Design as Regulation

Maja van Der Velden

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Opportunities and limitations for sustainable mobile phone design

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Abstract. Mobile phones have become one of the most unsustainable consumer goods. Social and environmental risks are found throughout the whole lifecycle of mobile phones. This chapter introduces the notion of lifecycle thinking to take sustainability beyond the product towards the larger product-system. Design can play a central role creating sustainable product lifecycles, but is constraint by other modes of regulation, such as law, social norms, and market. 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 designed with 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

Keywords. architectural regulation . *circular products* . *Fairphone* . *lifecycle* . *planetary boundaries* . *rebound effect. regulatory ecology*

1 Introduction

This chapter includes and builds forth on an earlier paper discussing sustainable technology design [1]. The focus is on the design of mobile phones, with the Fairphone 2, allegedly a fairer and more sustainable mobile phone, as the particular case. Mobile phones have become the most pervasive digital technology. For every computer, there are four smartphones on the planet [2]. Market saturation in the industrialised countries was reached in 2006 [3]. In 2012, the number of mobile phones per 100 persons reached 127 in the industrialised world and 95 in the developing world ibid. In the past years, on average 1.7 billion new mobile phones have been shipped worldwide. In the industrialised world, mobile phones are typical replaced with a new one after 18 months [4], even though these phones are technically still functioning. The majority of those phones are not recycled and mobile phones are the electronic device that is the most often disposed [5]. As will be discussed in this chapter, mobile phone production, use, and disposal is connected with significant social and environmental risks. Mobile phones have become one of the most unsustainable consumer products.

1.1 Sustainability

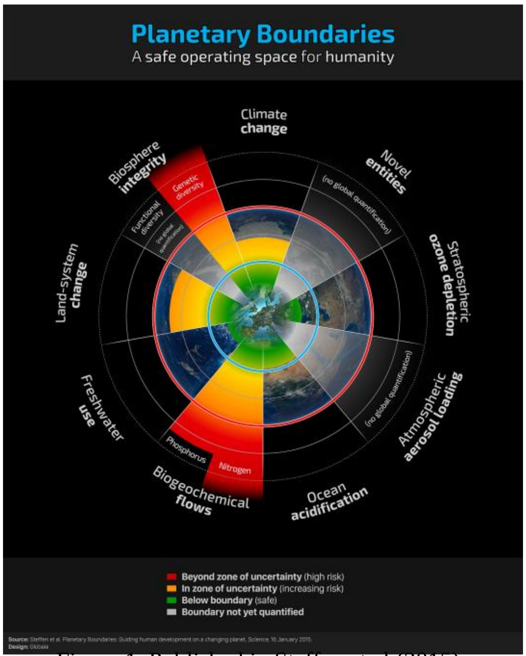

Figure 1. Published in Steffen et al (2015)

Sustainability has four dimensions, environmental, social, economic, and cultural. This paper will only deal with the first two dimensions, which will be discussed in the form of boundaries. For the environmental dimension, the work of the Stockholm Resilience Centre is of central importance. Their conceptual framework of *planetary boundaries is an* attempt to quantify the safe biophysical boundaries outside which the Earth System cannot function in a stable state, the state in which human civilizations have thrived [6]. Figure 1 shows the nine boundaries that are indentified in earth-system processes and shows that three boundaries are crossed “beyond zone of uncertainty (high risk) and two boundaries are crossed “in zone of uncertainty (increasing risk) [7]. In this context, sustainability can no longer be perceived as “doing less damage over time, but rather by finding ways of living that restore the eco-systems upon which we depend” [8].

Inspired by planetary boundaries framework, former Oxfam economist Kate Raworth translated the social dimension of sustainability into social boundaries or the *social foundation* that protects against critical human deprivations. Raworth combined these two framework into a figure, which she called, somewhat ironically, *doughnut economics* [9].

1.2 Lifecycle thinking

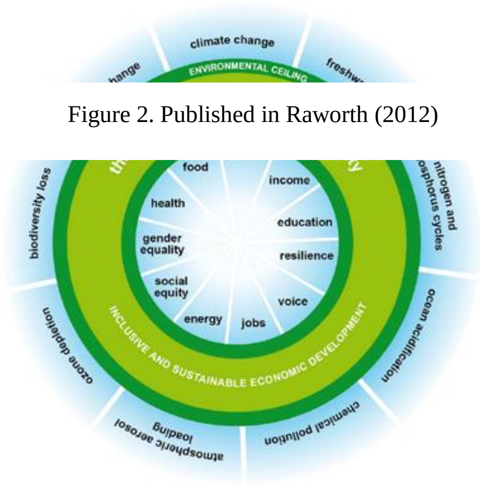

Figure 2. Published in Raworth (2012)

In the discussion of the sustainability of consumer products, the notion of lifecycle has become one of the central concepts. The term assumes a more systemic approach, emphasising 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” [10]. The term *lifecycle assessment* (LCA) is used for the analysis of the environmental impact of all the stages in a product-system, while *social lifecycle assessment* (S-LCA) is used for the analysis of the social impact of all the stages in a product-system.

A related concept is *lifecycle thinking*. In environmental management, see for example the revised ISO 14001 standard of 2015, lifecycle thinking is presented as taking a systematic approach, considering the environmental impact of the whole product lifecycle, not just the stage of phase or material for which a particular organisation is responsible. It also enables an organisation to understand how its decisions in one phase of a product can have significant environmental impacts in later phases of the product-system. For example, the choice of chemical components in the manufacturing of a product can have severe impacts in the end-of-life phase, when a product ends up in a landfill.

In this chapter, *lifecycle thinking* will refer to a holistic, systemic, and critical approach that guides the design, manufacture, transport, use, and end-of-life of product-systems. Lifecycle thinking 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.

In order to stay within the safe and just space for humanity, as conceptualized with the planetary and social boundaries frameworks, lifecycle thinking requires a move from linear to circular thinking, both on the level of products as that of the economy as a whole. A product can thus be considered sustainable when the lifecycle of its product-system is located within the planetary and social boundaries. The notion of *circular product design* [11] is gaining acceptance as a central concept in the transition to a sustainable circular economy.

1.3 Regulation

Regulation plays an important role in sustainable product-systems. For example, the regulation of the use of chemicals in the EU,[1] the so-called REACH database; ISO standards, such as ISO 14000 on sustainable development[2] and ISO 26000 on social responsibility;[3] and the EU legislation on EcoDesign and Energy Labelling.[4] This paper will look at the role of design in regulation and introduce a conceptual framework to discuss the regulatory role of design in sustainable mobile phone lifecycles.

Many authors maintain that 80% of the environmental impact of a product is determined in the design phase [12, 13]. 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. 14]. Thompson and Sherwin [15] deducted that therefore also 70-80% of the environmental costs were established in the early design phase. Correct or not, this statement places enormous power and control in the hands of the designer and the designed product. In order to unpack this power, this chapter will frame this power and control as regulation and ask: what are the opportunities and limitations of design as regulation.

The paper is organised as follows. Section 2 will focus on design as regulation. In regulation theory, design, nature, the built environment, materials, etc., are often dismissed as *regulators* of human behaviour, because they are seen as lacking intentionality. Those who do perceive those as having regulatory agency, often understand the relationship between design and human behaviour as deterministic: they see a direct, causal relationship between a design and its use or impact [16, 17].

Lawrence Lessig's [18] theory of regulation identifies four modalities of regulation, law, social norms, architecture (technology, nature, design, built environment, etc.), and markets. Lessig generates two important insights for sustainable design. Firstly, he establishes the role of architecture 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 opens up for a relational rather than determinist perspective on architecture as a mode of regulation.

This chapter discusses the concept of *regulatory ecology*, which refers 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 concept of regulatory ecology contributes to a relational understanding of design as regulation. Two additional concepts will be introduced to help explore the regulatory ecology of mobile phones, *script* and *affordance*. Script refers to the particular purpose and values inscribed by designers in a product. Affordance refers to the particular properties of a product, which emerge in the relationship between people and their environment.

Section 3 will start with an exploratory mapping of the social and environmental risks in the mobile phone product-system, using the planetary and social boundaries framework as a guide. I will then introduce the Fairphone 2 as a particular case and describe if, and how, these sustainability risks are addressed in the Fairphone 2. Based on the findings in Section 3, Section 4 presents a discussion of the opportunities and limitations of design as regulation, informed by regulatory ecology, script, and affordance. This is followed by some concluding remarks and a description of future work in Section 5.

2 Design as regulation

There are different definitions of regulation, mainly as a result of the different disciplinary approaches to regulation [19]. Lawyers have a different perspective than economists or political scientists. There is no particular understanding of regulation in design research, although in the broader field of science and technology studies (STS), several concepts and theories are proposed to understand the regulatory role of design and technology. A well-known discussion on the regulatory role of design was presented by Winner [20], discussing the height of the overpasses in New York, built in the 1930s, which prevented public transportation buses, mainly used by Afro-

[1] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency

[2] The ISO 14000 family of standards provides practical tools for companies and organizations of all kinds looking to manage their environmental responsibilities.

[3] ISO 26000 provides guidance on how businesses and organizations can operate in a socially responsible way. This means acting in an ethical and transparent way that contributes to the health and welfare of society.

[4] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products**.** Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.

American citizens, from reaching the beaches. It is not clear if the bridges were deliberately design with racist intend or not, but the effect remains the same. Design can have unintentional consequences that can exclude or result in other negative effects. Winner's point was that artefacts, designed things, can have politics and regulate because of those politics.

Regulation theorist Julia Black [21, 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." Koop and Lodge [19] analyzed the definitions or understanding of regulation in different disciplines, such as business, economics, law, political science, public administration, and sociology, and found that 100 out of the 108 articles that discuss the intentionality of the regulatory intervention argued that regulation is an intentional process. Karen Yeung [22] 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 STS, in which design, such as technology, is understood as "an assemblage of material objects, embodying and reflecting societal elements, such as knowledge, norms, and attitudes, that have been shaped and structured to serve social, political, cultural, and existential purposes" [23]. According to Yeung [ibid, p. 22] "design-based regulation operates by preventing or inhibiting conduct or social outcomes deemed undesirable".

Lawrence Lessig's [18] 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).

As Koop and Lodge [19] discussed, the consensus in regulation studies is that to have a constraining effect, intentional action by humans 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. Markets need two parties to agree to transfer a resource from one party to the other. 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" [ibid, 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) [24]. 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 entering 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 [ibid, p. 344]. For this to 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 behavior, even if we don't know what a speed bump is or where it is located.

Some 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 [25, p.1952]. Tien [26, p.2] 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". Tien is particularly concerned about the lack of transparency in computer code, a form of architecture, 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 [27] 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" [ibid, 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 behavior is not deterministic: the meanings of forms, designs, built environment, nature, can change and thus their influences. According to Lessig, a constraint doesn't need an agent and his descriptions of the interactions between the regulatory modalities in strengthening or weakening their regulatory action, point to a relational and holistic understanding of regulation, rather than a technological determinist argument as found in Tien [26]. 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 [27] 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.

Hosein et al. [ibid] 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" [ibid, p.365-6].

This notion of *regulatory ecology* describes not only the idea of a constructed regulatory regime. In what follows, I propose two ways to understand and use regulatory ecology. The first is as a descriptive (interpretative) figure to explain the regulatory complexity of an activity, such as knowledge sharing [28], journalism [29], biotechnology [30], and corporate sustainability [31]. The second is regulatory ecology as a critical figure or figuration. Donna Haraway describes figurations as "performative images that can be inhabited" [32, p.11]. Haraway's critical figures point to the understanding that things might always have been otherwise. In that understanding, 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. As a critical figure, regulatory ecology moves beyond social or technological determinist accounts of architecture, such as technology design, opening a space in which entanglements become visible. As is the case in the more convential understanding of an ecology, each intervention in a regulatory ecology may 're-set' other relations in the regulatory ecology. Maintaining a desired regulatory ecology can therefore require a tremendous amount of resources. Hosein et al.'s [ibid.] notion of *regulatory patching* can be understood as the on-going regulatory work to maintain or repair the desired regulatory regime.

2.2 A relational understanding of design as regulation

Yeung [22] 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 [33, 34] and Design with Intent [35] focus on changing human behaviour; ecodesign and cradle-to-cradle design [36] address the probability of the occurrence of undesired outcome; and design for remanufacturing [37] and design for repair [38] 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 [39].

What all these design approaches have in common is the intentional manipulation of the *scripts* and *affordances* of product-systems. The notion of *script* [40] 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. When innovators, designers, and engineers define the specifications of a 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" ibid, p.207–8]. 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 [41]. 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 [42] or re-inscribe a design, such as using a plastic bottle filled with water as a solar light bulb [43].

The second concept, *affordance*, originates in ecological psychology [44]. 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 [45] and perceptible, hidden, and false affordances [46].

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 (e.g. an hotel guest who puts the hotel key in her large bag) or they may go unnoticed when they don't fit with users' experiences or cultural knowledge [47].

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 constructivist and relational 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 Social and environmental risk in the mobile phone lifecycle

The lifecycle of a mobile phone is often described as a cycle of five phases: resource extraction (mining of minerals), production (manufacturing), transport, use, and end-of-life (re-use, recycle, disposal). Transport plays also a role in other lifecycle phases. What follows is a short description of some of the main social and environmental risks found in each of these phases in the mobile phone lifecycle. A risk is defined in this context as *an externality that pose a threat to defined planetary and social boundaries*.

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, 40% consists of plastics, and 20% ceramics and trace materials [48]. 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 [49, 50]. In particular mining in DR Congo is associated with so-called conflict minerals [49]. The environmental impacts of resource extraction for mobile phones, water and soil pollution, are especially the result of the poisonous waste by-products [51, 52], which affects both the miners and the communities around the mining sites [53]. Mineral mining is also water and energy intensive and produces a large amount of green house gasses [54].

Production

Social risks in the manufacturing of mobile phone and mobile phone components are lack of labour rights and low wage labour [55, 56]. 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 [57, 58]. Environmental risks 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.

Transport

Transport is a phase in the product lifecycle, in which the transportation of the product to the market is the main focus. Transport is also an important aspect of three other phases, resource extraction, production, and end-of life, in which it is about the transport of raw materials and components to the manufacturing site and transport of used mobile phone in the end-of-life phase. Once the mobile phones are manufactured, they will be transported from the manufacturing site to distribution centres and from there to outlets and consumers. There is not much research on the social and environmental risks of the transport of mobile phones. Maybe for this reason, the transport phase is excluded from impact assessments, e.g. [59]. The main environmental risk in the transport phase is CO_2 emissions [60, 61].

Use

The main social risk 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 [62].

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-service-system perspective, both the mobile phone network and the servers providing mobile phone services (apps, storage) need to be included. Suckling and Lee [61] 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 risks 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 [63]. *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 prevents the recycling of minerals and thus reinforces the social and environmental risks of resource extraction.

Other forms of end of life are re-use, refurbishing, and recycling. Risks are mainly found in the unsustainable recycling of mobile phones and other e-waste [64].

3.1 Fairphone

Extending the life expectancy of mobile phones and creating a fairer – more sustainable – mobile phone lifecycle, is the aim of Fairphone,[5] 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 [65]. In order to enable this conversation, Fairphone claims to be fully transparent about its supply chains and cost breakdowns and publishes reports and videos about its efforts in making the supply chain fairer. [6] Fairphone identifies social innovation as the main driver for its mobile phones [ibid].

The design of the Fairphone 2 differs significantly from other smartphones, in particular because it is the first modular mobile phone on the market. 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 or more [66].

Regarding fairer materials, the Fairphone 2 is manufactured with conflict-free tin and tantalum (coltan) [67], and it is the first mobile phone produced with fairtrade gold [68]. 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.

3.2 Fair Design

In their reports, video, website, and other media, Fairphone explains how it proposes to address some of the social and environmental risks in the mobile lifecycle (see Table 1). While design is often not recognised as a phase in the mobile phone lifecycle, the Fairphone 2 case shows the central role of design in addressing social and environmental risks. Design refers in this context to functional design, aesthetical design, and material design. In addition to the common functions of the mobile phone, such as communication, camera, storage, etc., the Fairphone 2 has a modular design to support repair. In case of malfunctioning, the different components of the Fairphone 2, the removable battery, main body, the display assembly, rear camera module, receiver module, the speaker module and back protective cover can easily be replaced by the user. The phone also comes with a hardware expansion port, providing the user with a platform to extend its functionality.

Table 1 How Fairphone addresses risks in the Fairphone 2 lifecycle

Lifecycle	Risks:	Fairphone 2:
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

[5] Fairphone: www.fairphone.com

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

	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 [69–71]. • Fairphone didn't use benzene, a widely-used hazardous material in the electronics industry, in the Fairphone 1 [72]. It is unknown if the same policy is used in the Fairphone 2. • Workers Welfare Fund established at main production site [73] • In 2016, Fairphone 2 will be produced continuously instead of batch production
	Environmental: Green house gas emissions; water and soil pollution	• The Fairphone is produced without charger or cables. Standard plugs can be used for charging, which users often already have. • The back plate of the Fairphone functions as a cover; no extra cover is needed.
Transport	**Environmental**: Green house gas emissions	• The Fairphone is shipped without charger or cables. This reduces the weight and, as a result, the CO_2 emissions per phone during transport to the market.
Use	**Social**: Health risks related to radiation exposure are not conclusive	• SAR is relatively low:[7] 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
End of life	**Social**: Health risks related to hazardous materials exposure because of unsustainable recycling practices	• In partnership with Closing the Loop,[8] 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	

In terms of aesthetical design, the Fairhone 2 has some features that make the phone different from other mobile phones. The Fairphone 2 comes with a removable back plate, which also functions as a cover. The back cover comes in different colours, of which several are transparent, thus enabling a view of the inside of the mobile phone, including a motivational message "yours to open, yours to keep" (see Figure 3).[9] When the phone is charging, the screen portrays the filling grade of the battery as well as some of the features inside the phone, such as the different repairable components with their screws (in blue circles) as well as a small map of DR Congo with pointers to the area where the conflict-free tin and tantalum is mined.

[7] Specific Absorption Rate (SAR): https://en.wikipedia.org/wiki/Specific_absorption_rate
[8] Closing the Loop: http://english.closingtheloop.eu/
[9] The first batches of the Fairphone 2 contain the message "one of the first 17,418"

4 Design as regulator of sustainability

Figure 3. Transparent back cover of the Fairphone 2

Design plays a central role in creating possible social and environmental risks that may emerge along the product's lifecycle. Such risks can be the effect of choice of materials, range of functionality, technical innovations, durability, etc. The question is, *Can these risks be regulated (controlled, eliminated) with an alternative design, and what are the opportunities and limitations of design as regulation?* Using the concepts of script, affordances, and regulatory ecology (law, social norms, market, architecture/design), this section will explore these questions, based on the alternative mobile phone design of the Fairphone 2.

First of all, it should be stated that the designers of the Fairphone 2 do not argue that they have eliminated all risks. The Fairphone 2 showcases how risks can be addressed in each of its lifecycle phases. An important part of Fairphone's design strategy is transparency [see also 74]. It challenges existing *social norms* in the mobile phone sector by providing full disclosure of its supply chain; openess about unsustainability in the Fairphone's lifecycle - and how they try to tackle these; openness about the Fairphone's hardware and software by providing open source licensing. In addition, 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 mobile phone are challenged. A good phone, they argue, in terms of material, functional, and aesthetical design, can also be a fair phone, fair towards people and planet.

This fair design, Fairphone anticipates, will constrain some of the social and environmental risks associated with the mobile phone lifecycle. Design thus presents particular *scripts*, which play a role in the making of our world. Some of the Fairphone 2 features, such as the use of non-conflict minerals and improved working conditions at the manufacturing sites, are difficult to express in the design of the mobile phone. These *social norms* are part of the script of the Fairphone 2, but they can't be perceived when using the phone. They become visible in the Fairphone "story", as it unfolds on the Fairphone website and promotion materials.

A central design feature of the Fairphone 2 is that it has a repair-centric rather than an obsolescence-centric design, which may extend the life expectancy of the Fairphone beyond the 5 years of its warranty. The modular design of the Fairphone 2 enables a repairability script, which is however invisible as long as the Fairphone's cover is not removed. On the other hand, by offering transparent back covers, the repairability script becomes partly visible in the form of the two blue switches that enable the disassembly of the screen and the removable battery. 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, which cannot be supported by the Fairphone 2. Research shows that consumers often replace their products before the product needs repair or breaks down. According to Khetriwal and First [75], as cited in [76], such reasons are style references, product feature and technology advances, marketing campaigns, changed family circumstances, and improved financial situation. Wilhelm et al. [77] report that marketing campaigns are the main motivator for young people to buy a new mobile phone, when they still own a well-functioning mobile phone. For some, a mobile phone is also a fashion statement [5], thus owning the latest model is a strong motivator. Also aesthetic design seems to play a role in product replacement. Sääksjärvi et al. [78] found that color and thinness of the mobile phone body can increase product replacement. Owners of colorful, thin mobile phones are more likely to replace their mobile phone for a new trendy one than owners of more traditional mobile phones.

Consumer behavior that results in premature product replacement, which is not the result of designed (planned) obsolescence but of perceived obsolescence. This type of obsolescence is the result of interactions between *markets* and *social norms*. Fully functional smart phones are replaced after 12 – 24 months with a new mobile phone. New legislation and law suits (*law*) have become one form of regulation that has made progress in dealing with unsustainable forms of obsolescence, e.g. the new anti-planned-obsolescence law in France[10] or the lawsuit that forced Apple to make the iPod battery replaceable.[11] Changing *social norms* about obsolescence may also support Fairphone's repairability script. The recent case of the planned obsolescence of working iPhones triggered a public outcry: iPhones stopped working after a software upgrade, which detected unauthorized repair of the home button or the Touch ID hardware.[12] The media described the case as an attack on independent repair shops, which boosted

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

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

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

the already growing *right to repair* movement.[13] 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).[14]

Telling the Fairphone "story" is an important aspect in Fairphone's strategy to change *social norms*. Research found that product appreciation is affected by the users' knowledge of the intentions of the designer [79]. This knowledge will strengthen the product's scripts as well as open up for new affordances.

A lifecycle perspective, in assessing the social and environmental risks of a product, considers the wider system. The mobile phone product-system is based on two central affordance, wirelessness and portability, which contribute to its wide variety of uses of the mobile phone. The GHG emissions in the use phase are high, but this risk is difficult to address 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 risk, other design options need to be explored, for example, continuous visualization of energy use related to charging, network connections, and overheating (*architecture* and *social norms*) and/or increased and more efficient battery capacity (*architecture*).

4.1 The Rebound Effect

In September 2016, the Norwegian Institute for Transport Economics (TØI) released a report on electric cars in Norway [80]. In order to stimulate the consumption of electric cars, the Norwegian government implemented a couple of incentives, such as no VAT on electric car sales car and lower road taxes. In addition, local authorities allow electric cars to use the buss/taxi lane and to use toll roads for free. National and local governments used a combination of *law* and *architecture* to stimulate sustainable behavior in personal transportation. While the number of electric cars has increased tremendously as a result of these incentives, there are some interesting findings, for example:

- Many electric car owners own also a gasoline or diesel car.[15]
- Eight per cent of electric car owners used to take public transportation to work, but now take the car.
- Electronic car owners drive more than non-electric car owners

TØI mentions that this might be explained with the consumption rebound effect. The rebound effect is an unintended side-effect of the introduction of technology and policy instruments aimed at environmental efficiency improvements, in particular where gains bring reduced costs [81]. Rebound effects are examples of how affordances and scripts can counter each other or how they can be ignored or re-scripted. The physical script of a more sustainable car, such as an electric car, which is embedded in the car in terms of material and functional design, can be ignored, as the socio-technical script of the car, e.g., the electric car as trendy car, invites people to buy the electric car as additional car. The environmental gain of less CO_2 emissions during the use of the car may be countered by increased CO_2 emissions in car production. CO_2 emissions may increase even more when the electric car replaces public transportation.

Laurenti et al [82] describe how increased efficiency in industrial production can result in lower consumer costs and therefore in increased consumption. Improvements in mobile phone design (lighter, faster, increased functionality, etc.) resulted in increased consumption of mobile phones, leading to increased demand of raw materials (gold, silver, tin, tantalum). Increased prices of these materials fuelled conflicts over the control of mining sites, displaced local communities, and degraded large areas of land.

Rebound effects are also visible in the material aspects of mobile phones. Paiano et al. [83] describe how the weight of Nokia mobile phones decreased from on average 500 grams in 1990 to 85 grams in 2011. The decrease in material inputs in mobile phones, which affects CO_2 emissions and other social and environmental risks in the raw materials, production, and transport phases, were counteracted by increasing demand and resulted in a net increase of material input. Secondly, Paianao et al show [ibid], the miniaturisation of mobile phones did not led to a decrease of material input per unit. Smaller mobile phones have a larger material base, because most materials are used in the production phase and are not part of the final mobile phone.

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

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

[15] The report mentions that some of these electric car owners would have bought a second car anyways, but now, because of financial incentives, chose to buy an electric car.

4.2 Regulatory Patching

A script, in the form of material or functional design aspects, can play a powerful role in design as regulation, c.f. the famous example of the speed bump in the road. In many cases, however, such scripts can be ignored or re-scripted. Mapping the regulatory ecology around design as regulation to constrain unsustainable mobile phone use is a helpful tool for both designers and regulators.

Figure 4 visualises how other modes of regulation directly or indirectly constrain a repairability script (*architecture*) in the Fairphone 2. While this script proposes to constrain unsustainable behaviour by the consumer, in the form of premature product replacement, its regulatory capacity is constraint in the form of warranty rules (*law*), marketing campaigns (*market*), price (*market*), trends (*social norms/market*), technological innovation (*architecture*), and aesthetical design (*architecture*).

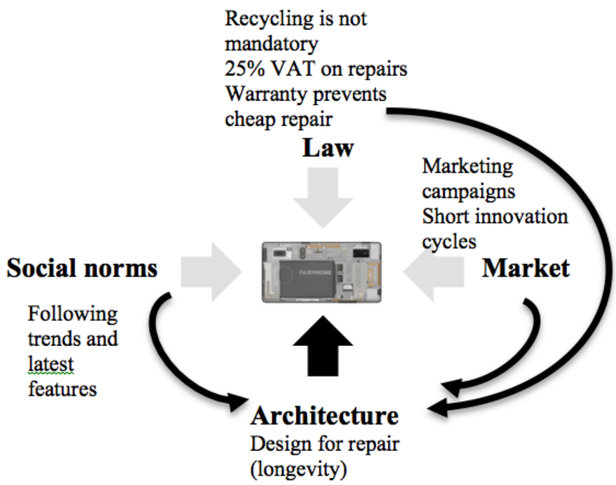

Figure 5. Indirect regulation (constraints) of design for repair

The concept of affordance is especially useful for explaining why a repairability 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" [44, p.127]. Repairability may only become visible (perceived) when a product breaks down. Decisions to replace the product are often taken before that, on the basis of other reasons for product replacement, such as new trends or technological innovation.

Gaver [46] 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" [27] While the authors 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,[16] or to other modes of regulation, 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 hidden affordances perceptible, thus triggering or constraining particular behavior [e.g., 84].

The repairability of consumer goods is usually not perceptible in the design, in the form of an affordance, but is part of the script of a product. This script can be strong, as is for example the case in washing machines and cars, and doesn't need to be made perceptible. But as a result of market strategies and perceived obsolescence, mobile phones are now perceived as disposable products. Repairability is not a strong affordance of mobile phones, at least not in industrialised countries, thus the Fairphone 2's repairability script needs to made explicit. Fairphone's design interventions, in the form of transparent back covers and illustrative charging image, and strengthened by the "Fairphone story", targeting social norms about perceived obsolescence, can be explained as regulatory patching of the affordance of mobile phone as a disposable consumer good.

Mapping the regulatory ecology of a product-system, can help to make clear when and where different modes of regulation strengthen or undermine each other. In the case of the Fairphone 2, it becomes clear that design (*architecture*) on its own isn't powerful enough to support sustainable behaviour in all of its lifecyle phases (see

[16] 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.

Figure 4). Thus, the regulatory framework of the Fairphone requires patches in the form of activities that support the construction of new social norms around perceived obsolescence.

5 Concluding Remarks

Based on Lessig's theory of regulation, this chapter presented design as a form of architectural regulation. Design as regulation is constructed and relational: its regulatory impact is the effect of the regulatory ecology in which it is located. Other modes of regulation can both strengthen and constrain the regulatory role of design. The rebound effect is one of the ways in which sustainable design and design for sustainability can have unexpected unsustainable consequences. Taking a lifecycle perspective (lifecycle thinking) may broaden the design space in which the designed is conceptualised and developed. Locating the design process within the planetary and social boundaries that form the safe and just space for humanity may guide a more reflective process.

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. They can help explore the rebound effect and other unintended consequences of design, such as the reasons for ignoring a script or re-scripting a design.

Regulatory ecology played a double role in this chapter. As a figuration, it establishes a network of relations in which the designer and designed emerge. The regulatory ecologies of Fairphone, as a social entrepreneur in the Netherlands, as a story, and as a functioning smart phone, enable a deeper understanding of the complexity of designing circular products for a sustainable circular economy. This chapter only gives a glimpse of what insights the mapping of the regulatory ecology of (unsustainable) activities may provide.

The case of the Fairphone 2 exemplifies the central role of design in the social and environmental sustainability of the product-system lifecycle, but that other regulatory modalities, markets, social norms, and law, can both strengthen and undermine how design can constrain unsustainable behavior. A further mapping the regulatory ecology of the Fairphone 2 may enable a better understanding of where regulatory patching may the most effective.

This chapter presented an exploration in the concepts and cases that inform Sustainable Market Actors for Responsible Trade (SMART), a research project based at the University of Oslo. One of the activities in this project is the mapping of the regulatory ecologies of significant social and environmental risks (hot spots) in the lifecycle of mobile phones. In this case, our main focus will be on understanding what enables and maintains these unsustainable practices.

Acknowledgement

This chapter is written as part of SMART, a HORIZON2020-financed research project (grant agreement No. 693642). I thank my SMART colleagues for valuable discussions and comments.

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