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DESIGN AS REGULATION: TOWARDS A REGULATORY ECOLOGY OF THE MOBILE PHONE

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Abstract

Mobile phones have become one of the most unsustainable consumer goods. New initiatives, such as Fairphone and Puzzelphone, are working on a more sustainable mobile phone design. This paper introduces the notion of lifecycle thinking to take sustainability beyond the product towards the larger product-system. Social and environmental sustainability needs to be addressed in the whole lifecycle of the mobile phone. This paper explores the opportunities and limitations of design as regulation. The relational concepts of script and affordance help to provide a non-deterministic account of design as regulation. The particular case of the Fairphone 2, a smartphone based on social and environmental values, will be discussed to investigate design as regulation. The notions of regulatory ecology and regulatory patching are introduced as tools to explore opportunities for constructing a more desirable regulatory regime.

1 Introduction

In 2012, the number of mobile phones per 100 persons reached 127 in the industrialised world and 95 in the developing world (Laurenti, Sinha, Singh, & Frostell, 2015). In the past years, on average 1.7 billion new mobile phones have been shipped worldwide. It is not surprising then that in the industrialised world, mobile phones are typical replaced with a new one after 18 months (Zadok & Puustinen, 2010), even though these phones are technically still functioning. Mobile phones have become one of the most unsustainable consumer products.

The term *lifecycle* is one of the central concepts in the discussion on sustainable products. Its systemic approach emphasises that sustainability is more than quantitative measures of certain aspects of a product. A product lifecycle can be defined as the "consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal" (Life Cycle Initiative, 2016).

The notion of *lifecycle thinking* refers to a holistic, systemic, and critical approach that guides the design, manufacture, use, and end-of-life of product-systems. This approach is applicable to all levels, from a single product-system, product sector or industrial sector, to that of an economy (e.g. circular economy). Lifecycle thinking can guide consumers, citizens, workers, designers, policy-makers, and industrial and business stakeholders alike.

Regulation plays an important role in sustainable design, for example, the regulation of the use of chemicals (the EU's REACH database), ISO standards, such as ISO 14000 (sustainable development) and ISO 26000 (social responsibility), or the EU legislation on

EcoDesign and Energy Labelling. This paper will look at the role of design in regulation and introduce a conceptual framework to discuss the regulatory role of design in constructing a sustainable mobile phone lifecycle.

Many authors maintain that 80% of the environmental impact of a product is determined in the design phase (e.g., European Commission, 2012; Maxwell & van der Vorst, 2003). The 80% seems to be based on research that shows that 70-80% of the features and costs of a product are established early in the design phase (e.g., Birou & Fawcett, 1994). Thompson and Sherwin (2001) deducted that therefore also 70-80% of the environmental costs were established in the early design phase. This statement puts a lot of power and control in the hands of the designer and the designed. Framing this power and control as regulation, the question this paper will address is: what are the opportunities and limitations of design as regulation.

The remainder of the paper is as follows. Section 2 will focus on design as regulation. In regulation theory, design and other forms of architecture are often dismissed as *regulators* of human behaviour, because they are seen as lacking intent. Those who do perceive architecture as regulation, often understand the relationship between design and human behaviour as deterministic: they see a direct, causal relationship between a technology's design and its use (Feenberg, 1999; Knox & Schweitzer, 2010).

Lawrence Lessig's theory of regulation identifies four modalities of regulation, law, social norms, architecture, and markets. Lessig generates two important insights for sustainable technology design. First, he establishes the role of architecture (nature, design, built environment, materials) as regulator of human behaviour. Secondly, Lessig's theory of regulation introduces the indirect regulatory effects of architecture, that is, architecture can strengthen or undermine the regulatory effects of other modes of regulation, markets, social, norms, and law. This perspective enables a relational rather than determinist perspective on regulation.

This paper discusses the notion of *regulatory ecology* to refer to the constructed regulatory complexity surrounding the lifecycle of a mobile phone. Regulatory ecology is presented as a *figuration* for the complexity of regulation in a product-system, as well as a visualisation or mapping of lifecycle thinking. The notion of regulatory ecology opens up for a relational understanding of design as regulation. Two concepts will be introduced to help explore the regulatory ecology of mobile phones, *script* and *affordance*.

In Section 3 I will undertake an initial mapping of the environmental and social hotspots in the lifecycle of mobile phones, based on existing literature, and I will turn to a particular case in sustainable mobile phone design, the Fairphone 2, and describe how it has addressed the social and environmental hotspots through design. Section 4 presents a discussion of the findings, exploring how regulatory ecology, script, and affordance can be used to understand regulation by design. Rather than trying to attempt to produce a complete regulatory ecology of the Fairphone 2, this account will contribute to understanding regulation through design. This is followed by some concluding remarks and plans for future work.

2 Design as Regulation

Regulation theorist Julia Black (2006, p. 11) defines regulation as "a process involving the sustained and focused attempt to alter the behaviour of others according to defined standards or purposes with the intention of producing a broadly defined outcome or outcomes." Karen Yeung (2015) points out that "defining regulation in terms of intentional action" excludes artefacts from having social or political effects. Her proposal to expand this definition of regulation, to include artefacts, is based on perspectives found in Science and Technology

Studies (STS), which studies technology in its unique social context, on a micro as well as macro level. Technology is defined here as “an assemblage of material objects, embodying and reflecting societal elements, such as knowledge, norms, and attitudes, that have been shaped and structures to serve social, political, cultural, and existential purposes” (Quan-Haase, 2015, p. 9). According to Yeung (ibid, p. 22) “design-based regulation operates by preventing or inhibiting conduct or social outcomes deemed undesirable”.

Lawrence Lessig’s (1998, 1999) theory of regulation supports the possibility of artefacts having regulatory effects. Lessig’s theory is based on four modalities of regulation: law, markets, social norms, and architecture. Lessig focuses on the way in which these modalities *constrain* human behaviour, directly and indirectly. Law regulates through a set of commands, backed by the threat of punishment, and markets regulate through price. Social norms regulate through sanctions that members of a community impose on each other, while architecture regulates through the way the world is (nature) or through man-made constraints (built environment, computer code, design).

To have a constraining effect, intentional action is required, e.g., law needs the police or the court system to have an effect, while social norms need people to notice and act upon non-conforming behaviour. In other words, laws, markets, and social norms are constraints checked by judgement. They are enacted upon when some person or group chooses to do so. This is different for architecture: once instituted, architectural constraints often have their effect until someone stops them” (p. 342-3); they are self-executing.

Another characteristic of these regulatory modalities is that they have a subjective aspect (how the constraint is experienced) and an objective aspect (how the constraint is observed when imposed) (Lessig, ibid). From an objective perspective, architecture and markets constrain up front, while law and social norms constrain after the fact. For example, a locked door (architecture) or a high price for a television (markets) constrain directly, while breaking into the neighbours’ home (social norms) to steal the television (law) may result in constraints (condemnation by the community or punishment by the court system) later on. From a subjective perspective, there is not much difference between the constraints; they can all constrain us before we act: the more subjective a constraint, the more effective (p. 344). For this happen, constraints such as laws and social norms need to be internalised to have this effect. This is not the case for architecture: the speed bump in the road will constraint our behaviour, even if we don’t know what a speed bump is or where it is located.

Law scholars have argued that even though “regulation through architecture is as powerful as law, it is less identifiable and less visible to courts, legislators, and potential plaintiffs (Schindler, 2016, p. 1952). Tien (2005) argues that it is, therefore, more dangerous: “Law as architecture operates differently: instead of affecting our calculus of choice, it structures the very conditions of action, such as social settings and the resources available in those settings” (p. 2). Tien is particularly concerned about the lack of transparency in computer code, which can regulate privacy and surveillance. Tien’s deterministic perspective on architectural regulation is based the understanding that its enforcement is less public and therefore reducing human agency.

Hosein, Tsiavos, and Whitley (2003) further explore Lessig’s account of the relationship between technology and regulation. They locate themselves in the field of Information Systems, which studies the design, implementation, and use of computer-based systems. They argue that the “regulatory nature of architecture starts long before it is in place. The regulatory nature of architecture lies beyond its ‘artefactual’ manifestation and is deeply rooted in human subjectivity” (p. 88). Technology can have unintended consequences and it can resist regulation or target objectives that are not supported by law, markets or social norms. They therefore conclude that technology is a particular type of regulation; technology is always a sociotechnical construct.

2.1 Regulatory Ecology

Lessig argues that the relationship between architecture and human behaviour is not deterministic: the meanings of forms, designs, built environment, nature, can change and thus their influences (p. 345). His account, that a constraint doesn't need an agent and his descriptions of the interactions between the regulatory modalities in strengthening or weakening their regulatory action, points to a relational and holistic understanding of regulation, rather than a technological determinist argument as found in Tien (2005). The regulatory effect of law can only be understood within the larger system of regulation, in which law is both strengthened and weakened by the effects of other regulatory modalities. When we add Hosein et al.'s (2003) analysis of technology as regulation to this understanding, we can see how technology can disrupt or promote regulation and thus undermine or strengthen certain human behaviour.

Tsiavos, Hosein, and Whitley (2003) argue that regulation has become global. People are no longer bound to the traditional centre of regulation, the state (law), as technology enables shopping, communication, work, etc. to become global activities. Architecture, markets, and social norms play a considerable role in the regulation of behaviour and provide a person with the option to choose or construct a regulatory regime. The authors introduce the notion of *regulatory patching*, which refers to the situation in which "the subjects "build" the regulatory 'ecology' that they wish to be subjected to" (p. 365-6).

The notion of *regulatory ecology* describes not only the idea of a constructed regulatory regime, it is also a very fitting figure to describe the regulatory system of an activity, such as knowledge sharing (van der Velden, 2006), journalism (Pritchard, 2014), biotechnology (Pottage, 2011), and corporate sustainability (Sjåfjell & Taylor, 2015). It acts as a *figuration* to represent the factors that regulate a particular activity in a non-deterministic manner. Using Donna Haraway's understanding of figuration, i.e. "performative images that can be inhabited" (p.11), a regulatory ecology is not a literal or static representation of regulation, but "some kind of displacement that can trouble identifications and certainties" (ibid). The figure of a regulatory ecology "troubles" accounts of regulation that ignore architectural regulation or that present technological determinist accounts of architectural regulation. Tsiavos et al.'s (ibid.) account of technology as regulation goes even further and point to a more *performative* understanding of regulation with the notion of *regulatory patching*: the on-going regulatory work to maintain or create the desired regulatory regime.

2.2 A relational understanding of design as regulation

Yeung (2015) identifies three mechanisms through which regulation proposes to work: i) changing individual behaviour; ii) prevent or reduce the probability of the occurrence of the undesired outcome; and iii) mitigate the harm. Design approaches that focus on sustainability have addressed each of the three mechanisms. For example, persuasive sustainability design (Lilley, 2009; Torning & Oinas-Kukkonen, 2009) and Design with Intent (Lockton, Harrison, & Stanton, 2010) focus on changing human behaviour; ecodesign and cradle-to-cradle design (Braungart, McDonough, & Bollinger, 2007) address the probability of the occurrence of undesired outcome; and design for remanufacturing (e.g. Hatcher, Ijomah, & Windmill, 2011) and design for repair (Jackson, 2014) support the mitigation of harm.

All these approaches have an outspoken regulatory agenda. Some, such as persuasive design approaches, are based on formal models of rational behaviour of individuals. Critiques of these approaches argue that design doesn't determine human behaviour and point to the need to understand human behaviour and sustainability from a more comprehensive and holistic perspective, not restricted to individuals and the products they use (Brynjarsdottir et al., 2012).

What all these design approaches have in common is the intentional manipulation of the *scripts* and *affordances* of product-systems. The notion of *script* (Akrich, 1992) comes from Actor-Network Theory (e.g., Latour, 2005) and is used to describe materials and products that are inscribed with particular purposes by designers - these purposes prescribe the possibilities and impossibilities of the designed without being determinative. A material script, such as a speed bump in the road or a hotel key made bulky so that hotel guests deliver it before they go out, enable the *affordances* of the material (Latour, 1991). Humans and non-humans can follow those scripts, but they can also ignore a script, such as in the example of the anti-sleep bench (Figure 1) or re-inscribe a design, such as using a plastic bottle filled with water as a solar bulb (see Figure 2).

Figure 1. Ignoring a script

Figure 2. Re-inscription

The second concept, *affordance*, originates in ecological psychology (Gibson, 1986). This concept can explain why material objects have more properties than just their physical properties. Gibson noted the importance of the relationship between the environment and the actions of an organism. Through perception, an organism perceives the affordances of its environment, which influences its range of actions. These affordances are additional properties that emerge in the relations between organisms and their environment. Affordance became an important concept in design. Further exploration resulted in the differentiation between real and perceived affordances (Norman, 1988) and perceptible, hidden, and false affordances (Gaver, 1991).

Affordance is not the same as function. Affordances emerge in a relationship and are the property of that relationship. If we look at the already familiar example of the bulky hotel key, and put that key in the hand of a hotel guest, we see that a particular affordance emerges in this situation: putting the key in a coat pocket is constraint by the size of the keychain; leaving the key at the reception is afforded by the size of the keychain. This affordance is the result of a particular *script*, the purposeful design of the hotel key and hotel guests with small pockets. Affordances may also be ignored or they may go unnoticed when they don't fit with users' experiences or cultural knowledge (Hornecker, 2012).

Scripts and affordances enable a particular understanding of situated actions between the social and the material or between people and things. Rather than the determinism found in certain understandings of architectural regulation, scripts and affordances enable a co-constructivist understanding of design. The scripts and affordances of design, or any other architectural regulation, can be ignored, re-scripted, and re-purposed: they can shape the social, but at the same time they are being shaped by the social.

3 Hotspots in the Mobile Phone Lifecycle

The simplified lifecycle of a mobile phone is often described as a cycle of four phases: resource extraction (mining of minerals), production (manufacturing), use, and end-of-life (re-use, recycle, disposal). What follows is a short description of some of the main social and environmental *hotspots* found in these four phases in the mobile phone lifecycle. A hotspot is a peak of resource use or a sustainability issue in a product's value chain (Liedtke, Baedeker, Kolberg, & Lettenmeier, 2010).

3.1 Hotspots

Resource Extraction

This phase concerns the mining of the minerals, metals, and rare earth elements, which are used in mobile phones and other electronics. About 40% of the average smart phone consists of metals of which many are rare as well as irreplaceable. (Graedel, Harper, Nassar, & Reck, 2015), 40% consists of plastics, and 20% ceramics and trace materials. Resource extraction is associated with several negative social impacts, such as slave labour, bonded labour, and child labour in countries such as DR Congo and Indonesia (Amnesty International, 2016; Apple, 2015). In particular mining in DR Congo is associated with so-called conflict minerals (Amnesty International, 2016). The environmental impacts of resource extraction for mobile phones, water and soil pollution, are especially the result of the poisonous waste by-products (BBC, 2015; Lima & Filho, 2015), which affects both the miners and the communities around the mining sites (Wilhelm, Hutchins, Mars, & Benoit-Norris, 2015). Mineral mining is also water and energy intensive and produces a large amount of green house gasses (Haque, Hughes, Lim, & Vernon, 2014).

Production

Social hotspots in the manufacturing of mobile phone and mobile phone components are lack of labour rights and low wage labour (Josephs, 2014; Ngai & Chan, 2012). Because of the volatility in production forecasts, resulting in batch production, workers experience a lot of overtime and lack of days off. Workers are also exposed to hazardous materials in manufacturing, resulting in serious health issues (Lee & Waitzkin, 2012; Yu et al., 2013). Environmental hotspots in the production of mobile phones are green house gas emission during manufacturing (mainly as result of electricity use) as well as water and soil pollution.

Use

The main social hotspot in mobile phone use is health risks related to radiation. In 2014, the World Health Organisation classified the electromagnetic fields produced by mobile phones as possibly carcinogenic to humans, based on a large study by the International Agency for Research on Cancer (WHO, 2014).

Traditionally, greenhouse gas (GHG) emissions during use were based on battery charges. With the introduction of smartphones, mobile phones are much more integrated with the internet. In a wider product-system perspective, both the mobile phone network and the servers providing mobile phone services (apps, storage) need to be included. Suckling and Lee (2015) show that in that case, the GHG emissions are five times higher and surpass the emissions during the extraction and production phases together.

End of Life

The social and environmental hotspots at the end of life of mobile phones vary tremendously. In industrialised countries, most mobile phones are stockpiled by consumers, and only 2.5 to 5% of all mobile phones are recycled (Navazo, Méndez, & Peiró, 2013). *Urban mining*, in which minerals from used mobile phones are recovered, results in at least 50% less energy use than conventional mining and has a higher recovery rate. Stockpiling thus reinforces the social and environmental hotspots of resource extraction.

Other forms of end of life are re-use, refurbishing, and recycling. Hotspots are mainly found in the unsustainable recycling of mobile phones and other e-waste (Böni, Schluep, & Widmer, 2015)

Table 1. Hotspots in a mobile phone lifecycle

Hotspots: ***Lifecycle phases:***	*Social*	*Environmental*
Resource extraction	Slave labour; forced labour; childe labour; health risks related to poisonous dust and hazardous materials exposure	Green house gas emissions; water and soil pollution
Production	Lack of labour rights; low-wage labour; health risks related to hazardous materials exposure	Green house gas emissions; water and soil pollution
Use	Health risks related to radiation exposure are not conclusive	Green house gas emissions
End of life	Health risks related to hazardous materials exposure because of unsustainable recycling practices	Water and soil pollution

3.2 Fairphone

Extending the life expectancy of mobile phones and creating a fairer – more sustainable – mobile phone lifecycle, is the aim of Fairphone,[1] a social enterprise based in the Netherlands. In December 2013, Fairphone brought its first mobile phone to the European market, followed by the Fairphone 2 in December 2015. Fairphone produces its mobile phones on the basis of *fairness*, which is the core value in its business model as well as its main strategy. Rather than defining fairness, the notion of fair is meant to start and guide a conversation about a socially and environmentally sustainable mobile phone lifecycle (Wernink & Strahl, 2015). In order to enable this conversation, Fairphone is fully transparent about its supply chains and cost breakdowns[2] and publishes reports and videos about its efforts in making the supply chain fairer. Fairphone identifies social innovation as the main driver for its mobile phones (Wernink & Strahl, 2015, p. 130) and values, such as

Figure 3. Design ambitions

[1] Fairphone: www.fairphone.com

[2] Fairphone resources: www.fairphone.com/resources/

sustainability and transparency, are "frontloaded" (van den Hoven, 2007) in their mobile phone designs.

Fairphone describes five ambitions for the design of its mobile phones (Figure 3). The design of the Fairphone 2 differs therefore significantly from other smartphones. First of all, it is the first modular mobile phone on the market[3]. The modular design of the mobile phone supports repairability without the need for specific expertise or tools. Repairability combined with a more robust design is expected to extend the longevity of the mobile phone from 2 to 5 years (Fairphone, 2015d).

Regarding fairer materials, the Fairphone 2 is manufactured with conflict-free tin and tantalum (coltan) (Fairphone, 2015e) and it is the first mobile phone produced with fairtrade gold (Fairphone, 2016). The plastic casing of the phone consists of 65% recycled plastic. Both the phone's hardware and software are open source, allowing others to develop hardware extensions, software, and operating systems. Table 2 gives an overview of how Fairphone proposes to address some of the hotspots in the mobile phone lifecycle.

Table 2. Fairphone addressing hotspots

Lifecycle	**Hotspots:**	**Fairphone 2 addressing hotspots:**
Resource extraction	**Social**: Slave labour and forced labour related to local armed conflict; child labour; health risks related to poisonous dust and hazardous materials exposure; armed and sexual violence for surrounding communities.	• Tin and tantalum are bought from smelters that process ore from conflict-free mineral initiatives supported by Fairphone. • First mobile phone with fairtrade gold. • Fairphone can't guarantee that child labour is taking place in the mines from which it sources its minerals
	Environmental: Green house gas emissions; water and soil pollution	• unknown
Production	**Social**: Lack of labour rights; low-wage labour; health risks related to hazardous materials exposure	• Audit of the working conditions in main assembly factory and components supplier. Implementation plans are in place to remedy some of the issues found (Fairphone, 2015a, 2015b, 2015f). • Fairphone didn't use benzene, a widely-used hazardous material in the electronics industry, in the Fairphone 1 (Fairphone, 2014). It is unknown if the same policy is used in the Fairphone 2. • Workers Welfare Fund established at main production site (Fairphone, 2015c) • In 2016, Fairphone 2 will be produced continuously instead of batch production
	Environmental: Green house gas emissions; water and soil pollution	• The Fairphone is shipped without charger or cables. It is using standard plugs, which users often already have. The back plate of the Fairphone functions as a cover; no extra cover is needed.
Use	**Social**: Health risks related to radiation exposure are not conclusive	• SAR is relatively low:[4] 0.288 W/kg for the head and 0.426 W/kg for the body
	Environmental: Green house gas emissions	• Unknown, but expected to be similar to other mobile phones

[3] In September 2016, the Puzzlephone will come on the market: www.puzzlephone.com, which is also a modular phone and is marketed as a sustainable mobile phone. Project Ara is an open hardware project for modular mobile phones of the Google and the first mobile phone coming out of the project is rumoured to be tested late 2016: www.projectara.com. There are significant differences between these modular phones. While the Fairphone 2's modularity is based on replaceable components with different sizes that provide basic mobile phone functionality (battery, cameras, microphone, speaker, etc.), Project Ara's modularity is based on hot-swappable modules with the same size. For example, an extra memory module can be swapped with an extra battery module without switching off the phone.

[4] Specific Absorption Rate (SAR): https://en.wikipedia.org/wiki/Specific_absorption_rate

End of life	**Social**: Health risks related to hazardous materials exposure because of unsustainable recycling practices	• In partnership with Closing the Loop,[5] Fairphone collects old phones in Ghana, Nigeria, Cameroon, Rwanda, and Uganda and ships them for more recycling to Belgium. They are exploring how to use recycled metals in the production of the Fairphone 2.
	Environmental: Green house gas emissions; water and soil pollution	

4 Designing for Sustainability

Fairphone engages existing social norms in the mobile phone sector by full disclosure of it supply chain, openness about unsustainability in the Fairphone's lifecycle - and how they tackle these, open-source hardware and software, and a repair-centric rather than an obsolescence-centric design. By building coalitions and partnerships, with organisations working on sustainability issues in the mobile phone lifecycle as well as with Fairphone owners and supporters, social norms about what is a good (fair) mobile phone are challenged.

Non-conflict minerals, fairtrade gold, open source, and modular design can be understood as the materialisation of values, such as fairness, sustainability, transparency, openness, and repairability in the design of the Fairphone 2. This design, Fairphone anticipates, will constrain some of the social and environmental hotspots associated with the mobile phone lifecycle. Design thus presents particular scripts, which play a role in the making of our world. When innovators, designers, and engineers define the specifications of a technological design, "they necessarily make hypotheses about the entities that make up the world in which the object is to be inserted, they thus define actors with specific tastes, competences, motives, aspirations, political prejudices, and the rest, and they assume that morality, technology, science, and economy will evolve in particular ways" (Akrich, 1992, pp. 207–8).

The concept of affordance is especially useful for explaining why a Fairphone script can be ignored. Gibson's theory of affordances was based on an animal perceiving its environment: "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Gibson, 1986, p. 127). For example, the repairability of the Fairphone 2 can only be perceived when the Fairphone is opened to insert a SIM card and the screws become visible.

4.1 Limits of Design as Regulation

A relational understanding of design assumes that design is not an autonomous actor neither a neutral actor. Design can be value-based, as the Fairphone 2 case shows, but how these values are expressed in the wider product lifecycle is the effect of interactions with other actors, such as users, laws, markets, cultural practices, etc.

A good example is the issue of greenhouse gas (GHG) emissions. Two central affordances of the mobile phone - wirelessness and portability - contribute to its wide variety of uses. We identified high GHG emissions in the use phase, but this hotspot is not addressed in the Fairphone's *design*. To decrease GHG, the Fairphone would have to diminish GHG emissions in the part of the mobile phone lifecycle that involves server and network connections. This would decrease central functionalities of the phone, such as storing data on the server and 3G and 4G network connections, which would radically change the mobile phone's affordances. In other words, *social norms* about what is a good mobile phone, in terms of what it affords, indirectly regulate GHG emissions. If Fairphone wants to tackle this hotspot, other design options need to be explored, for example, continuous visualisation of

[5] Closing the Loop: http://english.closingtheloop.eu/

energy use related to charging and overheating (*social norms*) and/or increased and more efficient battery capacity (*architecture*).

Another example is the repairability script. The modular design of the Fairphone 2, and the ease[6] of opening the phone and replacing components, supports the repair of the phone, which may extend the life expectancy from 2 to 5 years. However, this script can easily be ignored, in particular when other mobile phone brands, because of their shorter innovation cycles, introduce new aspects or functionalities within these five years that cannot be supported by the Fairphone 2. Also, the interactions between *markets* and *social norms* have created particular consumer behaviour when it comes to the frequency with which consumers buy a new phone. In industrialised countries, this has resulted in unsustainable consumer behaviour, in which fully-functional smart phones are replaced after 18 – 25 months with a new mobile phone. A combination of repair-centric design with other design details, such as those that increase attachment to a particular phone (Van der Velden, 2014), may further postpone replacement.

On the other hand, repair-centric design can be strengthened by other forms of regulation, such as the new anti-planned-obsolescence *law* in France[7] or the *lawsuit* that forced Apple to make the iPod battery replaceable.[8] Changing *social norms* about planned or functional obsolescence may also support Fairphone's repairability script. The recent case of the planned obsolescence of working iPhones, because of unauthorized repairs of the home button or Touch ID hardware, triggered a public outcry: iPhones stopped working after a software upgrade, which detected unauthorized repair[9]. The media described the case as an attack on independent repair shops, which boosted the already growing *right to repair* movement.[10] At the moment, the Fairphone is the only mobile phone that doesn't limit its warranty when the phone is opened and repaired by an unauthorised person (such as the owner).[11]

Challenges that affect the regulatory capacity of design for sustainability become visible when describing the different ways design and other forms of regulation act and interact, or regulate each other, directly and indirectly. On the one hand, extending the life expectancy of a mobile phone, through a repair-centric design, can have a major impact on the social and environmental hotspots in the mobile phone lifecycle, but current market forces counter this gain by using different forms of obsolescence to create an on-going market for their new models.

4.2 Regulatory Patching

Gibson's affordance concept has been extended in different ways. Gaver (1991) discusses the perceptual information of an affordance and argues that perceptible affordance needs to be designed. The already mentioned hotel key with bulky keychain is an example of a designed and very perceptible affordance. In Section 2, regulatory patching was introduced as a situation in which "the subjects build the regulatory ecology they wish to be subjected to"

[6] The author owns a Fairphone 2 and can confirm the ease with which one can open the phone and un/screw the different components.

[7] New regulation in France: http://www.theguardian.com/technology/shortcuts/2015/mar/03/has-planned-obsolesence-had-its-day-design

[8] Replaceable battery: http://www.girardgibbs.com/apple-ipod/

[9] Error 53 Fury: http://www.theguardian.com/money/2016/feb/05/error-53-apple-iphone-software-update-handset-worthless-third-party-repair

[10] iFixit: http://www.ifixit.com and Right to Repair: http://www.ifixit.org

[11] The warranty doesn't cover the opening up of components or replacement of third-party components.

(Tsiavos et al., 2003, p. 265-6). While Tsiavos et al. intended the patching of bugs or vulnerabilities in computer code (architecture), the meaning of regulatory patching can be extended to other architectural modalities, such as design,[12] or to other regulatory modalities, such as law. Designers of sustainable mobile phones and other electronic consumer products can apply regulatory patching when evaluating the social and environmental lifecycle of their design. Regulatory patching may make affordances more easily perceptible, thus triggering or constraining particular behaviour.

Secondly, when mapping the regulatory ecology of a product-system, it will become clear when and where different regulatory modalities strengthen or undermine each other. The mapping of the regulatory ecology of the Fairphone 2 makes clear that architectural regulation on its own isn't powerful enough to support sustainable behaviour in all of its lifecyle phases. Thus, the regulatory framework of the Fairphone can be patched up with activities that support the construction of new social norms around planned obsolescence and e-waste.

4.3 Concluding Remarks

By looking at design as regulation, its relational character became evident. The concepts of script and affordance helped to explore how the meaning and use of a designed object emerges in the relationship between the object and its human and nonhuman surroundings. A design can have unintended use or unintended consequences; design is not an autonomous actor causing change. The case of the Fairphone 2 exemplified how design can play a role in regulating the lifecycle of product-systems, but that other regulatory modalities, markets, social norms, and law, can both strengthen and undermine how design can constrain unsustainable behaviour. The notion of regulatory ecology was introduced as a tool to map the regulation of the mobile phone and to identify opportunities for regulatory patching.

This exploratory paper forms the start of a large research project, in which we will map the regulatory ecologies of the social and environmental hotspots in the lifecycle of mobile phones, with a main focus on the laws and regulations that maintain unsustainable practices.

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[12] For example, the bulky keychain can be understood as a regulatory patch in a situation where the sign "Please return your key to the reception when you leave the hotel" has no effect.

[13] SMART: www.jus.uio.no/ifp/english/research/projects/smart

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