} and FP_{DelGWP} are the GWP associated to the delivery stage for the battery, display and final product, Bat_W, Dis_W and FP_W are their weight, respectively, and $Pack_W$ is the weight of the packaging. A hypothesis had to be made in order to do this operation: the Xperia Z5 LCA article, which contained a Z3 LCA as well, did not depict the Z5 components' weight. However, it did of the Z3 ones, so an assumption was made that the ratio 'component weight/smartphone weight' would be constant from the Z3 to the Z5 so that we could use the Z3 data without incurring in much of an error.

Finally, we worked on estimating the potential emissions that could been saved by choosing to repair rather than replace when a single component malfunctions. We took the average time of malfunction for the battery and display (the most common and earlier component malfunctions observed), along with the extended lifetime we had estimated earlier from both component's repaiment, and managed to model a couple of scenarios for each one: one for the replacement of the smartphone at the average time of malfunction of the respective component and another for the repairment (at the same time of malfunction) of the component and its subsequent extended lifetime. It is worth noting that every GWP scenario is presented as an accumulated individual (per person) carbon footprint per year. For this purpose, we normalized the GWP of every consumption choice as an emissions/year variable. We chose this approach for analyzing the continuous nature of the consumption of smartphones in this age and quantifying its impact.

3. Results and discussion

A most interesting observation could me made of the smartphone's lifetime related questions: people tend to be very positive and optimistic about how much time will their actual smartphones last in comparison with how much the last ones did. It would seem either people expect for their devices to be more long-lasting than the previous one, or they expect themselves to behave in a different way than they ultimately do (the replace/repair dilemma). This is proven by the 2.81 years average lifetime of the respondents last smartphone and the 3.32 years average of their current smartphone's expected life. An even greater gap can be found between these numbers and the ones given as an answer to "how much do you think smartphones should last?": more than a 36% of the respondents thought smartphones should last at least 7 years, a lifetime not even manufacturers themselves support. The average lifetime smartphones should have, according to the respondents, was that of 4.67 years. These results are also similar to those of Jaeger-Erben and Hipp [2]: 2 years for the last smartphone's lifetime and 2.56 years for the current smartphone's lifetime. A full comparison between lifetimes can be found in Figure 1.

The main reason pointed for replacing a smartphone was some kind of malfunction (69%), followed by obsolescence (14%), having been gifted a new one (9%) and simply wanting a new model (5%). All the respondents who had answered they replaced their phones because of different kind of malfunctions were asked if they tried to repair them before acquiring a new one: 53% of them did not. Wieser and Tröger [3] reached similar conclusions for the tried-to-repair ratio, with 66% of the surveyed responding they did not attempt to repair their phones. At this point, the respondents who did not tried to repair their smartphones were presented with an explanation of how modular phones like the Fairphone 2 were built and how they allowed owners to self-repair their devices. Then, they were asked whether they would have tried repairing their last smartphone had it been modular rather than immediately replacing it with a new one. 51% answered positively. Since we have already stated how optimistic people tend to behave when facing the longevity of their phones, these results should not be understood as a foreseeable reality were modular phones a design standard. However, they help us understand how design becomes a most important consideration for taking the steps to repair one's phone or not.

Table 2. Average time of malfunction, frequency of malfunction and average extended lifetime after repairing for each component.

Component	Average time of malfunction (years)	n	Average extended lifetime (years)	n
Display	2.068	346	1.043	44
Battery	1.869	497	1.183	58
USB port	2.208	254	0.907	22
Microphone	2.415	171	1.480	5
Jack Port	2.517	151	0.794	5
Case	2.173	171	1.390	5
Camera	2.289	175	1.224	5

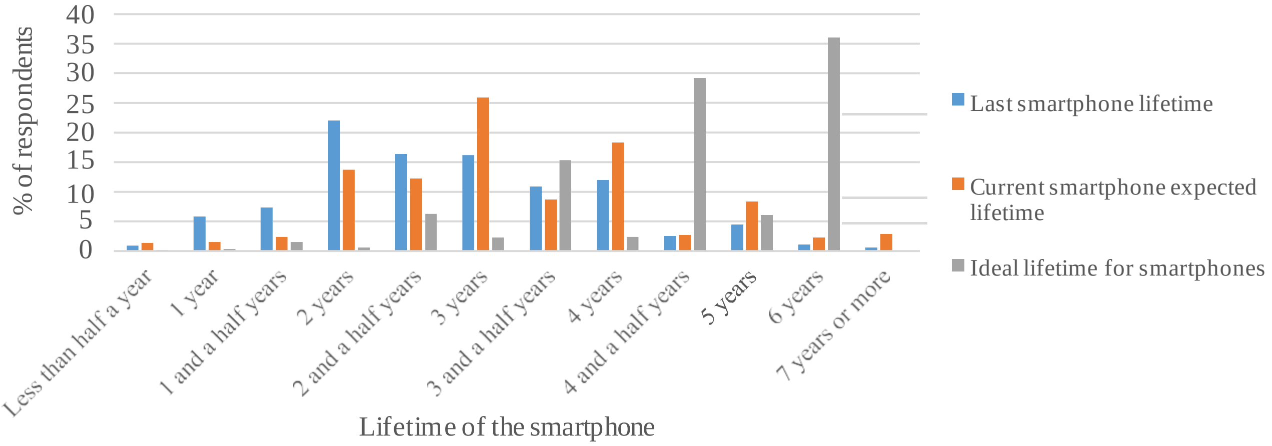

Figure 1. Distribution of the respondent's last smartphone lifetime, actual smartphone expected lifetime and their thought on how much time should smartphones last.

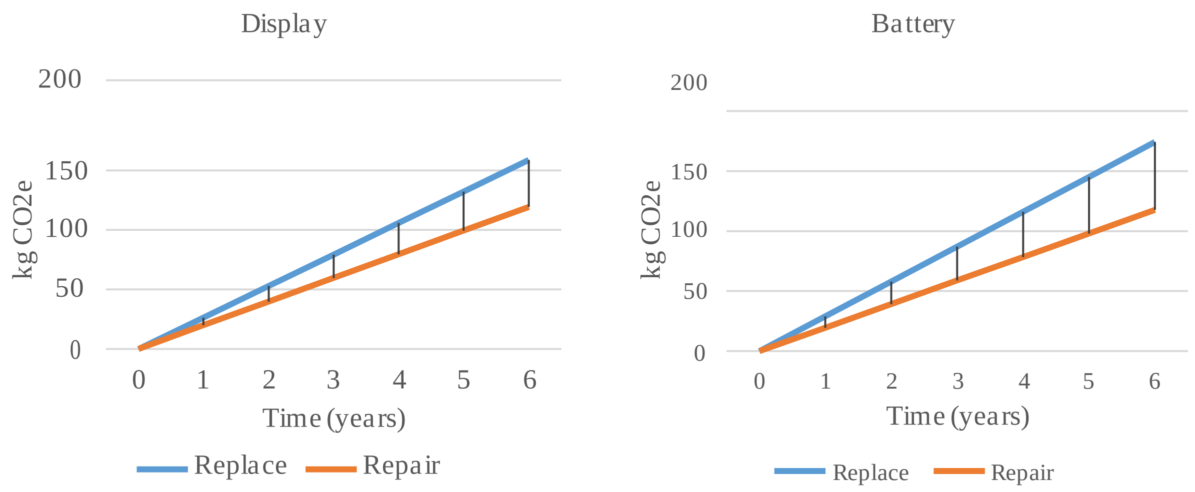

Figure 2. Accumulated individual carbon footprint for the display's and battery's replacement and repairment scenarios.

For properly understanding which the most common technical issues of smartphones are, we asked the 672 respondents to recall at what time did every component malfunction. Table 2 shows how many of them faced this kind of faults and the time since purchase/obtention they occurred.

As previously stated, an average smartphone "extended lifetime" was determined for every component (Table 2) and two scenarios were designed for each the display and the battery (Figure 2). We concluded that, if the average consumer were to repair the display or battery instead of replacing the phone at their respective average time of malfunction, 6.59 kg CO2e per year would be spared for the former and 9.43 kg CO2e per year for the later. Finally, we aimed at estimating how many kg CO2e would have been saved if every respondent that had proclaimed that he/she had replaced his/her phone because of a battery and/or display issue had instead repaired it/them. For every one of those respondents, we added to the lifetime of his/her phone the average extended life for the repairment of the faulty component they reported. When the malfunction of both components was the cause of replacement, we added the lesser average extended life of the battery repairment. Seventy-nine surveyed people were accounted under these circumstances and a total of 588.25 kg CO2e per year could have been avoided.

4. Conclusions

Along the discussion of this work we have seen how a change on new different kind of behaviors and habits can be a potential new path for diminishing the global warming impact of smartphones. This study has shown how easily, when faced with a component malfunction, consumers tend to replace their smartphone against the alternative of repairing them and what cost this has from a GWP perspective for the case of battery and/or display malfunctions. We have estimated an average lifetime for every component and an average extended lifetime for every phone repaired.

However, some improvements could be made to the model and scenarios, such as:

- Including replace/repair scenarios for every component.
- Including the extra lifetime of smartphones that find another use in developing countries.
- Evaluating at which point in a smartphone's life it is environmentally detrimental to repair the phone rather than replace it.
- Including the remaining impact categories of the environmental impact, as seen in the Xperia Z5 LCA.
- Considering pros/cons scenarios for a modular phone, since its gold coated connectors and additional board area increase environmental impact by 10% according to Proske et al. [6].
- Learning more about the amount of time people coexist with malfunctions in order to postpone the need for repair or replace their phones or components.
- Developing a new measure of "extended life" from repairment that takes into account the age of the phone, since the oldest it is, the more likely it is to malfunction again in some way.

References

[1] Greenpeace. (2016). *What do people think about their mobile.*

[2] Jaeger-Erben, M., & Hipp, T. (2018). *All the rage or take it easy- Expectations and experiences in the context of longevity in electronic devices. Descriptive analysis of a representative online survey in Germany.*

[3] Wieser, H., & Tröger, N. (2018). Exploring the inner loops of the circular economy: Replacement, repair, and reuse of mobile phones in Austria. *Journal Of Cleaner Production*, *172*, 3042-3055.

[4] Wieser, H., & Tröger, N. (17-19 de june de 2015). The Consumers' Desired and Expected Product Lifetimes. *PLATE Conference 2015*. Nottingham, England.

[5] Ercan, M., Malmodin, J., & Nilsson, E. (2016). Life Cycle Assessment of a Smartphone. Proceedings Of ICT For Sustainability 2016. *Proceedings Of ICT For Sustainability*.

[6] Proske, M., & Clemm, C. (2016). *Life Cycle Assessment of*

the Fairphone 2. Berlin.