Understanding Mobile Phone Situated Sustainability:
The Influence of Local Constraints and Practices on Transferability

Consumers discard roughly 125 million mobile phones into landfills every year. The authors explore how local and community factors affect mobile phone sustainability.

In 2007, the number of mobile phone subscriptions worldwide reached 3.3 billion, underlining the pervasiveness of these computing technologies.[1] In 2005, the US Environmental Protection Agency (EPA) estimated that roughly 125 million mobile phones are discarded into landfills each year, illustrating the unequivocal connection between a successful pervasive computing technology and a looming environmental crisis (www.epa.gov/epaoswer/education/pdfs/life-cell.pdf).

Mobile phones are composed of several electronic components, whose material compositions (batteries, silicone, lead, cadmium, and so on) pose a threat to humans and the environment. Extensive research has revealed the material dangers and toxic effects of mobile phone disposal,[2] and programs and regulations that encourage or mandate mobile phone donation and recycling are emerging to help address the problem (www.opsi.gov.uk/SI/si2006/20063289.htm). Despite these efforts, responsible end-of-life solutions for mobile phones remain elusive and underused. A comprehensive EPA report published in 2008 presented findings of several studies of consumer electronics over the past several years. One study, based on data collected between 2003 and 2005, found that roughly 10 percent of mobile phones (by weight) were recycled compared to the volume produced (www.epa.gov/ecycling/docs/fact7-08.pdf). In previous research using a North American study population,[3] we examined people's actions surrounding mobile phone sustainability, how they attributed value to their phones, and how these perceptions affected the choices they made in acquiring and discarding phones. In this article, we explored how perceptions and actions surrounding mobile phone ownership are shaped by local constraints and region-specific information and practices. Previous research has explored mobile phone usage and customs in varied cultural contexts and uncovered a range of local practices.[4,5] Thus, by studying practices in several countries specifically from a sustainability standpoint, we aim to understand how local and community context affects people's choices regarding mobile phone end-of-life practices and their ecological implications.

We refer to this idea as *situated sustainability*—the notion that a device's sustainability is dependent not only on its design and composition itself but also on how the use of and practices surrounding it are supported by the environment in the specific context in which it exists.[6] By considering mobile phones' situ-

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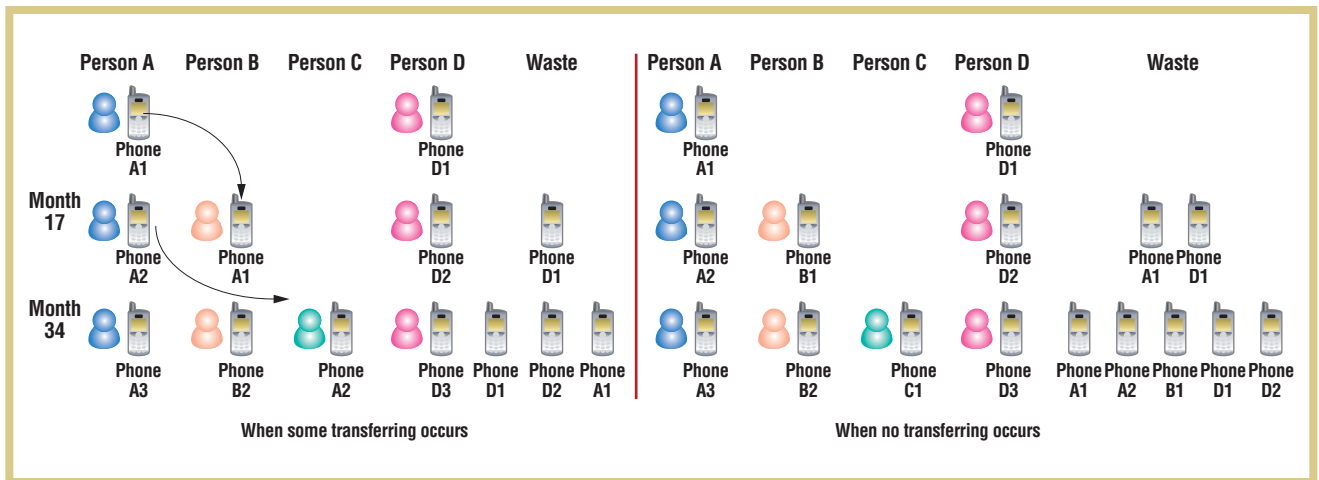*University of Washington*

Figure 1. Phone transfers. Transferring phones can slow the rate of e-waste production and lessen the need to produce new devices.

ated sustainability, we explored the complexity of the ecological problem posed by device proliferation on a global scale. This work illustrates that a single solution can't address the sustainability challenges posed to a device; despite the commonalities of mobile devices worldwide, the varied perceptions and practices represented in different regions and nations demonstrate a necessity for flexibility that suits the needs of individuals within their contexts.

Currently, several end-of-life options exist for phones and are exercised to varying extents. Options include recycling through electronics recycling programs, reuse of phones through reselling, phone giveaways, donation of phones to organizations that collect and distribute phones for reuse, and disposal of phones in the trash. Additionally, some actions cut across these options. For example, phone take-back programs offered by manufacturers or service providers might result in refurbishing and reselling, recycling, or disposal depending on the phone's model and condition. Donation programs might also distribute some phones for reuse while recycling others. Although sometimes not considered an end-of-life action, we also considered phone storage because it's an option that peo-

ple often exercise when they stop using their phones.

In this article, we report on findings from a larger ongoing inquiry into the sustainability implications of mobile phone practices around the world. Here, we focus on phone transferability—the ability to transfer device ownership easily to others through

- direct person-to-person transfers,
- mediated transfers such as donation for reuse, or
- refurbishing through a service or take-back program.

We explore how high transferability can open avenues for sustainability and how low transferability leads to increased waste and disposal and creates a barrier to sustainable end-of-life actions. Transferability has the ability to prolong the device's life, thus reducing e-waste and the burden on recycling centers, as well as the need to manufacture new devices. Although prolonging phones' life cycles and delaying disposal alone won't solve the waste problem, they're critical steps in reducing waste and the use of resources and materials. Figure 1 illustrates a simple example of how transferring cell phones can reduce the rate of e-waste.

Increasing transferability will also

be important in promoting the reappropriation of devices by other users or for other functions.[7] An emphasis on design that supports device reuse and reappropriation is a key tenet of sustainable interaction design.[8] Particularly for ubiquitous mobile devices, which are proliferating rapidly, increasing device transferability will be crucial to improving sustainability.

Study Design and Method

Though this work is part of a larger, ongoing study, for this particular study, we conducted semistructured telephone interviews with 35 participants in North America (11 participants from the US and Canada), Germany (8), and Japan (16). Variation in distribution reflects varying participant availability and access. Within each region, participant groups represented a variety of backgrounds, including students, retirees, salespeople, architects, administrative assistants, clergy, engineers, and artists. Participants ranged in age from their early-20s through early-70s, with the largest number of participants in their late-20s through late-30s. We recruited participants using snowball sampling, leveraging our personal and professional social networks of the researchers conducting the study. We recorded the telephone interviews, which

were conducted in languages in which the participants were fluent (English, German, or Japanese), and translated them into English for data analysis.

Interviews focused on participants' phone ownership history, inquiring about each of the mobile phones they had owned, their reasons for obtaining the phones, factors that had affected their phone choices, and motivations and actions for replacing or discarding phones. We encouraged participants to tell us stories about how they had obtained or abandoned phones, what they had liked or disliked about various models they had owned, and their decision processes. Although we also probed for actions such as selling old phones, giving phones away, disposal, and battery replacement, we avoided explicitly gearing the interview toward sustainability so as to minimize bias and instead, framed interviews as inquiries into ownership practices.

We analyzed our data by doing partial transcription from the recordings, transcribing over 1,200 relevant quotes. We conducted open-ended inductive coding on the quotes to identify themes pertaining to phone practices and contexts. Given the qualitative nature of the interviews and the modest size of the participant groups from each region, we can't assume that our interview populations are representative cross sections of the various countries,

frequency of these phenomena in the general population or within a country. However, the stories and perspectives that our participants expressed illustrate how actions and decisions relevant to mobile phone sustainability are influenced and shaped by local practices and constraints.

We discuss several contextual factors that were highly influential in people's practices surrounding the transfer of device ownership. We focus primarily on the economic benefits of transferability in Germany, the concerns regarding data privacy in Japan, and the role of service contracts in the US and Germany and the impacts of these issues on phone ownership and life cycle.

Germany: Transferability for Economic Fit

Ownership proved to be most fluid among the German phone owners we interviewed, with phones commonly having several lifetimes among multiple owners. For example, G1, an engineer in his 30s talked about having purchased his first mobile phone used from someone who had placed an ad for it in a newspaper. G1 subsequently sold that phone to a friend and former classmate after purchasing another used phone through a newspaper ad. In addition to buying and selling used phones, the ease of transfer was evident by the frequency of giving used phones away within peo-

family, giving it to our parents because they didn't have a mobile phone…. So we got them a prepaid card and gave them… her old mobile phones. [G1, engineer in his 30s]

Among the German participants, giving and receiving used phones was such a commonplace practice that seven of the eight people interviewed had either given away or received a used phone at some point, and many had done both. The remaining participant tried to give his only previous phone to his wife after obtaining a new one, but she had refused it because she didn't want a mobile phone.

Several contextual factors facilitated the transfer of phones for these participants. Given that phones in Germany are generally sold unlocked by default—that is, the phone can work with any wireless existing network without alteration—the need to ensure that phones are compatible with a recipient's service is obviated. This is in contrast to the US, Canada, and Japan, where people must take network and service plans into consideration when giving away or receiving phones. In Germany, the recipient can simply insert a new or existing subscriber identity module (SIM) card into the phone to start using it and there's no overhead or expense to unlock the phone. The fact that prepaid SIM cards are readily available, inexpensive, and commonly used also contributes to ease of transfer. Six of the eight participants we spoke to in Germany had used prepaid cards without contracts for their primary mobile phone service at some point, even though contract service was overall more common than prepaid service. Our participants' comments suggest that economical prepaid plans are often used in conjunction with used phones because new phones sold without contracts are generally not discounted. To purchase a full-priced phone would negate the financial benefits of using the economical prepaid cards for mobile phone service.

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nor can their practices be assumed to generalize across the greater population. We present some numbers to give readers an idea of the prevalence of certain behaviors across our population samples, but they aren't intended to provide statistical evidence of the

ple's social networks. The same participant also spoke about passing other phones around within his family:

With my wife's phone… She went through a couple of phones and those we distributed in the

Japan: Data Privacy as a Barrier to Transferability

In sharp contrast, none of the 16 Japanese participants had ever given a phone away, though one participant said he had previously borrowed a friend's old phone. Despite the fact that most of the participants replaced their phones quite regularly—yearly or bi-yearly—participants weren't distributing their old phones within their social networks, nor were they selling them or otherwise finding recipients for them. Mobile phones in Japan are typically acquired as part of a service contract, often free or at a discount. These mobile phones are also generally locked to a service provider, meaning that transferring a phone to another user would require either that the new owner use the same carrier, or that the owner have the phone unlocked, which isn't possible for several Japanese mobile phones. Unlocking a phone creates overhead for users because it entails paying the provider extra for the service or finding a method to unlock the phone oneself, which users might be hesitant to do.

Both of these constraints pose barriers to transferring phones among Japanese users, but surprisingly none of the participants mentioned them as reasons not to give a phone away. Although a few participants mentioned having returned their phones to stores through take-back programs at the time of replacement, most of the participants either kept their phones or discarded them in "unburnable" trash—trash that can't be incinerated or recycled. Overwhelmingly, these participants talked about data privacy as the primary motivation for their actions. Fourteen of the participants expressed some concern that others might have access to their emails, address books, or other data contained on their phone, a concern voiced by only one German participant and no North American participants. In comparison to users in North America and Germany, the purposes for which the

Japanese participants reported using their phones were more data intensive. For example, North American and German participants relied largely on SMS and voice calling for their communication. In contrast, the Japanese participants primarily used voice calling and email for their communication, with many participants reporting that they sent and received between 10 and 20 emails a day, and one participant reporting that she sent and received as many as 100 emails a day. Additionally, some Japanese participants reported other data-intensive phone use not mentioned by our other participants, such as using applications that let them access train schedules and maps.

This difference in phone usage among the various regions might explain in part why data privacy and transfer were such strong concerns among the Japanese participants and why it played such an influential role in decision-making surrounding end-of-life mobile phone practices. In many cases, participants kept old phones for reasons of privacy or data maintenance, rather than participating in mobile phone store take-back programs or other options:

> Even if I were to sell [my old mobile phones] at an auction or give them to my friends, I'm still afraid that the data may be leaked. [J6, manufacturing employee in his 30s]

Some of the Japanese participants also expressed doubt that it was possible for them or for mobile phone stores to completely erase or transfer all of the data saved on a phone:

> I read an article in a magazine and it said that we cannot erase all the data on a mobile phone. That made me scared and I decided to keep the old mobile phones. [J5, publishing professional in his 20s]

Participants who were especially worried that they couldn't erase their data and that this data might therefore be accessed by unauthorized individuals considered or even engaged in the extreme measure of destroying the phone to prevent privacy breaches, thus rendering the phones impossible to transfer, either through personal exchange or mediated transfer, such as donation or refurbishing:

Unlocking a phone creates overhead for users because it entails paying the provider extra for the service.

> I threw it away… I just forced it open and broke in into pieces and threw it away… I broke the internal parts into pieces so that others could not steal the data [stored on the device] and just threw it away. [J1, IT professional in her 20s]

Despite concerns over data privacy, some of the participants had given the phones to recycling and disposal programs offered by mobile phone stores after erasing their data. However, others expressed that their concern over data was their primary reason for not engaging in sustainable alternatives. It's possible that their practices might differ if their concerns over data privacy could be addressed. There was no mention of wireless exploits, such as Bluetooth attacks, which also pose similar privacy risks for their data. Just as there are best practices for avoiding Bluetooth attacks, there are ways to secure personal data on disk,

TABLE 1
Top four mobile service providers for 2007–2008.

	Company	Technology	% of Users
Japan	NTT DoCoMo	PDC FOMA	51.9
	au	CDMA	29.3
	SoftBank Mobile	PDC UMTZ	18.2
	Willcom	PHS	4.5
Germany	T-Mobile	GSM	37.8
	Vodaphone	GSM	34.2
	E-Plus	GSM	14.3
	O2	GSM	13.7
US	Verizon and Alltel	CDMA	31.7
	AT&T	GSM	28.0
	Sprint Nextel	CDMA	20.7
	T-Mobile	GSM	12.1
Canada	Rogers Wireless	GSM	38.3
	Bell Mobility	CDMA	32.3
	Telus Mobility	CDMA	29.2
	Sasktel Mobility	CDMA	2.3

including applications and services that will erase a mobile phone's content (www.recellular.com/recycling/data_eraser/default.asp). Thus, educating users about all the risks and helping them adopt better data protection practices might ease their reluctance. J5, who kept phones after having read the magazine article stating that phone data couldn't be entirely erased, talked about what he would do if he could be assured his data was gone:

> I am thinking that I could recycle any kind of electronic device. If possible, I would recycle [phones] like other electronic devices or appliances. [J5, publishing professional in his 20s]

Participant J6, who had the same concerns regarding data privacy, stated:

> It would be ideal if I could donate or [give them away for reuse]… whoever wants to use them. But the reason I don't is that my mobile phones have my personal data. [J6, manufacturing employee in his 30s]

Overall, data privacy was a major factor affecting end-of-life practices surrounding mobile phones among the Japanese participants, thus yielding a drastically different set of outcomes for mobile phones compared to those of the German participants. This contrast illustrates how the same or similar devices can have vastly different implications for sustainability depending on local contextual factors.

US and Canada: Transferability Constrained by Service and Contract

Unlike with the German and Japanese populations, interviews with North American populations didn't uncover any contextual factors that played an overwhelming role in phone transferability. Although context supported high phone transferability in the German participant population and yielded almost no practice of it among Japanese participants, the North American participants engaged in moderate phone transferability. This was influenced by a variety of factors, rather than a few extremely prevalent ones. The most apparent of these factors concerned limitations involving service plans and contracts.

Although phone transfer in the North American population wasn't nearly as widespread and commonplace as it was in the German population, we found evidence that it was a practice in which many people wanted to engage. In addition to attempting to find new owners for used phones within their social networks, participants also engaged in more structured forms of transfer, including donation programs, such as those that provide used or refurbished phones to domestic violence victims that let them make 9-1-1 emergency calls.

One participant, the CEO of an engineering firm, talked about keeping old company phones to serve as backup phones for employees and then distributing the remainder to employees for personal use:

> Well, if we had enough backup phones [for our company], like once we have enough backups—20 percent of the number of phones we have, after that, we'll probably just give [any remaining old phones] out to employees that need them, if they're functional. Yeah. Our policy is that if it's outside and we clearly don't want it anymore, then it's up for grabs. [NA4, CEO of engineering firm in his 20s]

Such practices, however, aren't the norm, and more often, people described barriers that prevented them from giving away their phones. In particular, North American participants mentioned technical limitations of service and contracts, which posed constraints on their ability to give phones to others and maintain them for longer. The variety of cell phone technologies

and providers in a given country can be an indicator of how transferrable a phone might be. Because there are so many different providers and technologies, and phones might be locked to a particular provider, this can prevent people in certain countries from transferring phones to others. Outside of Europe, it's more difficult to find others who use the same mobile phone technology.

Table 1 shows a breakdown of the top four service providers for the four countries we studied. We based our numbers on company press releases on their Web sites. The uniform SIM-card based GSM standard in Germany might contribute to the ease of transfer for mobile technologies. The lack of technology uniformity and increased reliance on unlockable technologies like CDMA and PDC formats in North America and Japan might contribute to fewer users transferring phones to others.

Participants were generally aware that they couldn't transfer phones easily from one service provider to another, with some being aware that this was because of the existence of multiple wireless network infrastructures:

> That's the other thing- I couldn't give phones away because many people are on GSM and I'm on a CDMA. So I couldn't give it to any family members or friends because most of them are on different plans. [NA8, journalist in her 30s]

As in the Japanese mobile phone system, North American phones are generally locked to a service provider. But unlike the Japanese participants, this was explicitly brought up as a constraint to transferability by the North American participants, whereas Japanese participants emphasized data privacy and didn't mention service constraints even though those exist. Two of the more tech-savvy participants talked about the possibility of unlocking phones for continued use or transfer, but also ex-pressed frustration about the effort and expense necessary to engage in a sustainable option as opposed to discarding the phone:

> I may just have to find an old cell phone disposal and actually get rid of them because no one seems to want them in the situations where it's come up. And in order to actually use them with any other provider at any time, like my current one, I have to pay to get them unlocked. Which is just going to kill… I mean if the phone's only worth $30 because I paid $50 for it and you have to pay twenty-something to get it unlocked, it's kind of insane. [NA6, student in his 20s]

Implications

We've focused largely on transferability, as it has strong implications for extending mobile phones' life cycles, as well as opening up channels for phone reappropriation and repurposing. Our research in North America, Germany, and Japan reveals factors inherent to mobile phone context, rather than phone design, which either serve to constrain or facilitate mobile phone transfer. Although further work remains to be done in terms of designing solutions to address transferability issues, we believe this research points to several channels for further exploration and design.

To understand the sustainability issues surrounding mobile phones, we need to consider not only what options are available but people's perceptions of their devices as well. For Japanese participants, data privacy was clearly a greater factor in phone transferability than technical constraints. This is perhaps not entirely surprising given the fact that they use their mobile phones for more data intensive purposes (email, video, and so on) than those of the North American and European participants. Their practices and concerns suggest that to improve mobile phone sustainability, users need to have a clear understanding of where data resides and when it's no longer present on the phones. For example, the information the Japanese participants obtained from the media, friends, and family members influenced them to destroy phones before discarding them. In addition to offering simple ways for users to transfer data and perhaps bring their phones back to an original, pre-use data state, phones might need to communicate more explicitly when personal data has been removed.

Given the experiences mentioned by North American participants as well as previous research, there's some desire on the part of phone users to find

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recipients for their old phones, but identifying potential recipients can be challenging. Finding ways to help phone owners transfer their phones to new users who can use them with minimal effort, expense, and overhead might encourage transfer and extend phone life cycles. Although constraints about locking and network compatibility appeared to be most influential and

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prominent in the North American data, similar solutions with some flexibility could be valuable for the German participants, who have a strong desire to transfer devices to new owners. There's also an opportunity with the Japanese participants, who expressed some value in reuse, assuming data privacy issues could be handled properly.

Additionally, this might also present an opportunity in which consumer education could help. Many customers aren't aware that unlocking op-tions are available through their service providers. Conversely, service providers rarely advertise that such options are available and usually require a lengthy procedure. For example, T-Mobile will unlock phones for free for international roaming purposes or for long-time users (http://search.t-mobile.com/inquiraapp/ui.jsp?ui_mode=question&question_box=unlock).

Another emerging technology option is multimode capability, which lets phones in propriety service markets roam between different networks. Although these capabilities were introduced for convenience during travel and for customers wanting to merge multiple phones lines, such an approach could greatly encourage transferability.

The perspectives and practices regarding mobile phone transferability in three different regions of the world serve to demonstrate how sustainability needs to be considered in a situated fashion, taking into account not only the design, materials, and function of the device but also the larger system in which it exists. Solutions that on the surface seem to be widely applicable, such as phone take-back programs, might not fit the needs and practices of vast groups of users. When considering how to design more sustainable mobile phones, regional variations and perspectives must be taken into context and solutions must be flexible to accommodate these perspectives.

Although our analysis focuses on Germany, Japan, the US, and Canada, we are currently collecting data from other countries in several geographic locations and of varied socioeconomic profiles to gain a broader picture of mobile phone sustainability and practices. In addition to examining transferability, we're also focusing on other factors affecting sustainability, including fashion's role in different countries, the roles of repair and part replacement, resource and information availability pertaining to environmental sustainability and how all of these affect and shape practices with mobile phones. As our research already indicates, perspectives and practices surrounding mobile phones vary greatly depending on context and local factors. By gaining a broader understanding of these factors and their influence, we can identify solutions that take situated sustainability into account and address users' concerns and constraints. ▣

REFERENCES

1. "Global Cellphone Penetration Reaches 50 Percent," (2008),. www.reuters.com/article/marketsNews/idINL2917209520 071129?rpc=44m.

2. B.K. Fishbein, "Waste in the Wireless World: The Challenge of Cell Phones," (2002), http://www.informinc.org/wirelesswaste.php.

3. E.M. Huang and K.N. Truong, K. N, "Breaking the Disposable Technology Paradigm: Opportunities for Sustainable Interaction Design for Mobile Phones," *Proc. CHI 2008*, ACM Press, 2008, pp. 323–332.

4. G. Bell, "The Age of the Thumb: A Cultural Reading of Mobile Technologies from Asia," *J Knowledge, Technology and Policy*, vol. 19, no. 2, 2006, pp. 41–57.

5. M. Ito, D. Okabe, and M. Matsuda, *Personal, Portable, Pedestrian: Mobile Phones in Japanese Life*, MIT Press, 2005.

6. E.M. Huang and K.N. Truong, "Situated Sustainability for Mobile Phones," *Interactions*, vol. 15, no. 2, ACM Press, 2008, pp. 16–19.

7. E. Paulos, I. Smith, and R.J. Honicky, "RE: REempower and Recycle," Workshop position paper for the Ubiquitous Sustainability: Technologies for Green Values Workshop at UbiComp 2007, 2007, www.paulos.net/papers/2007/RE%20REempower%20REcycle%20(UbiComp%20Workshop%202007).pdf.

8. E. Blevis, "Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse," *Proc CHI 2007*, ACM Press, 2007, pp. 503–512.

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