8. Scalability and durability, or: is modular the new durable? The case of smartphones

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8.1 Introduction

Few modern electronic devices are as frequently discussed in terms of their ephemerality as smartphones (see, e.g., Tröger et al. 2017). The smartphone has become a symbol of an accelerated modernity where multifunctionality meets multitasking and a fast market meets fast consumption. Thinking of a smartphone as a durable product seems like thinking of a racehorse as a turtle: slowness and a robust temperament do not seem to suit the smartphone as a highly equipped performer. But the smartphone race comes at a price. Even though the carbon footprint of a single smartphone is in the range of a few kilograms of meat (40–100 kg CO_2e (e.g. Apple 2022) compared with 22 kg CO_2e per kilogram of meat; Reinhardt et al. 2020), the rapid increase in global smartphone production has led to, among other things, high pressure on unrenewable resources such as gold, cobalt, tin, tantalum, and tungsten, as well as to long-lasting social-ecological damage in mining areas. From a sustainability point of view, further exponential growth of production in combination with short replacement cycles is not desirable, and thus questions of longevity and durability are brought into focus. The smartphone is an exemplary product for a discussion of the potential and limits of durability strategies, since it has evolved into a very convenient item due to high integration, but at the cost of durability-enhancing strategies such as repair and refurbishment. Taking smartphones as an example can help to clarify what shape(s) durability can take and which forms of durability are desirable from the normative perspective of sustainability. Is a durable thing something that is preserved as a whole, with all its (expected) functionalities? Or is it an entity that is adaptable or scalable in relation to changing needs and technological innovations and therefore can change its form or composition?

Since the acceleration of the smartphone market in 2007 following the introduction of the first iPhone, the device and its various features have undergone rapid technological progress. Immature technologies often have high failure rates and short lifecycles in the first phase after market entry. But, despite their increasing technological maturity, smartphones still have short production and replacement cycles and are used for only two to three years on average, with the majority of devices still working when they are replaced (Jaeger-Erben and Hipp 2018; Wieser and Tröger 2018; Schischke et al. 2021; Watson et al. 2017).

Technically, smartphones could last much longer than two to three years, particularly if small repairs (replacements of a broken screen or a weak battery, for example) took place and the software stayed up to date (Proske 2022). Considering this in relation to the usually highly intensive use of smartphones (on average, 3.5 hours a day spread over the whole day; see Statista 2020), the smartphone would qualify as a long-lasting product if it weren't for the short replacement cycles.

Short replacement periods have been considered one of the core issues when examining the sustainable use of smartphones and have been investigated in a few studies linked to product replacement, repair/maintenance, and the reuse of phones (see Wieser and Tröger 2018 for an overview). Since 2015, replacement cycles have steadily become longer, from an average of 23.8 months in 2014 to 33.6 months in 2020 (Statista 2021). It has been argued that reasons for this increase include a lengthening of smartphone contracts, mature markets, and higher prices (see also Wieser 2021). Still, most smartphones are being replaced before the end of their useful lifetime. Moreover, Benton et al. (2015) have found that if a smartphone is used for an additional year, the overall carbon footprint of the phone is reduced by 31 per cent. An overall benefit still exists if spare parts are needed for repair or if peripheral parts (display, camera, etc.) are upgraded to achieve this longer use time, as long as the mainboard is kept in use (Proske et al. 2020a). Summarising some of the literature on the reasons for replacing smartphones, Proske et al. (2016: 5) found that 'the main reason for replacement is that new devices have more functions combined with the opportunity for new devices through service contracts, the second reason are technical failures and breakage'.

In general, the reasons for replacement are related to a combination of usage patterns, use expectations, market developments, and (technological) device characteristics (see also Proske et al. 2016; Jaeger-Erben and Hipp 2018; Wieser and Tröger 2018). For example, users replace their still functioning devices when unsatisfied with storage space (e.g. after not regularly emptying the memory) or with the image quality of the camera (e.g. after a new smartphone with a better camera has been introduced). Another typical reason for replacement is the decreasing capacity of the battery; this is among the weakest points in a smartphone's technical durability, but the battery's durability is also related to or impaired by the high intensity of average smartphone usage. Thus, the 'durability problem' mainly seems to concern the performance of smartphone components, such as the capacity of the memory and the quality of the battery and camera, which then affects the evaluation of the smartphone as a whole. Therefore, component repairability and replaceability might be key to durable smartphones.

Backed by these ideas, modular product architectures became a promising design strategy. Modular architectures decouple products into components that can be independently and easily replaced or reused (Schischke et al. 2019, Proske et al. 2016, Agrawal and Ülkü 2013). Modular product designs have been around for over 50 years (Starr 1965) and have been touted as a means to offer customised products to the masses. It was only with the arrival of the circular economy debate in the last decade that modular product design became seen as a possibility to enhance longevity and sustainable consumption (e.g. Revellio et al. 2020). From the perspective of producers and product providers, modularity allows for the extension and simplification of services, since modules can be replaced more easily in case of malfunction, they can be upgraded if customer needs or technology changes, and their storage and redistribution can be more straightforward than for the entire device. Instead of an understanding of innovation that is based on the development of ever new technologies to constantly create new incentives to buy smartphones, modularity allows innovation to be thought of in smaller terms and to relate to the constant improvement of components or services geared to replacement and second life. Innovation through modularity also enhances user innovation by enabling the re-combination of modules.

As highlighted in Chapter 1, durability and scalability are important features of a durable economy. We understand scalability as the ability of an entity (e.g. object, system, or network) to change its boundaries – that is, to grow or shrink or to enlarge or decrease its reach or functionality. The creation of scalable things ensures the long-term functionality of singular products and of networks of connected things in the case of infrastructures such as railway or communication networks. In digital devices, scalability means the ability of a system of hardware and software to increase performance within a defined range by adding resources, such as further hardware. Modularity (as a quality of an entity) and scalability (the ability to extend beyond boundaries) are connected but independent features. A modular entity, such as an extendable crib, is scalable if modules are added or removed. Modularity can help to extend the functionality or reach of an entity beyond its initial boundaries; thus, it is one – but not the only – possibility to allow for scalability.

This chapter investigates the assumption that modular product design has the potential to connect durability with environmental sustainability by keeping one of the shortest-used digital devices in use for longer. This is important since modular product design can also lead to an explosion of resource use and an even faster market (this time for components), since it promises an ideal synergy between a never ending (cultural) need to improve individual consumer performance, the (capitalist economic) need to maintain or, better, constantly expand sales markets, and the (engineering) drive to reinvent and innovate technological systems. Therefore, we analyse the various relations between durability and modularity or scalability on the one hand and environmental impact on the other, and we discuss possible challenges and trade-offs. We highlight that in-depth knowledge of smartphones as popular cultural artefacts and everyday multifunctional companions is a prerequisite to design a durable and sustainable combination of product and services (or a 'product–service system') with modular smartphones. We present a typology of smartphone usage patterns based on a qualitative study and develop different durability scenarios. Based on this, we reflect on which form of modularity, and thus scalability, provides the optimum durability.

8.2 Modular smartphones: potentials, challenges, and tensions

Our chapter deals with touchscreen smartphones, which became the dominant design from the late 2020s (see Proske et al. 2020b), and focuses on the smartphone as the basic material entity. We also consider parts of 'smartphone systems', in the sense of bundles of phones, apps (software), and services. Hardware-focused modular designs for touchscreen smartphones became popular with the design experiment Phonebloks, which was created around 2013 by the Dutch designer Dave Hakkens.[1] The study describes the idea of a fully modular and upgradable smartphone, primarily to reduce electronic waste. Phonebloks essentially consists of a motherboard (called a 'base') onto which individual modules ('bloks'), including a battery, camera, or antenna, are plugged. If a component breaks, only this component needs to be replaced or repaired instead of the entire smartphone, and so less electronic waste is produced.

Although the design idea received much attention and inspired other attempts to develop modular smartphone concepts, it was never technically realised or commercially implemented. Other attempts have focused on upgradability and personalisation, such as project ARA, a prototype modular phone from Motorola that was later taken over by Google. The design was quite similar to Phonebloks; besides waste reduction, the objective was to offer a cheaper phone since only the modules had to be replaced in order to stay up to date. The modular device was developed to a high degree but never entered the market (Statt 2016; Hankammer et al. 2018).

The first devices with a modular design that entered the market were Fairphone 2 and SHIFT6m. Both designs were developed by start-ups that were driven by the motivation to develop a more sustainable phone. The two companies stated that they were founded to create an alternative to the fast-moving market and to maintain social and ecological standards. Longevity is also intended to compensate at least to some extent for the high and not entirely avoidable social and ecological costs. These designs mainly focus on easy reparability and thus the restoration of the device's functions, as well as possible upgrades. In contrast, a more dynamic modularity design strategy would allow for a flexible use of a diverse set of parts and modules (as intended by the Phonebloks concept).

Even though extensive modularity is still a niche phenomenon in the smartphone market, it can be assumed that modular devices will become increasingly important as the circular economy movement progresses, especially for fast-moving products, since modularity enhances possibilities for repair and refurbishment instead of replacement (see Revellio et al. 2020).

However, the relationship between modularity, durability, and sustainability is complex and by no means clear-cut. The decisive question is, first, what durability refers to: to the smartphone as a whole with all its (expected) functionalities, to the possibility of adaptation to changing needs and technological

1 See, for reference, www.onearmy.earth/project/phonebloks.

innovations, or to the robustness of all devices. If the first is foregrounded, then a 'simple' modularity that is limited to those parts that break down most often or wear out fastest, such as batteries and screens, is sufficient. If the second is intended, then modularity must be more pronounced and extend to those components that are most likely to be affected by technological innovations, such as the camera, memory, or possibly the sensors. Both interpretations of durability can have a positive or negative impact on the environment, because the more complex and elaborate the device, the higher the ecological costs. These decrease the longer the device and its components last, but only if repairs are made and upgrades are not too frequent. If, on the other hand, the focus is on durability, then modularity is often rather weak, because the more integrated the individual parts of the device, the less susceptible to breaking down they are. This can be seen, for example, in the question of water resistance. Liquid penetration is a common type of damage in smartphones (Agrawal and Bellos 2017). If smartphones are waterproof, they (potentially) last longer, but they are more difficult to modularise and repair. Furthermore, touchscreen smartphone designs often aim for a timeless, smooth, and seamless appearance, which can make them less susceptible to falling out of style, but the high integration of components again decreases the rate of repair and hardware upgrades.

Table 8.1 provides an overview of different durability strategies, the dominant features of the design, and their relation to sustainability. Depending on the durability strategy, the design focuses on robustness and resistance, repairability, adaptability, or expandability. Each level of modularity shares the sustainability risk that the more fragile design is more susceptible to failure and therefore more repairs and replacements are needed. Furthermore, higher degrees of modularity run the risk of inviting a (too) fast replacement of new components.

Table 8.1: Relations between modularity, durability, and sustainability.

Durability strategy	Designed for...	Modularity	Sustainability challenges and risks	Examples
Persevere	Robustness, resistance, and timelessness	Low modularity and high integration	Reduced lifetime in case of failure, since repair options are small	Rugged smartphones and premium smartphones (e.g. Apple or Samsung)
Repair	Repairability	Medium modularity with exchange of few parts (battery, screen)	Reduced lifetime if repair is not done or available Reduced lifetime through fragile design	Repairable: Fairphone 2, SHIFT6m Exchangeable battery: Fairphone1/2, most 'conventional' smartphones
Adapt	Adaptation and customisation	High modularity with exchange of several parts for customisation and adaptation to personal needs and adjustment to up-to-date performance parameters	Fast consumption of fast-moving upgrades Reduced lifetime through fragile design	Google ARA, LG G5
Upgrade and expand	Expandability and upgrades	Open modularity, expandable to up-to-date feature spectrum and add-on functionality	Fast consumption of fast-moving add-ons Reduced lifetime through fragile design Overconsumption of components	Google ARA, Moto Z (+ Moto Mods)

The key aspects for sustainable durability of modular smartphones relate to how the more fragile design is embedded in a 'robust' service system. While for non-modular devices it is primarily the design of the device that matters, for the different levels of modularity it is primarily the relation between developments in consumer expectations, technology, and the market on the one hand and, on the other, the product–service systems that determine whether durable is also sustainable. Durability through repair is about quick and easy availability of spare parts and repair services. A high level of modularity that allows consumers to exchange parts – or even expand existing parts if newer, more efficient, or faster components are available – can also increase consumption if the new components appear regularly and aspirations and user expectations rise at the same time.

Furthermore, the success of circular and durable design and business strategies relies on the development of appropriate usage practices. In the case of modular designs, the first issue is to understand which social practices in the context of smartphone use can ensure that modularity and durability go hand in hand and lead to a better lifecycle assessment overall. Second, it is necessary to investigate how much 'desirable' modularity-relevant practices differ from current smartphone usage practices. But, as mentioned earlier, the idea of durability through hardware modularity must accommodate a device that has become more and more integrated during its evolution until it is now something like a Swiss army knife, offering a wide variety of options to users as well as a high level of convenience. Smartphone designs and user practices have come together in a way that might make modular hardware design much less likely to succeed. We therefore start our investigation into the potential of 'durability through modularity' with a review of the evolution to the smartphone into a highly integrated device – not only technically but also socially.

8.3 Smartphone research

8.3.1 Touchscreen smartphone as a popular cultural artefact

The introduction of the iPhone by Apple marked a turning point for the concept of the mobile phone. The iPhone had an integrated operating system (OS), a web browser, and the iTunes store for downloading audio and video files. It had a touchscreen (instead of a keyboard) with a software-based keyboard. With the concept of the iPhone, Apple was able to redefine the market's boundaries by combining different industry branches: the mobile phone sector with the internet and portable music industry (Giachetti 2018). It further introduced the concept of an almost endlessly scalable device by means of constantly adding new apps to the available services in the app store. Apple set an example to the rest of the smartphone sector, and even though a multitude of smartphone providers appeared on the market, the design principles introduced by Apple have been adopted by almost all other players. Physical keyboards gradually disappeared, form factors became uniform, and all manufacturers relied on flexible operating systems that could be extended with third-party apps. The historical development of mobile phones shows that performance densities and the integration of parts and features have intensified enormously within the market. Moreover, novel use patterns have been integrated into mobile phones (e.g., clocks and diaries). For most devices, not even the battery or displays can be swapped easily. The architectural innovation of the smartphone (as a converging system of different technologies) was accompanied by an increasing integration of single components that are glued together within the phone.

The introduction of the smartphone transformed not only the market but also the social practices of mobile device usage and their integration into everyday life. While some smartphone studies focus on the negative psychological and health impacts of intensive smartphone usage, such as addiction, depression, anxieties, and various other public health concerns (e.g. Alhassan et al. 2018), others have underlined that people's relations with smartphones in their everyday lives are more ambivalent and complex (Ytre-Arne et al. 2020). In 2019, Daniel Miller wrote:

> Has there been an invention so integral to our lives, and so intimate, as the smartphone? Yet they are slippery things. Smartphones are both a step change in the ability of human beings to communicate with each other and become informed, and new point of vulnerability to penetration by the outside world … Apple makes the iPhone, Samsung the Galaxy; these are phones with the capacity to be smart. But what really makes them smart comes from below: from their appropriation by users. (Miller 2019: 1–2)

Mobile technologies have radically altered ways of self-fashioning and being connected to each other. New cultural and social forms arose and new modes of interacting, sharing, and self-organising led to new ways of 'being in the world' (Frömming and Köhn 2015). Like no other mobile device, the smartphone has become an extension of bodies, senses, and minds, something that is used to organise everyday life, to improve the self, to learn about the world, and to assist in social interaction.

Scholars within the fields of media and communication studies have argued that the smartphone 'is not itself a medium but is instead a convergence point for a wide range of media' (Farman 2012: 4), allowing for diverse uses (Boehmer et al. 2011; Ling et al. 2015). Some of these studies are not only about how often and how smartphones are being used, but also about the changing organisation of everyday life and the associated interpersonal relations that are part of smartphone use (e.g. Brown et al. 2002; Katz and Aakhus 2002; Baym et al. 2004; Lapierre and Custer 2021). For example, Ytre-Arne et al. (2020) have examined how people manage and experience time through their smartphone. They have found that, although smartphones promise to make some everyday tasks more efficient, this is not always straightforward to achieve in everyday life. Time management strategies need to be implemented that must overcome several temporal conflicts (Lohmeier et al. 2020; Ytre-Arne et al. 2020).

Similarly, a group of anthropologists have conducted ethnographies into the impacts of smartphones on the experience of mid-life (Miller 2021). They have argued that the smartphone's capacity to be smart does not derive from its design and production, but rather from how it comes into being through people configuring their phone through applications and settings and the phone's ability to learn about its user over time (based on algorithms). As outlined in a recent book description, 'smartphones have become as much a place within which we live as a device we use to provide "perpetual opportunism", as they are always with us' (Miller et al. 2021: 297).

In addition to literature derived from media studies and anthropology, research studies have emerged that examine strategies and ways towards a more sustainable use of smartphones. Studies have looked at, for example, replacement cycles (e.g., Wilson et al. 2017; Wieser and Tröger 2018), energy consumption levels when using smartphones (e.g., Tarkoma et al. 2014), including practices of charging and managing power (Horta et al. 2015), phone hibernation (i.e. keeping a phone even though a replacement has been acquired) (Wilson et al. 2017), and sustainable product–service systems (e.g. Hobson et al. 2018). A UK study has also shown that 'there was little sense that giving users more information about the ethical and environmental dilemmas embodied in the mobile phone would make a difference to purchasing, use and disposal behaviour' (ibid.:155), demonstrating that developing strategies for making the use of smartphones more sustainable might not be straightforward.

8.3.2 Smartphones as scalable and modular devices

Smartphones as multifunctional, integrated, and convenient tools enable or assist a great variety of everyday practices. They can be described as an 'all-round medium' that picks up more and more functions, diversifying how people use their phones in daily life. The scalability of smartphones is mainly due their modular software design, which allows – at least to a certain extent – the inclusion of more and more functions via apps. In the last decade the app market has grown immensely. In 2020, people were able to choose from 2.59 million applications on Google Play and 1.96 million applications on the Apple App Store (Statista 2021). The average user has around 40 applications on their smartphone (Simforum 2021).

Given its software scalability and ability to constantly fulfil new and additional functions, the smartphone can already be described as highly modular. Used with additional items, such as covers, earbuds, external loudspeakers, and power banks, the smartphone can become a 'smartphone system' made up of different modules. However, when it comes to the core item, the smartphone itself, we can speak only of a 'soft modularity', whose scalability requires the most extensive basic hardware equipment possible. The smartphone design is like a Swiss army knife (Satyanarayanan 2005) from the start; it provides the right hardware tool ready for all possible eventualities. Multiple cameras, sensors, microphones, extra memory, and graphics capacity, among other elements, ensure that a wide range of apps can be installed and used. Thus, most smartphones are sold and purchased as an 'all-inclusive device' and may have many more function options than are actually needed.

Thus, it seems obvious that, at present, the scalability of smartphones leads to more unsustainable consumption of smartphones, since the devices might be overequipped when purchased and the user might install more apps than needed. The rapid development of the app market and the increasing use of apps can also lead to a device's hardware reaching its limits more quickly and the device then being replaced sooner. Thus, scalability reduces durability. Nevertheless, the scalability of smartphones also offers the potential to downscale the range of functions (and the hardware required) and to orient consumption towards sufficiency and not extensiveness.

If hardware modularity should lead to more sustainability, because of durable smartphone use, we need to understand better how people make use of the different functions of a smartphone and how much they tend to upscale its functionalities or are likely to downscale software and hardware use. Our first question is: what kind of 'sustainable consumption potential' can we find in existing patterns of smartphone consumption? And how do these patterns relate to (downward) scalability and durability? Our basic argument is that modular devices and corresponding modularity-embracing practices need to be embedded into product–service systems that are geared towards a durability-enhancing modularity that takes different qualities of scalability into consideration.

But current product–service systems are oriented towards extensiveness; they provide 'all-inclusive hardware' and abundant software that are likely to trigger overconsumption. Our second question therefore is: how and what kind of product–service systems can better connect to the sustainability potentials in current consumption patterns? The third question is: how much do the different scenarios of sustainable product–service–consumption systems differ in their ecological benefits and their potential to reduce their environmental impact?

The following analysis mainly focuses on everyday routines and practices around smartphones; this also includes non-consumption practices that are related to maintenance or care. From our point of view, actual practices are more important for more or less modular designs than general attitudes concerning smartphones or the role of the smartphone as a status object.

8.4 Durability through modularity: developing modular designs based on a typology of smartphone practices

8.4.1 Approach and methods

To collect data for our research, 24 in-depth interviews were carried out over the period of one year. The selection of interviewees was based on theoretical sampling: that is, categories of possible contrasting smartphone use patterns were developed based on analysis of the first few interviews and new interviewees were chosen who potentially showed contrasting characteristics (e.g., people with more versus less intensive usage patterns or people with high versus low technical expertise). The interview guide was broadly based on five themes: daily practices linked to the smartphone; a tour of people's smartphones (mainly relating to apps); smartphones set against the wider media context of people's homes; norms and meanings attached to smartphones; and modular smartphones. A total of 24 interviews were analysed based on interview transcripts, open coding, and constant comparison, using ATLAS.ti qualitative analysis software. An inductive coding structure was developed to be able to carry out an initial thematic analysis; codes consisted of topics such as my smartphone and its daily tasks, optimisation of wider media, and changes in smartphone use (e.g., weekends, holidays, and life changes).

After an initial thematic analysis of the in-depth interviews had been conducted, several steps were undertaken to develop a typology of smartphone use and scenarios for modular usage practices.[2] The processed aimed at the development of scenarios for sustainable modular smartphone designs and associated practices (sustainable product–service–consumption systems). Based on our initial research into modes of modular and scalable product–service systems, we developed scenarios that would allow for a long-lasting – hence sustainable – use of smartphones. The developed scenarios were than qualitatively assessed in terms of their positive environmental potential.

8.4.2 Insight into everyday smartphone use

On overall analysis of interviews about everyday life with a smartphone validated the results of other qualitative studies that describe smartphones as everyday multipurpose companions. The list of everyday activities that use a smartphone is long and comprises almost all domains of everyday life – housework, family and social life, paid labour and other forms of work, shopping, leisure and entertainment, and mobility. The smartphone also creates new, virtual everyday spaces where users engage in digital self-presentation via social media apps or self-optimisation via timers and fitness or meditation apps. The smartphone not only supports the organisation of everyday life, but also helps organise past and future, by means of documentation of experiences and archiving of memories or by forecasting and planning. Interestingly, the smartphone is no longer (only) a phone, since calling somebody or receiving calls is sometimes the thing people do least with their smartphones.

In line with the findings of media studies, we could find examples of convergence and de-convergence. The smartphone sometimes replaces other devices, particularly small and monofunctional devices such as alarm clocks or wristwatches, but even though smartphones are often used as cameras or music/movie players, people tend to have an extra camera, television or big screen movie player at home.

2 See Hielscher et al. (2020) for a more detailed description of the research process.

A key insight was that smartphones are mainly 'function carriers' or tools. Even though most people spend a great deal of time with their smartphone and keep it close throughout their everyday lives, they do not develop an emotional attachment to the device as such. In many cases, people value and appreciate the many functions of the phone, but if something is dysfunctional over a longer period, they tend to replace the phone instead of investing time and effort in restoring its functions. This is a possible threat to durability. The smartphone's tendency to be (up)scalable increases users' expectations that they can continuously enlarge the spectrum of functionalities on their smartphone. But the growth of functionalities meets hardware limits eventually, and so it is increasingly likely that people become dissatisfied with their smartphone as a function carrier.

Nevertheless, these more general insights can be further differentiated by our typology of smartphone usage patterns introduced below.

8.4.3 A typology of modularity-relevant usage patterns

This section outlines our empirical findings, by introducing a typology of smartphone usage patterns based on four dimensions that describe a continuum of two opposite poles.

I. Stability-optimisation

This dimension distinguishes use patterns that either keep the functionalities of a smartphone stable over time or continuously experiment with new or altered functionalities. Stability means that a user keeps the apps and the associated functions on the phone stable over time and does not connect it to other devices. With functions, we relate to the different practices a smartphone facilitates by means of apps (software). Since most smartphones have similar hardware, the spectrum or pattern of functions used in the smartphone are mediated by apps. 'Stable users' spend little time organising their phone – for example by deleting unused apps or uploading new ones – and are habitual in their smartphone use. They could probably do without some hardware components of their phones since they never use them (e.g. cameras). Optimisation-oriented users use a diverse set of apps and functions and change the constellation of their apps continuously. Users on this side of the continuum often use their smartphone within a larger media ensemble: for example, together with a smartwatch, a tablet, or a laptop. They regularly (re)organise their phone and media ensemble to find their 'optimal' set-up. Part of this group likes to have the newest phone. They enjoy discovering new apps and functions on their phone.

II. Reduction-extensiveness

In this dimension users can be distinguished according to the extent of their smartphone use. Extensive consumption is characterised by very frequent consumption, using a great variety of apps and functions. Extensive users frequently change and enlarge the apps and functions on their phone to be able to use the phone for every possible situation (i.e. going on holiday). They use the full range of hardware components of their phones and reach the limits of the hardware earlier then less extensive users. Reduced consumption is characterised by a conscious motivation to use the smartphone as little as possible. People actively try to reduce their use time, they delete apps they do not use, and they rarely add new ones. The smartphone is considered to be a tool for particular situations. These users would probably discard not only software they did not need but also hardware components if they realised that they could do without them.

III. Convenience-takeover

This dimension distinguishes users according to their engagement with the smartphone beyond using its functions. Convenient users expect their smartphone to work properly at all times but do not want to engage in maintenance or care activities, for example. They add apps as they see fit but do not want to invest time in (re)organising them, deleting unnecessary apps, or managing storage space or updates. Convenient users would rather buy a new phone than upgrade or repair their old one. 'Takeover' describes practices that actively engage with the phone's settings, by organising apps and settings efficiently, while keeping an eye on the storage space and actively looking for updates. Takeover users might also conduct basic repairs to the software and hardware and/or engage with privacy and data security issues connected to using the phone.

IV. Overwhelm-control

This dimension is closely related to the technical and use competencies of the smartphone user. 'Overwhelmed' users have low technical competencies and often feel stressed and overloaded when they have to deal with any kind of technical problem or demand. They often feel dependent on and ruled by technologies that are at the same time a 'black box' to them. These users have difficulty maintaining their phones properly or diagnosing the cause of a failure. On the other side of the continuum are users with high technological and/or use competencies. These users know how to manage their smartphone to make it work properly and how to deal with most problems. These users would be able to assess the necessity of upgrades, updates, or repairs.

The last two dimensions are related, but convenience–takeover is more closely connected to the patterns of using smartphones (the actual engagement with the device) whereas overwhelm–control is connected to (the lack of) competencies that enable (or disable) certain practices. Very competent users are more likely to show takeover patterns of smartphone use, but they can also be convenience-oriented and uninterested.

Depending on their position within the different dimensions, we were able to identify six different types of smartphone use as described in Table 8.2. Figure 8.1 shows the positions of the types in a multi-field scheme. Since the first two dimensions are more critical to the differentiation of usage patterns, they are presented more prominently. And since we concentrated on actual usage patterns, the durability of the smartphone in amount and length of use did not feature in the development of the typology. Nevertheless, both aspects differ between the identified types and are included in the typology description. The scalability of the phone is mainly relevant to the optimisation, extensiveness, takeover, and control dimensions, as can be seen in the type description on the next page.

Figure 8.1: Position of the six smartphone usage types within the stability–optimisation and extensiveness–reduction dimensions.
Note: Italic letters are used for convenience-oriented users and the font size characterises the use competencies (larger fonts for higher competence).

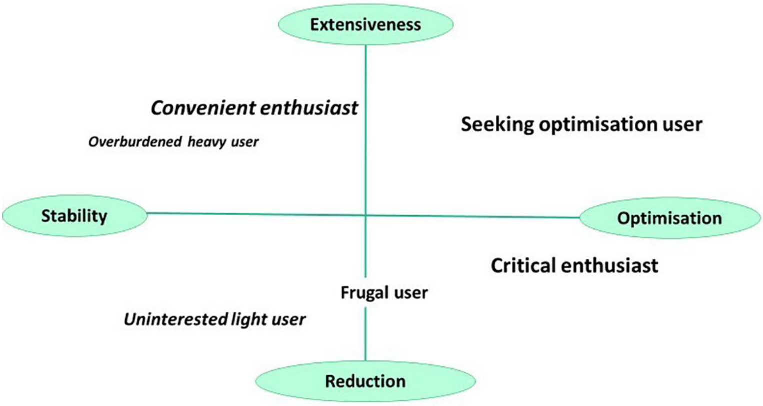

Table 8.2: The six types of smartphone use patterns and their characteristics.

Type and typical quote	**Use patterns**	**Scalability**	**Durability**
Uninterested light user *'I only use a few things linked with my smartphone. Telephone, I am calling people very small amounts of time. I have 100 free minutes and I never use them up. I use WhatsApp a lot.'*	High convenience and reduced use: usage concentrated in particular apps (e.g. social media) High stability: new apps/functions are rarely added Neither competent nor incompetent	Small scale of hardware and software in use Neither up- nor down-scaling software and hardware	Durability in terms of long use times mainly due to reduced use but challenged if device does not work as intended
Frugal user *'I try not to install all apps, just because everyone has them … I try to read through things so that there is a level of data security … I turn my GPS off, so that no one can reach me like this.'*	Optimisation and takeover towards reduced use Competence is acquired to make the use long-lasting and sufficient Control is important	Medium and reduced scale of hardware and software in use Downscaling both software and hardware	Durability as part of sufficient long-term consumption
Critical enthusiast *'I serve the device so that it serves me. So especially all these complex things, when you can do more and more with the electronics, it also puts a strain on me. That means I have to learn how to do it, and how to avoid mistakes, all this data protection and what's all connected to it, there's an ever longer tail of rats attached to many devices.'*	High competence, takeover and control, but critical towards issues of security and data protection Tendency to reduce use	Broad but varying spectrum of hardware in use Both up- and down-scaling of software in order to fit own standards	Durability and longevity depend on how the device meets own standards (e.g. of privacy, adaptability)

Type and typical quote	**Use patterns**	**Scalability**	**Durability**
Overburdened heavy user *'It's a device that can transmit data, that makes things public, I don't know how it does things. It's hard to describe. You never know what kind of things are stored somewhere, what kind of things are posted, what kind of terms and conditions you haven't read properly, what kind of GPS was on. So, you do not really have control.'*	Extensive use but low competence and tendency to be overwhelmed Dependent on social support and provider's services if device fails	High scale of software and hardware available but not entirely used Mostly upscaling with a tendency to have more apps and functions than needed	Low durability connected to short use times, since device is not well maintained and replaced when not working properly
Convenient enthusiast *'I think, this is because one is used to such a high level, it probably is hard to go down. Because everything is working absolutely fine all of the time and seamless, even when changing the smartphone. This is not a big issue and one can do [it] rather quickly. And I would say that such high content levels one does not want to reduce.'*	High to medium competence but low engagement and strong convenience orientation Smooth and fast operation is important and latest model is preferred Use is extensive and used apps/functions are stable over time	High scale of software and hardware in use Upscaling more likely but more or less stable use	Comparatively low durability, and replacement likely when device becomes less convenient
Seeking optimisation user *'It's great that you now have these cloud services that replicate everything directly, i.e. you have your images in the cloud and don't lose your valuable treasures. So that's the important thing!'* *'I always take the apps down and back on it, depending on where we are and what we need. So when I'm on the road, if we are in Berlin subway network, S-Bahn network, streetcar, on it and if we are in Hamburg, then the port forums and so.'*	High competence, strong orientation towards optimisation Smartphone is connected to cloud services and other devices High importance of control	Broad but varying spectrum of hardware in use Dynamic up-and downscaling	Orientation towards high durability connected with long use time, if optimum is found

8.4.5 Modular product-service systems for different use patterns

The six types show distinctive differences in how they make use of the smartphone as a scalable device. They also differ in the range of hardware they need on their phone. The frugal user, the user seeking optimisation, and the critical enthusiast are more likely to downscale their device in terms of software and hardware and use a durable design to its full extent, but for different reasons and under different circumstances. The frugal user has low expectations and only a few needs that should be fulfilled by a smartphone; they use only some aspects of the smartphone (calling people and browsing the internet but not using the camera, for instance). The other two types of users have high standards and expectations concerning their device and would rather replace a smartphone that does not fit their standards than keep it. They quickly reach their limits with a given smartphone and would benefit from upscaling. Since all three types have rather high competences that make use of the functional (software-related) modularity of a smartphone, they could also profit from a hardware-related functionality that fits their needs at the same time as it builds on their technical or use competencies to control and adapt their phone. The optimisation seeker and the critical enthusiast could both profit from dynamic product–service systems (PSS) that adapt hard- and software services to changing needs and standards. In the case of the optimisation seeker, the PSS should provide help for optimisation; for the critical enthusiast, it is more important that it offer high standards and quality for particular functions. The frugal user could profit from PSS that offer a 'frugal phone' that does not provide more hardware and software than needed. This also applies to the uninterested light user, who might need a bit more help in finding out what their basic needs and expectations really are. The convenient enthusiast and the overburdened heavy user tend to keep their smartphone at an upscaled level; for them, the Swiss army knife smartphone is the best option. In this case, durability and hence sustainability are not reached through modularity-oriented PSS but by high-quality and reliable products and refurbishment or take-back services.

Reflecting on the six use types in the context of the relation between durability, scalability, and sustainability led us to four different PSS scenarios that seek to optimise a sustainable use of smartphones. These four scenarios mainly relate to the dominant first two dimensions of the use typology (see the two axes in Figure 8.1); the other two dimensions are relevant for variations within the scenarios (see Figure 8.2). Table 8.3 describes the basic characteristics of the scenarios, their potential to foster durable, hence sustainable, consumption, and critical aspects regarding the environmental dimension.

Figure 8.2: Four scenarios for modular PSS.

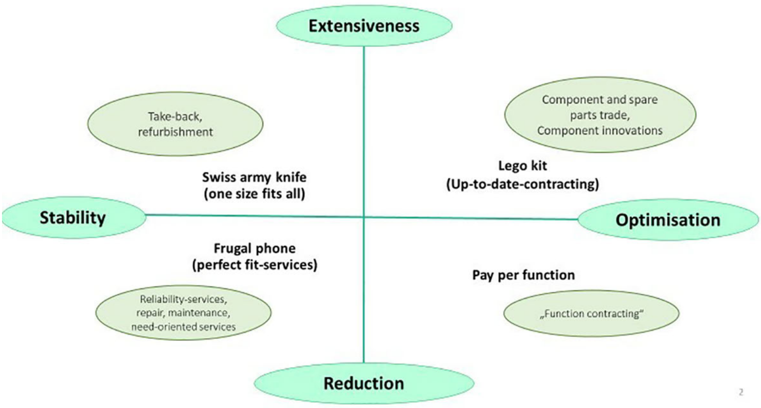

Table 8.3: Description of PSS scenarios.

PSS scenario	Swiss army knife	Frugal phone	Pay per function	Lego kit
Description	Product: One (biggest) size fits all, up-to-date technology Services: Take-back, refurbishment	Product: Basic modules Service: Needs-oriented sale, repair, and long-term updates	Product: Basic modules and expanding/upgrading options Service: Professional service at eye level, regular updates, and lending instead of owning	Product: Variety of modules Service: 'Up-to' contract that covers hardware upgrades and new modules
User types (and possible variations)	Overburdened heavy user (needs full service and high support) Convenient enthusiast (could be motivated to engage more, e.g. for maintenance, feedback to service provider)	Frugal user (could be motivated to engage more, e.g. for maintenance, repair) Uninterested light user (needs basic service that requires low engagement)	Critical enthusiast	Seeking optimisation user
Durability requirement	High-quality/high-end hardware, robustness, high up-scalability of hardware (particularly storage space allowing use of many apps)	Sufficiency/basic need orientation, down-scalability of hardware, reliability, fewer functions	High security, adaptability, dynamic up-/down-scalability of software and selected hardware	Expandability, adaptability, dynamic scalability of hardware

PSS scenario	Swiss army knife	Frugal phone	Pay per function	Lego kit
Requirements to reduce the environmental impact	Upgrades of peripheral parts could keep the mainboard in use Long overall product use time ensured through second and third use, main electronics are kept in use (e.g. for frugal users) Easy data transfer to new devices and secure data erasure enhances fast return of devices to enable second-hand use	No need for functional upgrades due to sufficiency orientation, repairability can deliver full potential, maintainability (battery exchange) is necessary to ensure longevity	Efficient connector design (small connector size, low amount of precious metals) Short-term need for certain hardware would not require a full high-end device (e.g. camera upgrade only for holidays) Easy and secure data erasure is needed to support short-term lending	Efficient connector design (small connector size, low amount of precious metals) Optimisation might lead to reduction in other devices (one product for everything)
Critical aspects regarding the environmental dimension	Modularity and PSS might accelerate upgrade cycles, including for main computing parts	Hardware functions might be rarely used but still needed from time to time, so no actual reduction in hardware components Reduced use of smartphone could require other products (e.g. digital camera if no camera is installed)	Short-term availability might lead to accelerated adaptation to new technical features	High frequency of module replacement, high fragility of overall device, resource intense production

8.5 Doing durability with modular smartphones

The aim of this chapter is to explore the potential for sustainable smartphone consumption, considering both existing usage patterns and new technological and service developments. The smartphone has a particular place among modern digital devices, because hardly any other device combines a similar number of functionalities and usage options with a comparatively short usage period. The scalability of a smartphone in terms of the expandability of functions makes the device an 'infinite machine' that is potentially eternally durable, but also carries the risk of reducing durability. This is mainly because this scalability of a smartphone mostly affects the software, while the hardware tends to remain stable. Although there are models of different hardware quality and equipment (e.g. in terms of storage space), once purchased, the equipment usually remains stable. If the usage volume increases due to the number of new apps, the hardware soon reaches its limit, and the device is replaced. On the other hand, the hardware can also be overequipped if users use only a few functions via apps. In this case, electronics are unnecessarily installed, and resources are overused. Both cases – quickly achieved under-equipment and permanent over-equipment – are ecologically problematic.

In this chapter, we have addressed the question of how the scalability of hardware can be increased in such a way that permanent and more ecologically compatible use is promoted. In doing so, we explored the potential of modular product–service systems with respect to different types of smartphone use.

The comparison of the contrasting types of smartphone use reveals a diversity of meanings, competences, and material arrangements that are associated with smartphones in everyday life. Growing old with a phone does not seem to be a straightforward process, given that the smartphone has become an integral part of people's lives and is linked to several daily practices. As argued by Miller et al. (2021: vi), the name 'phone' no longer really applies, 'since traditional phone calls now represent only a small part of usage'. Therefore, it is important to consider what function(s) a smartphone fulfils in the everyday life of a particular user and what type of relation and patterns have evolved between user and object. Our findings show that frugal and uninterested light users would benefit from a 'basic or downscaling' modularity, whereas users seeking optimisation and critical enthusiasts would value upgradable and expandable modularity with dynamic scaling options. Convenience-oriented users would not benefit from modularity but would need other types of PPS to be facilitated in sustainable smartphone consumption.

But downscaling is not a straightforward process. Miller et al. (2021: 104) have referred to the term 'perpetual opportunism' – i.e. 'simply because the smartphone is always with us, it creates the possibility to being opportunistic as a constant'. For example, the use of the smartphone has redefined how we take and store photographs, look at the news, listen to music, etc. Keeping the functions and applications of a smartphone over time is not easily done. A frugal phone requires the user to be extremely reflective about their existing and potential future practices that are enabled by the smartphone to prolong customisation and associated use for as long as possible.

The positive environmental effect of modularity results not only from the modularity of the product but also, as described above, from modular utilisation concepts. The PSS should also be modular in design. In particular, the linking and interaction of several user types within a service platform promises improvements. Quick upgrades for overburdened heavy users will never be truly sustainable, but by sharing devices and modules, this form of usage can be mitigated. While this can happen with the 'Lego kit' within a group of users seeking optimisation, since users rarely all have the same expandable needs at the same time, with the heavy user this would occur primarily through phones being passed on to other user groups with lower demands for technical high performance.

The PSS therefore needs to focus on the products, the modules, and the different users. As for repair in general, upgrades need to be 'easy' to be used. This could mean that a module is easily swappable by the end user, but it could also mean that upgrade cycles are already defined in a basic PSS contract and users do not need to keep track of which modules are available and when. Automatic information (e.g. on the phone) regarding new modules could makes processes easier for the user, but they could also accelerate upgrades as users are made aware constantly about new modules. This could even accelerate the exchange of the whole phone, if users are confronted with a range of new modules for almost all features and decide to ditch the product because of 'so much progress'. On the other hand, successive updates of certain modules in fixed time intervals could extend use time by upgrading the device without adding much acceleration.

Depending on the user and their specific knowledge, online shops and exchange platforms could be efficient means of disseminating new modules. For others, services such as professional exchange and advice on module choices could be needed.

Efficient linking of different user types with the passing on of modules and devices could thus make middle-class and low-end devices unnecessary. 'Yesterday's flagship can out compete today's best seller,' wrote Benton et al. (2015). Utilising used devices to fulfil lower demands instead of producing specific low-end devices would reduce the quantity of permanently required devices in the long term. The problem of functional obsolescence within a certain user group would be significantly lower for another user type. The prerequisites for this are general reliability, the possibility of replacing worn-out parts such as batteries, and the ability to repair damage easily.

Notions of longevity and sustainability are not inherent in smartphones, even if they are modular. These technologies are interpreted and adapted within the existing patterns of people's everyday life. How people use and live with their smartphones is deeply embroiled with, for instance, existing digital infrastructures, media ensembles, family relations, and changes to work situations and lifestyles. Developments towards a 'perpetual opportunism' and integrated smartphone designs (i.e. glued parts) do not necessarily make it straightforward to introduce different types of modularity to prolong a mobile phone's useful life. Thus, a smooth transition seems unlikely from the current, rather unsustainable use of the static modularity of a smartphone to sustainable consumption and a dynamic modularity that enables a circular economy. Modular smartphones (such as Fairphone or SHIFT) are currently niche products that cater for smartphone users who like the idea of such a phone. Within these niche markets, a lot of thinking seems to go into the technological developments of modular smartphones and related business models to increase the potential for more sustainable production and consumption patterns. Considerations of how modular smartphones are being domesticated in people's daily life – that is, what types of meanings are created and how the phone is placed within existing patterns of daily life – often seem to be neglected within these developments.

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