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KARINA VISSONOVA

EXPLICATING THE SUSTAINABLE DESIGN OF TECHNICAL ARTEFACTS

PH.D. THESIS

Karina Vissonova
Ph.D. Thesis

EXPLICATING THE SUSTAINABLE DESIGN OF TECHNICAL ARTEFACTS

The Royal Danish Academy of Fine Arts
Schools of Architecture, Design and Conservation

Explicating the Sustainable Design of Technical Artefacts

Karina Vissonova

Ph.D. Thesis

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List of Publications

1. The main line of reasoning underlying this Ph.D. project was summarised in the form of a book chapter, which is currently in the process of publication:

Vissonova, K. (forthcoming). Effects of design and sustainable design of technical artefacts. In P. E. Vermaas & S. Vial (Eds.), *Philosophy of Design*. Springer.

A near-final draft of the book chapter is submitted for assessment along with the present monograph, but is not included in it.

2. Vissonova, K. (2015). *Insidious side effects of design and how to turn them into values of sustainability in design.* Paper presented at the Cumulus Mumbai 2015: In a planet of our own – a vision of sustainability with focus on water, Mumbai. http://www.cumulusmumbai2015.org/home.html.

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A friend once told me that writing a doctoral dissertation is a very personal journey. It has been so for me. This journey has enriched me. I cannot think of a better way to have spent the last three years of my life. I would like to express my heartfelt gratitude to those who have made my journey possible and to those who contributed to its richness.

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Industry Partner side - Trine Richter, the director of Green Solution House. Trine is responsible for making the project happen on the island of Bornholm, which is known for its efforts in bringing about sustainable development. Her engagement has been incalculable, as she raised the funds for this project, shared her rich insights in a broad range of sustainable design solutions, as well as the strategies of their selection. Additionally, she made available the Green Solution House as a place of observation, while also hosting my stay at its "greenly" designed hotel.

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I consider myself fortunate to have worked with these individuals and organisations. As the saying goes - if I had to do it all over again, … I would choose the same path.

Abstract:

Sustainable design of technical artefacts is referred to as if it were a kind of design with some specific characteristics. However, in design research and practice alike, there appears to be a lack of shared conceptions of what such a design might entail. Furthermore, we have no clear grounds for evaluating what makes the sustainable design solutions permissible. The lack of shared conceptions is largely due to ambiguities associated with the notion of sustainability. In response to these challenges, the aim of my study is to offer a definition of sustainable design of technical artefacts. I argue that despite the ambiguities, there are discernible necessary and sufficient conditions by which the design may qualify as the sustainable kind. My claims are constructed based on two assumptions: the first being the presence of side effects of the design of technical artefacts, and the second being the values afforded by the properties of artefacts.

The study is a conceptual analysis and as such belongs to the field of epistemology of design. It offers three contributions to the design discipline: (1) a proposition of the definition of the sustainable design kind; (2) a proposition of the concept of technical intervention; and lastly, (3) the explicated concept may assist the design practitioners when qualifying their design solutions as sustainable.

Key words: Sustainable Design, Technical Artefacts, Technical Intervention, Design for Sustainability, Dispositions, Side Effects, Utility Value.

1. Introduction

> "Since the human beings have been human beings, they have been handling their environment. It is the hand with its opposable thumb that charactarises human existence in the world. … The world is grasped, by the hand, as being made up of things. And not just grasped: The things grasped by the hand are possessed so as to be transformed. The hand in-forms the things grasped by it. Thus the human being is surrounded by two worlds: the world of 'nature' (of things that are to hand and to be grasped) and the world of 'culture' (that of handy, in-formed things). Until quite recently, one was of the opinion that the history of humankind is the process whereby the hand gradually transforms nature into culture. This opinion, this 'belief in progress', now has to be abandoned. … The hand consumes culture and transforms it into waste. The human being is not surrounded by two worlds, then, but by three: of nature, of culture and of waste. This waste is becoming more and more interesting … . And it turns out that waste returns to nature. Human history, then, is not a straight line leading from nature to culture. It is a circle turning from nature to culture, from culture to waste, from waste to nature and so on." (Flusser, 2009:90)

What do we mean by the term 'sustainable design'? Is there a kind of design that is thus discernible, and if so, what are the characteristics by which we may identify design as the sustainable kind? These questions form my research enquiry to which I here offer my proposition.

It is fairly clear that by 'sustainable design' we are not referring to the design discipline's own resilience in the changing world. Rather, as argued in Vissonova (forthcoming), we are referring to a notion of 'sustainability' partly as a concept of environmental conservation in ecology, and partly as principles guided by the sustainable development agenda articulated by the United Nations Sustainable Development Goals (2015); as well as the distinctly recognised Brundtland Report (WCED, 1987). We adopt the notion to envision and to subsequently formulate design requirements, where then 'sustainability' is translated into the requirements as a value, just as we do with safety, energy efficiency, privacy, etc. (van de Poel, forthcoming). Because the notion is adopted in the design discipline, catering for the value is commonly referred to as 'design *for* sustainability'.

I find that despite ample empirical examples of various conceptual and marketable sustainable design solutions, typically such as electric cars, renewable energy sourcing technologies, biodegradable plastics, certain type of architecture and so on, our conceptions on what precisely constitutes 'sustainable design' are vague and informal. We appear to be in the dark when it comes to evaluating what the right or the wrong solutions are so as to discern what is 'sustainable'. We presume that an application of one of the many sustainable design methods automatically makes the technical artefacts sustainably designed.

I also find that studies on the sustainable design of technical artefacts are focused on the different design methods, analysing the existing ones (see Weever and Vogtländer, 2015) and sometimes offering new methodological perspectives (see Dusch et al., 2010, van de Poel, forthcoming); as well as on the adaptation of design to the environmental discourse or to the principles of sustainable development (see Brumsen, 2011, Chapman, 2009, Thorpe, 2010, Lovins et al., 1999, Stebbing, 2015, Tischner, 2015, Reller and Diesenbacher, 2015, Tonkinwise, 2015, Tukker, 2015, Rockström et al., 2009, Manzini, 2008). However, I find that the studies in the design research surprisingly lack reflection on what is being attained by the 'sustainable design' and what then the design kind is. I believe that such a reflection is absolutely necessary if we are to claim with confidence that the kind of design is to be perceived as a part of the solution in the matters pertaining to sustainability. Therefore, quite unusually and untraditionally to the design studies addressing the impacts of design on the environment, I address the impacts of sustainable design. In the process, I come to define the conditions that make a design the sustainable kind.

My argument is that our use of the term 'sustainable design' is loose, prescientific and inconsistent, whereas the corresponding design solutions are difficult to evaluate as right or wrong. I would like to suggest, considering that the sustainability agenda is not just simply going to go away, it is time we form a consistent understanding, a definition if you like, of what should fall under 'sustainable design' kind and what should not. What I am proposing through my research is an explication of the concept of *sustainable design of technical artefacts*. I believe that the explication is not only helpful in a theoretical referencing of the design kind, but also as a contribution improving the design practice: an improved understanding and clear and consistent conception of what constitutes the design kind will produce more consistent solutions better for the people and the environment.

The focus of my research regards the conceptual rather than practical aspects of sustainable design. I think of it as a sense-making exercise. Perhaps therefore, I draw my contemplations from concepts in philosophy, with a purpose to understand what is being attained with the sustainable design practice. My interest in the design of technical artefacts extends to the value the artefacts may create for us, or more often than we would prefer, quite on the contrary take a value away from us. Because of this particular nature of the design, I look at *side effects* of the design of technical artefacts. In particular, I look at the *known undesirable effects*, as I come to define them. I assert that the design of technical artefacts is very much about producing the *desirable effects* - these are the values created by design we appreciate the artefacts for - their function, as well as their other beneficial properties, or utility values as I shall argue. The effects are afforded by *dispositions* of materials and substances (Mumford, 1998), which are selected for the technical artefact. Some dispositions afford effects which we are not aware of, these I call the *unknown undesirable effects*.

Side effects in design are rather accepted as such. Side effects can be negative, they do not bear the good desirable values but rather negative values. Car emissions of carbon dioxide and NOx particles are side effects bearing negative values of the greenhouse effect and pollution respectively. Side effects of bottled water are quite ironic - it takes just over 7 litres of water to produce the plastic for one average commercial bottle containing water, according to the Treehugger organisation (Merchant, 2009). That same plastic, if not captured at a disposal phase, is more than likely to end up as a hazardous toxic sludge in our oceans jeopardising the marine life, contaminating the fish as tiny micro-particles and eventually reaching our food chain as our dinner, as for instance stated by the Natural Resources Defence council. Nearly every technical artefact manufactured has side effects either at the mining or material sourcing stage, the manufacturing stage, the sales, the use and the disposal stages. But, side effects are not studied, they are tolerated as a part of the design of technical artefacts.

Sustainability, I argue, has everything to do with the effects of design. We seek those effects that bear the value of sustainability while also looking to curb the side effects. Sustainable design is often summarised as the efforts to design with less impacts, i.e. less side effects. I explore this notion, essentially making the argument that technical artefacts are designed as sustainable based on the extent to which side effects are addressed by design.

However, if I have lulled you into a false sense of clarity over the notions of sustainability and the side effects, then you are in for a surprise - as I was at the outset of my research. The challenge begins with the notion of sustainability. Those who do not work with sustainability, take it for granted that there is an agreement in what is being represented by the notion. Those who do work with sustainability take a position with one or another interpretation of the notion (Dusch et al., 2010), or selecting a different interpretation in each new design context. My understanding is such that sustainability represents a value, a value of something that can objectively be observed as good and desirable. For this understanding of sustainability, I am grateful for the work of van de Poel (forthcoming), where he explains the rather contestable notion as a value which then is translated into design requirements.

As for the side effects, I find, we tend to be significantly more interested in studying the desirable effects of design of technical artefacts than the side effects. Although side effects result from the design along with the desirable effects, typically we do not consider them as a property of artefacts (see van de Poel, 2009). Hence we are limiting our knowledge on the range of effects of design. This, in turn, prevents us from adequately understanding the occurrence of side effects and how these are being addressed by the design practice.

My assertion is that side effects, just like the desirable effects, are afforded by dispositions of the structure of the technical artefact. Side effects manifest themselves when the design of a technical artefact is realised and an intervention by that design takes place in an environment, and within the lives of humans and other living beings. I call this a *technical intervention*, which I discuss more elaborately in chapter 3. With the technical intervention I conceptualise where the effects of design manifest themselves. I furthermore claim that sustainable design can only be so characterised if the known undesirable effects are curbed throughout the associated intervention. I come to argue that sustainability, with reference to the design of technical artefacts, cannot be isolated to the design methods, to being a property of the artefact, or even to the value being attained. Rather, sustainability that we strive to design for must be considered as pertaining to the technical intervention. Otherwise, I fail to make sense of what is it that we are seeking to attain with sustainable design. It is time we addressed the notions of sustainability and side effects with a more formal approach.

1.2 Methods of Enquiry

This thesis is a result of over three years of researching on the subject of sustainability and analysing products of industrial, engineering and architectural designs. It grew out of my contemplations of sustainability as a value, the meaning of the idea for the planet and its living occupants; as well as, whether the way we have connected industrial and natural processes by design is the best that we can do. The concern expressed in my work is towards what is being produced by design under the notion of sustainability.

My aim is to explicate the sustainable design so that the concept can be used in the design research and practice, as well as in different fields of sciences when referencing the design as the sustainable kind. The aim has been not to make inductive inferences from empirical data to form some new sustainability principles for designing technical artefacts, but rather to develop a useful conception by philosophical reasoning illustrated with specific examples. Therefore, you will find that the study is conducted by means of conceptual analysis and is supported by empirical data.

I conduct the conceptual analysis in order to discern what constitutes the seemingly all-around familiar idea of sustainable design. The call for clarification of the definition of sustainable design has been sounded across design research and practice alike, thus motivating my research. While the lack of clarity over what is sustainable and what is not frustrates the design practitioners, it seems we, the design academics and practitioners alike, have not yet overcome the threshold that separates the pre-scientific and science-based conceptions on the subject of sustainability in the design discipline. The overcoming of the threshold should silence the frustrations, and I hope that my research is a much needed step towards resolving the ambiguities related to the concept. Nonetheless, I believe that the conceptual clarification I offer may be just one of possibly many attempts based on other perspectives.

To the reader who is not familiar with reasoning of a philosophical nature or does not care much for the knowledge about values in design and side effects, my work may appear somewhat abstract and difficult to apply to everyday practicalities of designing. This is understandable, as the work concerns epistemology of design, while it also has some degree of criticism of the current industry practice. However, my pursuit of making a more explicit conception of a thus far tacit notion may offer some valuable contributions to the design research; as well as, my hope is that it may help to bring a tangible point of reference to those designers who seek inspiration to change the world for better by design.

The conceptual analysis is informed by the empirical examples, leading to the explication of the concept (I offer a brief overview of the method of explication as described by Carnap (1950) in chapter 2). Since we refer to sustainable design as a kind of design, I set out to gather from the ample empirical evidence an understanding of what conditions must be satisfied for a design of technical artefacts to fall under the concept of sustainable design.

Some of the examples are discussed more extensively than others, and some are collected by a kind of field study, where I partook as an observer and as a participant in the development phases of two projects. One of which was an architectural object designed for sustainability, the other was a value retrieval project of the nearly depleted phosphorus.

The first case, an architectural object called *Green Solution House*, is a retrofitted hotel on the island of Bornholm, Denmark, in which I stayed over some of the period of my study. I witnessed the hotel turning into a unique conference centre expressing the state of the art in sustainability. The retrofitted sections of the buildings on site were equipped with a range of sustainable design products, which were sufficiently informative for me to gain comprehensive knowledge about the state of the art in the sustainable design practice, starting from the roofing membrane Noxite, continuing to the Cradle to Cradle certified fabrics of some of the furniture, and the non-bitumen based materials in the landscape. In the study, I exemplify some of the points with the Noxite roofing membrane.

The second project in which I partook, and wherefrom very interesting data ensued, is a 'phosphorus retrieval' project called *Nutrient Retrieval from Seabeds*, by Teknikmarknad, Sweden. The project is a technology development and testing for the value retrieval and processing of phosphorus found in seabeds around the Baltic region.

Taking into consideration the relation of the philosophical nature of my enquiry and my partaking in the two empirical cases, the data collection has been somewhat unconventional. To some extent my method was a form of action research, where I contributed with my "practitioner knowledge" (McNiff and Whitehead, 2011) to the developments at the architectural object and the phosphorus retrieval project. According to McNiff and Whitehead (2011:8), action research takes place when the researcher takes an active part in the context she is investigating. The researcher may contribute with an evaluative aspect of things the way they are; or an evaluative aspect of an improvement done with the participation of the researcher. In the practical sense, the data ensues from hands-on participation rather than observation or interviews. As one of the examples of my participation, I contributed to classifying the sustainable design products used at the architectural object together with its architects-consultants GXN, Denmark, which simultaneously was part of my data gathering process and knowledge dissemination for the architects-consultants and the object. In the second case, I contributed by adapting circular economy principles applicable for the phosphorus retrieval project, which were used in the project's development phases and its public reporting; thus disseminating the knowledge while 'learning by doing' on the project.

However, the action research method was used less systematically for generating reports of the observations. Rather, the strength of the method was particularly in the knowledge dissemination between the practitioners and myself, representing both the academic and practitioner's positions. Undoubtedly, the knowledge dissemination contributed to both - the development phases of the two projects, and to developing the grounds for discerning the kind of design. From a methodological point of view, the uniqueness of this study does not lie in the empirical cases, but rather in the way that the empirical cases inspired the conceptual analysis.

In the closing of the Methods of Enquiry, I should state for the sake of clarity that my attempts are not concerned with the term 'sustainability' per se, or whether it fairly justifies the generally intended meaning carried by the term. Nor am I proposing alternatives to how and in what contexts the general term of sustainability should be used. My deliberations are only in reference to sustainable design of technical artefacts as a concept. In other words, I propose there are available examples of relatively clear necessary and sufficient conditions for the design of technical artefacts to qualify as 'sustainable'.

1.3 Overall Structure of the Thesis

Following the introduction, with chapter 2 I introduce the reader to the general notion of sustainability as commonly used in the studies of sustainable design. I introduce some of the main challenges faced by the current interpretations of sustainability in design, which I claim to arise from limiting evaluations of effects produced by design. I continue by introducing the *technical intervention* to conceptualise where effects of design manifest themselves thus making them available for evaluation of the side effects. Further, I question if the sustainable design is perhaps a design that deals with the kind of wicked problems, and hence the design kind may not be discernible. I argue against such a view. Thereafter, since the work is a process of explication, I introduce the concept of explication as developed by Carnap (1950).

In the following two chapters, 3 and 4, I analyse two aspects of the design of technical artefacts. The first being the effects afforded by *dispositional* properties of materials and substances selected for the structure of the technical artefact, discussed in chapter 3. The second aspect being the values rendered by the dispositions, respectively discussed in chapter 4. By analysing the two aspects of design, the kind of design can be explicated.

I make a distinction between *desirable* effects and *undesirable* side effects, which can be *known* and *unknown* at the time of designing. While the dispositions affording the known desirable effects render *values*, the dispositions affording side effects pose *hazards*. To make the causal processes of dispositions leading to values and hazards easier to follow, I illustrate the conceptual machinery of these processes in Figure 1A and 1B (Vissonova, forthcoming):

Figure 1 A: Dispositions and Effects

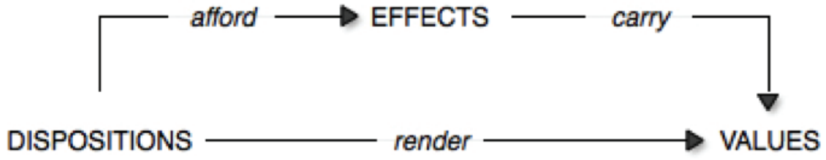

Figure 1 B: Dispositions and Side Effects

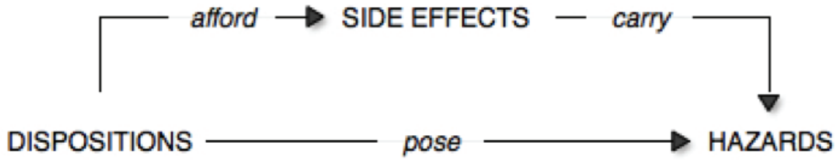

Figure 1: A conceptual machinery of dispositions (Vissonova, forthcoming)

In the last chapter of the discussion, chapter 5, I come to discern the 'sustainable design' kind. I do so by firstly classifying the sustainable design of technical artefacts into four classes, each presented with empirical examples and their explanations. I make a more explicit correlation between the sustainable design and sustainable technical interventions, thus constructing the *explicatum* of the design as the sustainable kind.

In the closing of chapter 5 and thus the discussion of my thesis, I offer the reader a definition of *sustainable design of technical artefacts* by conditions of which *sustainable technical interventions* can be maintained.

I conclude the thesis by summing up my contributions in the research field, and suggesting indications for future research.

2. State of the Art in the Field of Sustainability

> “Anybody who wants to know about our present should concentrate on examining present day factories critically. And anybody who addresses the issue of our future should raise the question of the factory of the future.” (Flusser, 2009:44)

This chapter is an introduction to the subject of sustainability and the problems experienced when working with the subject. I look at what is represented by ‘designing for sustainability’. I introduce the term *technical intervention*. I also discuss whether sustainability is a ‘wicked problem’ that the design of technical artefacts is attempting to resolve. In the closing of the chapter, I reflect on the method of explication.

2.1 Designing for Sustainability

To design for sustainability is to design with a concern for imbalances in the natural environment coping with our industrial activities, as well as for the imbalances in the global distribution of wealth and acquisition of resources. The imbalances occur from pollution of water, soil, the atmosphere, and bodies of living beings; loss of biodiversity; climate change and the rate at which non-renewable resources are being depleted, and the risks and benefits of which are unevenly distributed between intra- and intergenerations. All of these are almost exclusively caused by the way we have been designing our technical artefacts since the industrial revolution. In the words of UN Secretary-General Ban Ki-moon, when addressing World Economic Forum at Davos (2011), we quite literally have “mined our way to growth” and “burned our way to prosperity”. The latter, I take it, referring to the burning of fossil fuels for energy. Such a behaviour we describe as ‘unsustainable’ as we risk the possibility of an irreversible deterioration of the planet leading to dramatic alterations in our ways of life or our very existence for that matter. The risks reduced, within the capacity of man, and hence such undesirable events countered pertains to the notion of ’sustainability’.

However, any conceptions that the notion of ‘sustainability’ is a perspective, or somehow a uniform end, or an end per se, towards which then the sustainable design kind is oriented, would be rather misleading. This is because the notion of sustainability is always representative of a capacity of continuation of a particular eco-system, or of a selected development pattern of an industrial character that involves an eco-system (Vissonova, forthcoming). Sustainability, it can be said, is very much a context-bound notion. In the words of Tonkinwise (2015:286), who I think has succinctly captured the notion: "Sustainability is an evaluation of risks, a measure of the capacity of a system to respond to a series of more or less likely impacts"[1]. He further narrows it down by calling it an "evaluation of probability", which, I interpret, just like a chemical reaction conducted in a laboratory involves a cause and effect relationship between some certain selected elements, and not the entire stock of substances in the laboratory. Having in mind the articulation of the notion as proposed by Tonkinwise, designing for sustainability then entails making up a selection of considerations, as for instance, towards issues with fresh water, or phosphorus cycles, or access to renewable energy. The assumed result is that by doing little by little by design in the diversity of systems, many a system will be turned from unsustainable, i.e. unable to withstand impacts, to sustainable which then has the ability to withstand the impacts (Vissonova, forthcoming). Tonkinwise calls this effect "cumulative".

With respect to the above, and while keeping the cumulative effect in mind, the question then is - what is it that drives the efforts of designing for sustainability. The answer, I find, lies within a human striving for some general, or normative, values, which exceed personal preferences. 'Sustainability' is an expression of one of such efforts, an understanding based on the work of van de Poel (forthcoming). van de Poel proposes to conceive 'sustainability' as a value. He states,

> "Values express goals or state-of-affairs that are worth attaining. Values do not express preferences or things we want to attain just for ourselves, but things that we think are worth striving for in general. Values are normative, in the sense that they express what is good and desirable to attain. To say that 'sustainability' is a normative notion is to say that it somehow refers to the goodness of a certain

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[1] I would like to note that the articulation of sustainability offered by Tonkinwise is aimed at explaining one of the four typologies of sustainable design practices and studies - "Get it eco-right". Thus the given articulation is not intended as a definition of sustainability but rather is representative of actions taken towards sustainable development (2015:285-286)

'matter'." (van de Poel, forthcoming:2).

Conserved eco-systems and thus reconciled imbalances represent conditions of goodness to which we commonly agree and consider as desirable. Such conditions can be viewed objectively, for instance clean seas, biodiversity, healthy people, air free of pollution, etc. When I say that these conditions can be viewed objectively, I mean that regardless of personal preferences and aspirations, these conditions are not disputable, because we are able to share the foundations for judgement whether the conditions represent a goodness or not (which is not the same as having a shared judgment) [2]. The value that we associate with sustainability and so translate into the design requirements, pertains to this 'goodness' (Vissonova, forthcoming). In this regard, for instance, the developers of the Cradle to Cradle method, McDonough and Braungart (2013), suggest a '"more good less bad" continuous improvement' principle to designing technical artefacts. They illustrate it as the over time accumulation of resolutions for goodness by design and reduction of badness ultimately resulting in a "well-designed abundance", as they call it. Thus, sustainability is a value and it implies goodness of some things being in a certain and objectify-able way.

Be it as it may, a less commonly discussed issue with sustainable design is that by designing for a conservation of one eco-system, i.e. for the goodness of that ecosystem being conserved, another eco-system may be disturbed or even made service as a part of the design (Vissonova, forthcoming). As an example, photovoltaic solar panels provide renewable energy, while requiring silver in order to create the electricity. Silver is a finite resource, and as presented by Reller and Diesenbacher (2015:161), may be exhausted more or less within 22 years. A similar problem is faced with rare earth minerals required for the function of electric car motors and for rechargeable batteries, as well as for the wind turbine motor function. As Reller and Diesenbacher (2015:160) explain the situation, "we are practically shifting from a dependence on carbon compounds (gas) to a dependence on metals and from carbon dioxide emission to a type of mining that may well have greater effect on humans and the environment". Therefore, while with the

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[2] See Rittel (1972) discussion on 'objectification', p. 394

kind of design we attain the desirable effect, and hence the value of sustainability, side effects are produced which ramify in the eco-systems irrespective of the good intentions behind the design.

Subsequent to such a selective nature of designing for sustainability, it is rather a challenge to consistently evaluate the 'sustainability' attained with the kind of design. To put the cumulative design efforts into perspective, it becomes rather difficult to envisage as to what it is that we are aiming to achieve, if some ecosystems are being made a priority, some being neglected, and some made service to the kind of design, sometimes, regardless of the side effects produced on the way.

The above challenge, I believe, primarily stems from the fact that we appear to hold very different interpretations and rather varied priorities of what ought to be sustained, irrespective of our common strivings for the 'goodness' of things. The notion of sustainability has more than one meaning and, as Hopwood et al. (2005:38) state, it provokes many different responses. There are two main pulls dividing the notion of sustainability and hence the meaning of sustainable development (see Figure 1).

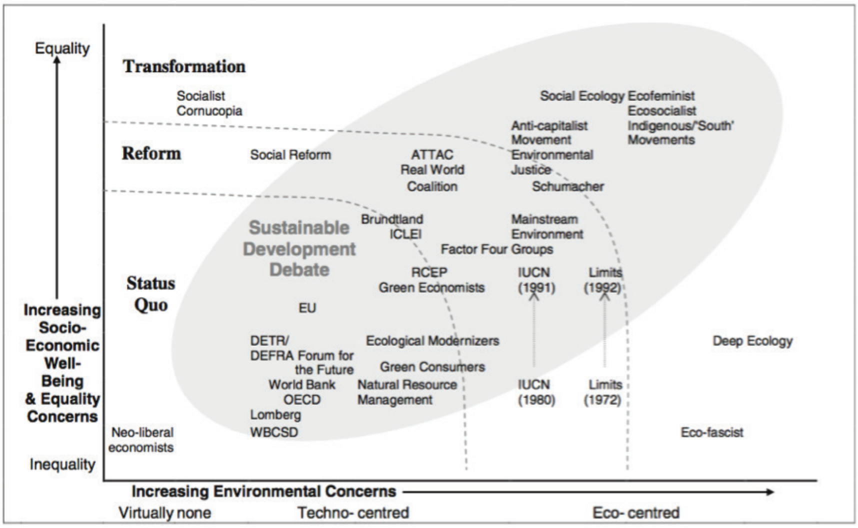

Figure 1. Mapping of views on sustainable development. By Hopwood et al. 2005. Copyright 2005 John Wiley & Sons, Ltd and ERP Environment. License to republish No. 3824220068651.

The authors propose a broad conceptual framework of how these different interpretations map out. Dusch et al. (2010) building further on the ideas developed by Hopwood et al. (2005), explain the historic formation of the two main pulls dividing the notion of sustainability. They present that one is where considerations towards the environmental degradation are motivated by concerns for its intrinsic value, as it is a good value in and of itself. This is referred to as a biocentrism, also called eco-centrism. The other pull is where people with the help of technologies maintain the environment for its instrumental value, which must be equally accessible to all. In this view, the environment is instrumental in for instance, supplying the resources for human activities, implying that it has no intrinsic value. In which case the environment should be preserved for as long as it proves more efficient than artificially replacing all of the resources it has for us, (if that may be considered as a possibility). The given priorities to the human activities, over the conservation of the environment, we refer to as an anthropocentrism, also called techno-centrism (Dusch et al., 2010, also see van de Poel, forthcoming, and Brumsen, 2011).

Consequently, although we commonly agree on the 'goodness' of conservation of all eco-systems and of welfare of all people across generations, a value of healthy people may be maintained on account of loss of biodiversity, as an example. This produces a value conflict, as there is no longer an objectively observable 'goodness' as a value of something to somebody is jeopardised [3]. Value conflicts often, but not exclusively, arise from incommensurability of factors that come up for evaluation (van de Poel, 2009, and van de Poel and Royakkers, 2011). We simply cannot compare a loss of biodiversity and welfare of people.

In the light of the above, it comes as a no surprise to find that the design approach to sustainability is to select a position of either biocentrism or anthropocentrism, or quite commonly, a resolution of both by following the principles of the sustainable development (see Figure 1, chapter 1). The latter formation is also the most common inspiration to the sustainable design methods.

Several approaches, checklists and quantitative methods to design for

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[3] See chapter 5 for a discussion on value conflicts

sustainability have been developed to serve the sustainability agenda. Life Cycle Analysis is a widely recognised approach to assessments in the design stages in industrial, engineering and architectural design disciplines. With an application of this method, it is implied that a compatibility can be found between industrial and natural processes. In industrial design for mass scale products, the Cradle to Cradle principles, developed by Braungart and McDonough (2002), are well recognised and increasingly applied in new product developments. Other models of assessment, checklists, benchmarking tools, mapping of impacts are widely available for designers. (For an in-depth analysis of the most popular sustainable design methods, see Wever and Vogtländer, 2015, also see Fuad-Luke, 2009). It is widely accepted that a practical application of the sustainable design methods in design phases automatically marks the outcome of that design as an attained value of sustainability.

However, the aforementioned Cradle to Cradle design method, for example, advocates that as long as we can contain the materials within the production and consumption loops, thus also eliminating waste, we can maintain the production and consumption cycles infinitely (Vissonova, forthcoming). The idea of "remaking" by using "technical nutrients" as advocated by McDonough and Braungart (2002) implies that there is a perpetuated use for factories and manufacturing processes. Whether we are able to eliminate the waste entirely, free the production from all sorts of pollution, and effectively use only renewable energy for these processes is one question concerning our ability of attaining the value of sustainability as suggested through the method. Another question is, even if the consumption were at no cost to the environment, is such a social structure nevertheless justifiable. Which technical artefacts, and to what extent are they necessary for human wellbeing? As Thorpe (2010) and Chapman (2009) argue, some extent of an absence of material goods may enhance our wellbeing and thus are foundational to the attainment of sustainability. This is explained as reduced consumption leads to a reduced production of goods and waste, hence, being better for the environment while making us happier. Therefore, what is being offered as a sustainable design by one method may be conflicting with another proposition of the sort. The sustainable design methods project the different approaches, and are expressions of the contextual and arbitrary interpretations of what value is to be made attainable with the design.

As the final observation concerning the subject of sustainability, which I believe plays a significant role in the design of technical artefacts, is that the notion of sustainability, one way or another, implies an acknowledgment of restrictions to how we are accustomed to design as well as use the technical artefacts (Vissonova, forthcoming). It is undoubtedly a strenuous task to seek out alternative resources with overall less negative impacts; then, to mitigate the negative impacts by design in the use phases of the technical artefacts, while planning for a safe disposal of the artefacts. Adding to the difficulties, the material sourcing, the manufacturing and the custom of consumerism are not particularly geared to accommodate proposals of alternatives so shaped by designing for sustainability, as argued in Vissonova (forthcoming). Tonkinwise similarly asserts that

> "Sustainability is a challenge to our existing notions of freedom: it is about a certain kind of choice architecture; it is about acknowledging limits; it is about accepting responsibility for longer term and wider afield consequences; it is about accepting interdependence rather than autonomy." (2015:290-291).

Therefore, in seeking to design for sustainability, the act of designing encompasses a broader scope of considerations, as for instance a toxicity and bio-capacity to absorb waste; as well as it may also require a non-arbitrary moral judgment so to translate the value of sustainability into the design requirements. Sustainable design, I find, is a matter of principles, equally moral and methodical, rather than a matter of doing better by not doing worse.

2.2 Technical Intervention

In order to create technical artefacts, we consume natural resources while the technical artefacts may pollute the environment during their use and after. Meanwhile, without appropriate innovations in design, we will not be able to clean up the environmental pollution or out-phase the artefacts we deem to be unsustainable. Therefore, it is perfectly sensible to say that technical artefacts are as much a part of the problem as they may be part of the solution (van de Poel, forthcoming:1). Thus, for us to balance our industrial processes with the natural ones, we must be aware of some safe operating limits, considering that much of the planet's life support systems are finite and its coping mechanisms exhaustible. Rockström with a team of scientists and researchers under the scope of Stockholm Resilience Centre have identified such safe limits, calling them the Planetary Boundaries (Rockström et al., 2009, 2010, 2015). The boundaries are proposed in a framework of nine segments, each of which has been marked for its different levels of exhaustion. These are climate change, ocean acidification, stratospheric ozone depletion, biogeochemical flows of nitrogen and phosphorus, freshwater use, land use, biodiversity loss (in 2015 report extended to a segment of biosphere integrity), atmospheric aerosol loading and chemical pollution (or in 2015 report renamed as 'novel entities'), the latter two are yet to be made quantifiable. The segments which we have exhausted entirely are biodiversity and nitrogen flows, the phosphorus flows and climate change being not that far behind. All the segments are to be seen as interdependent. Meaning, a pressure on one segment may produce accelerated exhaustion of other segments.

Because the design of technical artefacts is inherently dependent on the natural resources, as well as because it inevitably produces side effects in the form of, for example, expelled emissions and pollution, including that of abiotic waste, I believe it is adequate to recognise this element of design as an intervention in nature's coping mechanisms [4]. I suggest we call this thus far undeclared element of the design a *technical intervention* (Vissonova, forthcoming).

Technical interventions, I explain (Vissonova, forthcoming), result from the design of technical artefacts the effects of which may manifest themselves throughout the entire life cycle of the artefacts, i.e. creation, sourcing, production, distribution, maintenance and disposal. A technical intervention relates to materials mining, factory machinery, emissions from components of hazardous gasses and substances, transportation, and waste. (A wooden spoon for that matter requires very little processing in its life cycle, therefore its role in an intervention is rather insignificant).

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[4] By saying 'the nature's coping mechanisms' I imply also living beings and humans as part of the nature and constituting eco-systems.

With technical intervention it is implied that there is an element pertaining to the design of technical artefacts where the side effects ramify and also where they can be evaluated as such and eventually curbed. As an analogical example for the technical intervention, think of a medical pill created to treat an ailment like a headache. The pill is designed to address the headache - certain chemical compounds are put together for that purpose. The pill is a technical artefact made with a purpose, and it is quite likely to have side effects, such as drowsiness or nausea for instance. However, that intended effect along with the side effects will only come to manifest itself once the pill enters the body with the ailment, i.e. when the specific technical intervention has taken place. The side effects may be inferred, but they are nevertheless more comprehensively evaluated together with the desirable effect only through the technical intervention. Such an analogy may be helpful to be kept in mind when thinking of the design of technical artefacts and their effects in the world.

As the Planetary Boundaries illustrate, technical interventions lack the balance between the industrial and natural processes. Moreover, the design efforts in the name of sustainability may not necessarily be reconciling these two processes. As Reller and Diesenbacher (2015:160) state, we the mankind, are dependent on mining the resources stored around the geosphere of our planet. We extract "these resources from their original compounds" and spread "them over the techno- and biospheres". Therefore, as the environment's abilities to cope with our interventions are running low, a necessity arises for the design to include a focus on the technical interventions.

Considering the above, in order for us to qualify the design of a technical artefact as sustainable, I suggest, one must consider the entire technical intervention to which the design gives rise. I shall consider the design of a technical artefact sustainable to the extent that the associated technical intervention is sustainable. The task of explicating *sustainable design*, therefore, involves explicating *sustainable technical interventions*.

2.3 Is Sustainability a 'Wicked Problem' in the Design of Technical Artefacts

To draw on the discussion above, we appear to hold rather fragmented interpretations as to what is represented by the notion of sustainability; as to whether sustainability represents infinite growth based on smart technologies which in parallel to taking care of humans also care of the environment; or the notion represents prioritising the conservation of the natural environment, where the current human social setups may or may not be an integral part of it; or, whether the ideas about sustainability maintain intragenerational or intergenerational equality. Keeping in mind the considerations towards the notion of sustainability in design as discussed here, it is indeed challenging to make evaluations as to what are the right and wrong solutions when it comes to the sustainable design of technical artefacts. How can we then discern the design as the sustainable kind? Perhaps, arguably, designing for sustainability may be the design dealing with 'wicked problems' - a term proposed by Rittel (1972).

As argued by Rittel and Weber (1973), wicked problems are problems which are difficult to solve but where some resolutions may be delivered. They imply some extent of uniqueness and hence non-replicability of the resolutions in new situations. The wicked problems occur in planning for systematic solutions, where all information may not be available at once, and where there are multiple factors all of which may be causal in producing new and unanticipated effects. Typically, such systematic solutions can be associated with social structures, simply because people are unlikely to behave with the same extent of predictability as in mechanistic laws of physics. Nonetheless, it is reasonable to argue that there are many situations, including conservation of eco-systems, where it is difficult if not impossible to have all information available at once. Furthermore, the authors describe that for the wicked problems:

> " … many parties are equally equipped, interested, and/or entitled to judge the solutions, although none has the power to set formal decision rules to determine correctness. Their judgments are likely to differ widely to accord with their group or personal interests, their special value-sets, and their ideological predilections" (Rittel and Weber, 1973:10).

The authors then conclude that their "assessments of proposed solutions are expressed as "good" or "bad" or, more likely, as "better or worse" or "satisfying" or "good enough"" (Rittel and Weber, 1973:10).

Reflecting back to the discrepancies with the notion of sustainability, as well as its context-bound nature, it may appear to be a wicked problem for the design of technical artefacts to resolve. The selective way of the resolutions being sought through the sustainable design methods would also indicate that the design is thus coping with the wickedness of the problem. Identifying sustainability as a wicked problem in the design of technical artefacts would also offer some justification for our inability to make consistent evaluations for what is the right or wrong 'sustainable design'. Rather, an attitude may be acceptable that it is better to do 'something' for the sustainability with the aforementioned cumulative effect in mind, and hence designing for "good enough" resolutions (Vissonova, forthcoming).

That being so, it might be a fair argument for plausibility that sustainability is being treated as a wicked problem in design of technical artefacts. In which case, the sustainable design is the design that deals with the kind of wicked problems that occur in eco-systems and in social setups with demands for equal distribution of risks and benefits of the resource use (Vissonova, forthcoming). As this by all means is considered a good deed and the right thing to do, irrespective of the chosen approach and the selected sustainable design method, a certain extent of objectivity is being held in the way we conceive the notion of sustainability associated with a goodness, as proposed earlier in this chapter. This extent of objectivity, I argue (Vissonova, forthcoming), generally serves as a necessary condition for a design of technical artefacts to count as sustainable, if one bears in mind the "cumulative" effect.

My position is that such a condition although being desirable is significantly insufficient for qualifying the design as sustainable. This is because, if to take into account the diverse pulls and inconsistencies of the notion of sustainability, certain doubts can be raised with regards to our ability to consistently qualify the design as the sustainable kind. That is to say, I am rather hesitant to assert that the criteria for the design to count as sustainable only concerns the kind of wicked problems, and the good intentions behind addressing these, and not the kind of design. The ample empirical evidence makes it clear that there are characteristics sufficiently similar in sustainable design and that the kind of design is hence discernible. Consequently, the task then is to explicate what is the sustainable design of technical artefacts.

2.4 The Task of Offering an Explication

An explication, as defined by Carnap (1950), becomes necessary when we require more exact terms based on logic or empirical explanations to an imprecise and a pre-scientific concept, such as is the notion of sustainability in design of technical artefacts. The somewhat imprecise concept, typically loosely referring to some kind of a thing or phenomenon, is called an *explicandum*. The concept resulting from explication is an *explicatum*. The explicandum nevertheless is made fairly clear by examples and less formal explanations in order for it to be followed by the explicatum. Therefore, in the case of explicating the sustainable design, the groundwork is made by the design practice providing the necessary empirical evidence. However, as is the case with the sustainable design, it is implied by the explicandum that the data it entails is inexact, and therefore the solutions pertaining to the concept will also be inexact. Furthermore, the solutions pertaining to the concept are difficult to evaluate as right or wrong, since no exact terms are associated with the concept. "Strictly speaking," as Carnap (1950:4) explains, "the question whether the solution is right or wrong makes no good sense because there is no clear-cut answer".

As noted above, the explicandum is to be made practically clear and this can be reached with the help of examples of what might be the intended meaning of the concept. Nevertheless, what is formulated based on the examples does not yet supply the explication. The formulations will still belong to the problem and not the construction of the explicatum (Carnap, 1950). Meaning, an identification and a subsequent grouping of the sustainable design examples only indicates that there is a design kind, albeit a definition of the concept is nevertheless necessary so as to qualify what falls under the concept.

2.5 Concluding Remarks

Thus, in closing this chapter dedicated to the state of the art of sustainability, I propose that the conditions by which the design of technical artefacts falls under the kind of design that we can consistently evaluate as sustainable, i.e. which helps us to attain the value of sustainability, concern the effects of design. More specifically, I propose that it is by looking at the mechanisms of cause and effect between the structure of technical artefacts and the thereby initiated technical intervention, that we may qualify the design of technical artefacts as 'sustainable'. In the following chapter, I focus on the effects of design as produced by the properties of the structure of the technical artefacts.

3. Dispositions and the Effects and Side Effects of Design

> "Design means, among other things, fate. This process of asking questions is the collective attempt to seize hold of fate and, collectively, to shape it." (Flusser, 2009:170)

In this chapter, I look at the *dispositional* properties determining the structural and the functional compositions of the artefacts and the subsequent effects ramifying through the technical intervention. I focus on the *dispositions* of materials and substances which are selected for the design of a technical artefact. However, the dispositions may afford effects irrespective of the good intentions behind the design. These, when materialised through the technical intervention become undesirable side effects. As I am discerning what may characterise the sustainable design of technical artefacts, my concern is with the broader effects of the design. I discuss the side effects of design and how these relate to sustainable design.

3.1 Dispositions

Imagine for a moment that you are in a store and the item that you need is on a shelf out of your reach. There are no assistants around and you absolutely must acquire that item. You look around for an object that appears to be solid and durable to hold your weight, and also in a form that allows you to briefly stand on it. If the object is, say, flexible, it may make you bounce which may not be so good for your purpose. If it is fragile, it will obviously crush once you try to step on it. Besides any other possible properties of the object, you know what the primary desired properties for your use are. In addition, you know with certainty that once you use the object, it will not quite suddenly become flexible or fragile just as you step on it, or change its properties otherwise. Knowledge of the properties of technical artefacts with a fair amount of certainty helps us to create and use the artefacts in ways which meet our needs.

Properties are constantly present in an artefact. They constitute the artefact, although they may not manifest themselves until certain conditions obtain. This is why properties are *dispositional* (Vissonova, forthcoming). For example, if to consider a fragile artefact, like a wine glass, its fragility is constantly present however it will only manifest itself once sufficient force is applied to it. The fragility is a *disposition*. Furthermore, the fragility of the wine glass is not a disposition of the wine glass in its shape, but a disposition of the glass material used in the particular shape of the wine glass. While any other glass vessel may have the same disposition as the wine glass, but not any other shape of a wine glass may possess this disposition. In contrast to dispositional properties, properties may also be categorical. The contrast is a result of how we ascribe the dispositional properties to being conditional, and the categorical properties un-conditional (for a discussion on the distinctions see Mumford 1998). I endorse Mumford's view that dispositional properties are those which do not manifest themselves unless certain conditions obtain.

In philosophy studying causality, dispositions are frequently referred to as powers. As Ellis (2002) views, what we understand behind the notion of a causal power constitutes the driving force in a causal relation. There are many attempts to explain the workings of the causality and the archetypical rules of cause and effect, (see Kleinberg, 2013, Russo, 2010, Salmon, 1998, Sloman, 2005, Williamson, 2006, and Groff, 2008, to name but a few authors on the subject). Typically, in the field of philosophy concerned with artefacts, the cause and effect relationships are conceived as principles of mechanistic nature. Which is to say, an evidence of a causal relation suggests a regularity of some relations being relatively deterministic given certain conditions. As for instance, round objects roll on a sloped surface, while heavy objects sink in water, and acid dissolves stuff. Concerning technical artefacts, it is natural for us to rely on our knowledge of causal relationships (see von Wright, 1963, also Hughes, 2009:378). I tend to favour Groff's (2008) proposed articulation of causality because of the implied common sense of such an understanding.

> "to say 'x caused y', or 'x is the cause of y', is to express our common sense conviction that there is something *about* x that made it be that y happened. It is not to say 'every time I observe x, y follows, and so now I expect y to follow'. Nor is it to say 'We cannot help but conceive of x-followed-by-y as a lawfully governed sequence.'

> Rather it is to say, 'x is such that it has the power to bring about y, other things being equal (and so will continue to do so in the future)'". (Groff, 2008:2)

The causal production is the mechanism that qualifies the properties to be dispositional and hence able to afford effects when certain conditions obtain[5]; and the effects afforded are what qualifies (or disqualifies) the technical artefact for us.

By referring to a property of a technical artefact as a disposition, we acknowledge the artefact having the distinctive property which makes it intrinsically disposed to take part in the specific causal processes associated with that property (see Ellis, 2002:82). Think of an elastic band - its elasticity is a disposition to stretch and contract when a force is applied or released. Hence, the dispositions participate in causal processes or, in fact, determine the causal processes that take place within the physical structure of the technical artefact (Vissonova, forthcoming). Moreover, dispositional properties, as succinctly put by Witt (2009:131), "are exercised in certain circumstances but not in others". As the elastic band will only comply when being stretched, but will not do so without the force. However, the dispositions should not be confused with a manifestation or reduced to an event where the manifestation is caused (see Mumford, 1998:74). As noted earlier, fragility is a constant property of a wine glass. In a way, as Mumford (1998:74) articulates, a disposition is a potentiality of its manifestation.

Furthermore, dispositions may help to categorise a technical artefact along with other similar kinds. For example, two artefacts can be structured in very different ways, equipped with very different mechanisms, as for instance batteries. But as these are disposed to produce certain effects, in this case releasing energy when stimulated to do so, the same function will be achieved regardless of the differences in their structure. Whereas, a jersey material and a rubber band have the same disposition of elasticity enabling them to stretch in certain given circumstances, yet the functions of these materials are not alternative to one another. Thus, as proposed by Ellis (2002:89), the term 'dispositions' denotes genuine properties, rather than describing behavioural tendencies, i.e. *to* stretch

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[5] That is not to imply that dispositional is the same as mechanistic. For the discussion on this subject see Mumford (1998).

or *to* release stored energy.

Nonetheless, the dispositions affording effects are intrinsic to the physical structure of the technical artefact, for which a set of materials and substances are selected so that it can support the artefact's function (Vissonova, forthcoming). It is by recognising the dispositions of materials and substances that we can design the physical structures of the technical artefacts so that they help us attain our goals by fulfilling their intended functions.

3.2 The Known Desirable Effects of Design

The significance of a technical artefact is in its properties, the effects of which help us to realise our goals and shape our environments (Vissonova, forthcoming). One of the earliest advocates of sustainability in the design of technical artefacts, Papanek (1985:28), suggests that the purpose of design is to transform the human environment by extension transforming the humans themselves. Similarly, Simon (1996:111) postulates that we may conceive the design to be an act of devising a course of action that aims at "changing existing situations into *preferred* ones" (emphasis added). We see the products of architectural, industrial and engineering design shaping our world. Buildings, transport, medical equipment, household items and the machinery and factories associated with making these – all are designed with an intention to produce certain effects: to shelter, to deliver, to save lives and to perform all sorts of everyday functions. As succinctly articulated by Kroes et al.(2009:3), "Despite its diverse manifestations … all design can increasingly be seen as aimed at the same goal: production of our material environment and the way in which we are designed to live in that environment". It can thus be said that the design of technical artefacts is very much about the production of the desirable effects. It can also be said, sustainability results from some desirable effects, somewhere along with the function of the technical artefact, yet not necessarily pertaining to the artefact's function.

Technical artefacts, as asserted by Franssen et al. (2009), are made to be used for something, or they may be components serving in another artefact, which may yet serve another larger artefact made to serve a purpose. All technical artefacts are designed with some purpose in mind and what they are for “is called the artefact’s function.” (Franssen et al., 2009). We categorise artefacts as technical if they have characteristics of an object with “a physical structure consciously designed, produced and used by humans to realise its function” (Kroes, 2002:294). Materials and substances which are selected for a technical artefact’s structure have a set of dispositions, and the dispositions display causal powers in given circumstances; (for that matter, materials and substances which are made artificially are components, and thus are also technical artefacts). Generally, the effects afforded by the dispositions are aimed at supporting the artefact’s function[6].

Vermaas et al. (2011) interpret the function as the desired properties and capacities. With such an interpretation of the technical artefact’s function, the authors emphasise the power of the properties to cause events so that the function may take place. They illustrate the notion with an airplane with the capacity to be airborne with the passengers on board; opposed to an interpretation of an airplane’s function as a means of transport from *a* to *b*, which, perhaps, is expressing less explicitly a relation between the specifics of the powers within the structure of the artefact and its function[7].

The function of a technical artefact pertains to effects which are desired. The function is desired for the obvious reason because it is the end which we have aspired to attain. The materials and substances are selected among those that can best afford the desired effects (Vissonova, forthcoming). The materials and substances may at first be selected due to some of their distinguishable dispositions which will fulfil the design requirements and whereby the function will be made attainable. Typically, this is a process of the ends being prescriptive to the identification and selection of means (see Kroes, 2009). However, once the materials and substances are selected, other dispositions may become evident during the design phase affording other effects.

Let me give an example with a chair, almost an archetypical design exercise

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[6] An exception to the rule are artefacts of art which have a different purpose, typically perceived as non-functional

[7] The authors argue that there is some ambiguity with the interpretations of the ‘function’. See the discussion in Vermaas et al. (2011) pages 24-25. Also see Vermaas and Houkes (2006) discussion of ‘use plans’, and Houkes et al. 2002 earlier publication on “*design* and *use* as plans”.

expressing the variations of materials and interpretations pertaining to its function. In his study on product design, Parsons (2009) reflects on the design process leading to the Eames Fibreglass Chair from 1950. The designers' intention was to design a chair that fits the contours of the human body, a "body-hugging" form, and which would be made in one piece thus reducing the amount of materials and components necessary. As Parsons reports, by discovering fibreglass-reinforced polyester resin material, the designers realised that besides the desired properties to be contoured to the human shape, and to be produced in a one piece shell, the material also had certain aesthetics and durability dispositions, which became the desirable effects of the design of this chair. These effects are desirable along with the chair's function, yet are not necessarily what makes the chair desirable. Because the effects such as illustrated with the chair become evident during the design phases, when the materials with the certain dispositions are being selected, and thus the designer is able to infer the effects, the desirable effects are intended by the design. I call these the *known desirable effects*.

Saying that, I acknowledge the effects may also be unknown yet desirable. These, are not intended in the design of technical artefacts as the designer has no knowledge of them at the time of designing. The unknown desirable effects are likely to manifest themselves during the use phase of an artefact and through the technical intervention, when other parties besides the designer find other ways to make the technical artefact beneficial. The unknown desirable effects have no significance in my study, and therefore do not figure in the discussion.

It is important to note that there may appear to be some similarities between my explanation of the effects of design and how Wood (2009) describes *behaviours* of artefacts in relation to their function. He writes: "Function is the subset of behaviours that we design into an artefact; the rest of the behaviours are simply 'along for the ride.'" (Wood, 2009:544). His definition of the behaviours is that they are the effects of interactions that take place between the artefact and the physical world. The conception of the behaviours, as Wood explains, is similar to the concept of *affordances* (introduced by Gibson, 1979), which place a focus on an actor and an environment and not on the intent of the designer. The primary difference between my proposition of effects and Wood's explanation of behaviours is that the latter considers the effects provided by the technical artefact once it is designed and is being used; whereas my proposition considers the design of the technical artefact beginning with the very design phases and the technical intervention it gives rise to. Therefore, in my view, the design begins to shape our world from the moment a technical artefact comes into realisation, by demanding for the mining, transporting and manufacturing of materials and substances. The desired effects not only ought to be concerned with the aims made attainable with the technical artefacts, but also with the entire technical intervention.

Continuing on the subject of the known desirable effects, I stated earlier that the dispositions of the materials and substances support the function of the technical artefact, and that the process of selection is typical to a means-ends perspective of designing. Nevertheless, my assertion is that the known desired effects are not necessarily all goal oriented, i.e. the function of the artefact, but rather the function pertains to the known desirable effects, as earlier illustrated with the Eames Fibreglass Chair. Broadly speaking, the desirability of the known effects is informed through the intended function. The selected materials and substances for the structure (which enables the function) may also inform the design of other dispositions affording desirable effects which are not necessary for the technical artefact's function, but somehow add to the value of the artefact [8]. Either way, the known desirable effects are always intentional in the design of technical artefacts.

In order to continue this chapter arguing for the desirable effects and leading to a discussion on the undesirable effects, a reference I believe ought to be made to the terms of 'an intention' and 'desirability'. The term 'intention' associates with an agent's practical reasoning for what she ought to do (see Audi, 1982). Therefore an intention may lead to an action. An intention is most likely based on a desire to attain an end and a willingness and capability to act upon the desire (see Houkes et al.'s notes on 'intention' and 'practical reasoning' 2002). While it is explicit that the design of technical artefacts is an act, which, as I argue, is intentional, my focus is not to examine the reasoning behind the designer's actions resulting in technical artefacts. The enquiry is aimed at the 'object' and the (non-deontic) causal

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[8] I discuss the value of technical artefacts in chapter 5.

mechanisms that result from the intentions. Anyhow, 'intention' and 'desirability' are inherently linked, as the latter is likely to motivate the former. With regards to the known desirable effects, I make a postulation that once the materials and substances with certain dispositions are selected for the structure of the technical artefact, the various powers known to the designer are thus intentional in the structure of the artefact. Let me explain by referring to the ideas offered by Harre and Madden (1975).

Harre and Madden (1975:72) propose that discovering dispositional properties[9] of an artefact enables us to explain and justify our interpretation of the artefact, how we discern it and distinguish it as belonging to a type of artefact. We thus determine its "nominal essence", as the authors call it. The nominal essence grants the development of a meaning and thus a value may be ascribed to the properties. The authors further argue, that once we grasp the causal production characteristic of these properties, i.e. the specifics of the cause and the resulting effects, we may therefore claim the necessity of these effects. In other words, we make the discovered effects desirable. Moreover, the authors explain, we create a legitimacy of the properties for just that specific causal production affording the particular effects.

The implications of the above are that when designing technical artefacts, we align the known desired effects afforded by the dispositions with our intentions. We do so through our selection of materials and substances, each with particular dispositions. For example, elasticity is a disposition to stretch, solubility a disposition to dissolve in liquid, conductivity is a disposition to transport electrical or thermal energy, and biodegradability a disposition to degrade without a trace over a period of time. All these are dispositions the effects of which make the artefacts somehow useful to us - the effects are desirable for their value (Vissonova, forthcoming). Furthermore, dispositions are intrinsic to technical artefacts and our treatment of all artefacts is certainly shaped by the extent of our knowledge of their dispositions (Mumford, 1998:3). In consequence, the design, aiming at the production of the desirable effects, is concentrated on the dispositions and their causal mechanisms that serve the goals in question, as we define them through design requirements.

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[9] The authors refer to all properties as dispositional if the properties are able to display causal powers.

However, what then is implied is that we take into account the dispositions to the extent that it is within their capacity to deliver some known desirable effects, including fulfilling the function of the artefact. And so the dispositions with the power to cause effects other than those desired are accepted rather than intended. Thus, the effects afforded by the dispositions of the artefact's structure along with the known desirable effects are *side effects* (Vissonova, forthcoming). In this study, my concern is with the *undesirable* side effects. Side effects may be known at the time of designing, as well as unknown. It is particularly the recognition and addressing of the side effects of the design of technical artefacts that help us to qualify the design as sustainable.

3.3 The Known and Unknown Undesirable Effects of the Design of Technical Artefacts

I find that a strong focus on addressing side effects is particularly characteristic to the design of technical artefacts dealing with issues of sustainability. Waste products of mining and manufacturing, such as scraps and by-products, disposed abiotic and biotic waste, emissions and pollution, to name some, all are side effects as their occurrence is unintended, or rather unwanted by their creator. Nor are they wanted by the users of the technical artefact due to the making of which the side effects come about. In other words, side effects are the unwanted effects of bringing about some desirable effect (Vissonova, forthcoming). Moreover, these side effects may have their own physical structures with properties, which are, technically speaking, of artificial nature; but as these come about through unintended actions, they fall between the categories of the 'natural' and the 'technical' artefacts. Allow me to explain with a similar thought proposed by Franssen (2009:923, also see Franssen et al., 2009):

> "The defining characteristic limits artefacts to a subclass of the class of all things that are made by humans, in the sense of resulting from an intentional act that consists in the modification and reshaping of material bodies. Other elements in this class, for instance waste products, such as exhaust fumes and sawdust, and other things that are the by-products or side-effects of human action, such as footprints and fingerprints, are not artefacts, because, although the process from which they result

> is (presumably) done for a purpose and the maker is aware of producing them, the fact that they are made is accepted rather than intended and the maker has no purpose for them" (Franssen, 2009:923).

Thus, the side effects may be 'undesirable' because firstly, they are not intended and as such may be a by-product of a material or a component which otherwise serves its purpose in the function of the technical artefact in question (that is, without the production of the by-product the function would not be possible, as is the case with Nitrogen oxide emissions from cars, for instance). It could be said that side effects pertain to effects that we somehow practically could not do without if we are to pursue the known desirable effects, but which we would rather not have, based on ethical or moral judgments [10]. Secondly, the side effects are likely to pose hazards[11] throughout the associated technical intervention, and hence are also unintended based on the moral judgments.

Furthermore, as discussed above, we generally conceive the side effects to be unintentional, and also, as van de Poel (2009:983) describes them, not something that we may characterise the technical artefacts by. At least, not for qualifying them as the artefacts they are. Nevertheless, the dispositions affording the side effects belong to the physical structure of the technical artefacts, therefore in a practical sense, side effects are inherent in technical artefacts (see van de Poel, 2009:984). For example, most sports footwear are made of materials with the disposition of non-biodegradability, among other of their properties. Yet, we cannot surely refer to the effects afforded by this disposition as intended or desirable, nor would we typically identify the footwear for their disposition to not degrade at their disposal phase, when the undesirable effects ramify through the technical intervention.

Side effects are the effects resulting from the selection of the materials and substances with certain dispositions for the structure of a technical artefact. This however does not imply that side effects begin to ramify only once the materials and substances are physically put together to constitute an artefact's structure. Rather side effects occur when the materials and substances are *selected*, hence

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[10] We generally conceive design being for improving conditions, and thus it is assumed to be accompanied by moral values or ethical obligations not to (purposely) inflict harm (see van de Poel and Royakkers 2011).

[11] See chapter 4 for a discussion on hazards

requiring the mining, through which then resources are depleted, as well as the production of the materials, and their transportation, through which emissions and waste are produced. Therefore, side effects may be conceptually divided between those which ramify before the structure of the technical artefact materialises, and those which ramify when a technical artefact is designed and released into the consumption leading to the eventual disposal. Consequently, since the side effects of the design of technical artefacts occur during the phases of mining, production, use or disposal, they do not only pertain to technical artefacts, but to the technical intervention the design gives rise to.

In a tradition of studying the design of technical artefacts, the given acknowledgement of side effects is enough, i.e. we know the design produces side effects and that is the state of things. I think, it is safe to say that the matters changed with the design practice turning to the issues of sustainability. The side effects ramifying through technical interventions became the design's focus or the new problem area for the design to resolve. As for instance, during the first decade of this century, there was a significant increase in the number of experimental and mainstream housing improvements for cutting down on heat loss via improved insulation techniques, meanwhile cutting down on the energy needed for heating. The heat loss and the high emissions from the heating were both side effects of the older housing (and the associated product) designs that needed to be dealt with. During the second decade of this century, there has been a heavy focus on the materials and substances that are components of various technical artefacts - from coffee machines to buildings[12]. Circular Economy, as promoted by the Ellen MacArthur Foundation, organisations working with the Cradle to Cradle certification systems, as well as biomimicry principles all focus specifically on material flows and reduction of undesirable effects such as resource exhaustion, waste and pollution resulting in an oversaturated biocapacity - all side effects of various "pre-sustainability" materials, as it were.

I think, it is fair to say that side effects were accepted to a certain extent, in

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[12] See e.g. Fuad-Luke's (2009) Eco-Design Handbook for collection of sustainable design examples, including materials. Also the work by the Materia organisation promoting innovative materials.

a practical sense, as part of technical artefacts, such as emissions and pollution, as I noted just earlier. Nevertheless, evaluations of side effects were made outside the design discipline by environmental or health scientists and policy makers. With the rising efforts in designing for sustainability, the side effects came to be perceived as a design problem to be resolved, and hence their evaluations are no longer external to the design (at least the design which we may qualify as sustainable). Conceptually, side effects belong to the design of technical artefacts, however, not in the same sense as the intended known desired effects do. Rather, they belong to technical interventions associable with a particular design, or those which have risen from other designs. The point is that the design efforts to deal with sustainability signify the efforts in dealing with side effects.

Be this as it may, this, however, does not mean that only the design of technical artefacts without any side effects may qualify as the sustainable kind, although, arguably such a design may be stated as an ultimate goal of designing for sustainability (Vissonova, forthcoming). Rather, it means that the design can be said to be 'sustainable' to *the extent* it curbs side effects. And since the side effects ramify through technical interventions, the extent has to concern the technical interventions and not just the physical structure or just the function of the technical artefact we may have considered to be 'sustainable'. In this regard, let us look at a wind turbine blade as one of such designs.

Irrespective of the good intention by the design of a wind turbine blade, the dispositions within the structure of the artefact harbours some effects that are undesirable in the life cycle of the artefact and hence the technical intervention it gives rise to. Particularly, concerning the sustainable design of technical artefacts, some of the effects are undesirable as they represent a conflict in what is being offered as sustainable, which in the case of the wind turbine is the production of renewable energy and hence lowering carbon emissions.

Clearly, a wind turbine blade is an essential element in the turbine's function to produce energy from renewable sources. The blades are made of several materials which all must share a range of properties, some of which are: low weight and density, high fatigue resistance, rigidness, stiffness, low conductivity of electricity, and resistance to variations in temperature. However, the blades come with a rather infamous problem as presented rather extensively by an organisation

Materials today (Larsen, 2009). That is, to this day the blades can be used only once, because they are made from materials and substances which have very little chance of being reused. The majority of wind turbine blades are made from composites of fibre-reinforced polymers, sandwich core materials, bonded joints, and polyurethane coating. Due to the dispositions of these materials, the wind turbine blade is perdurable. Reprocessing the materials of the blade is complex and currently not practiced, while the disposal of the material presents new challenges. This is mainly due to the composition of fibre and polymer matrix, which is not processable for separation and thus reuse of the fibres, the adhesive, nor the other materials. One of the methods of handling the used blades is to dispose of them in a landfill. However, the massive amounts of the blade material constitute a problem: estimated each installed 1 kilowatt requires 10 kg of blade material, i.e. a 7.5 megawatt turbine requires 75 tonnes of blade material, according to the report by Larsen (2009). The blades exceed 60 metres per blade on onshore wind turbines and the estimated life span of a blade is 20-25 years, while the blades are regularly replaced for efficiency and safety. Based on these facts, we are going to inherit substantial amounts of discarded blades in the coming decades. Additionally, the most practiced method of disposal is an incineration for energy recovery. However, the process produces ash as much as 60% of the scrap. This ash is a pollutant due to abiotic compounds of the composite material. It is either dumped in a landfill or, if processed, introduced in construction materials. Lastly, the wind turbine blades are recycled. However, there are too few established methods for recycling. Only 30% of fibre reinforced plastic waste can be reprocessed, although, preferably not for making new blades.

In the light of the above, while the wind turbine counters the use of fossil fuels, thus being instrumental in attaining sustainability by its function, its structural composition is rather contradictory to what may be a sustainable technical intervention. Thus, while the dispositions of the materials afford the known desirable effects in support of the function of the technical artefact, their powers remain when we no longer have any use for them. These effects afforded by the dispositions become undesirable in the new situation of a post-function-phase.

Furthermore on the subject of undesirable side effects. An aspect of dispositions important to note is their power to manifest side effects without us being aware of them. Because the display of dispositions is often through complex processes, like for example a disposition to conduct electricity, or to transport radio waves; it is reasonably easy to have little or no concept of the dispositional properties of materials and substances selected for a structure of a technical artefact. Dispositions are present whether we know of them or not, regardless to what extent we are able to recognise the effects afforded by them. As Witt (2008:131) notes, fire has the power to heat irrespective of whether it is actually heating anything. Meaning, whether or not we recognise a disposition, things are structured in certain ways and possess certain powers to behave in certain patterns (Vissonova, forthcoming). Therefore, besides the effects known at the time of designing yet are rather accepted than intended by design, as illustrated above with the wind turbine blades, unknown effects may be present, as dispositions cannot always be known. Dispositions can be dormant and for different reasons not manifest themselves.

Mumford (1998) offers three ways in which the notion of dormant dispositions may be clarified: (a) an artefact can be fragile for a long time without ever being broken, (b) an artefact can have a disposition which diminishes without ever having manifested itself, and (c) an artefact can have a disposition for which the manifestation has yet not been experienced and for which we have no concept that we can refer to as such a disposition. Ancient papyrus scrolls preserved over time are known to be fragile without being broken. This is based on someone's experience of breaking such a thing. Further, freon gas has a disposition to evaporate and release chlorine atoms which in time and accumulation deplete the ozone layer of our atmosphere. Without an accumulation factor, the disposition might never have caught our attention, or without further emissions it might have dispersed before we noticed the side effect. And lastly, older forms of PVC contained pigments and stabilisers in turn containing cadmium and lead. Due to the toxicity disposition of these compounds, the older type of PVC is no longer legal for use in building components, according to a report by the Centre for Sustainable Textiles in the Construction Industry (Jerichau, 2013:21). Although we are frequently unaware of such insidious effects at the time technical artefacts are designed, sooner or later undesirable effects of materials and substances may be discovered.

Thus, in the attempts to understand all conditions present, we find that dispositions, as expressed by Mumford (1998), may go beyond observable events and, therefore, some dispositions are verification transcendent. Nonetheless, it is so that dispositions afford effects that are knowable, along with unknowable and undesirable. In order to make a practical distinction between the dispositions and the afforded side effects as illustrated with the wind turbine blade and as with the dormant dispositions, I suggest we call the former the *known undesirable effects* and the latter the *unknown undesirable effects*.

All in all, the undesirable side effects can take many well recognised forms, to name but a few: common emissions such as the Nitrogen oxide, toxic compounds such as phthalates in plastics, leaked nutrients such as phosphorus in lakes and seas causing eutrophication, and many other side effects of design. Waste water from water flushing toilets is also a known undesirable effect, as the design involves the use of water for the purpose of flushing human waste, although without an intention to produce waste water.

The undesirable effects may occur in all design of technical artefacts indiscriminately, also in the sustainable kind. Firstly, it may be due to their dormancy. Secondly, the reason for their occurrence is most frequently due to the known effects evaluated against the goals we aim to attain from a "viewpoint of efficiency", as Grunwald (2009:1125) has argued. That is to say, typically in design, also which we may qualify as sustainable, ways are assessed that attain the goals with "fewer side effects, fewer risks and at lower costs, etc.", explains Grunwald (2009:1125). While pursuing known desirable effects in the design of technical artefacts, including the sustainable kind, a production of an undesirable effect is likely, and thus side effects result. Nonetheless, the acceptance of side effects is presumably evaluated not for whether we may tolerate them ramifying through the technical intervention, but for the desirable effects that they go along with.

Lastly, with regards to the undesirable effects, as Vermaas et al. (2011:18) point out, the occurrence of the undesirable side effects indicate that the design of technical artefacts "is not only about their efficacy and efficiency. One should also bear in mind that it is not just through being used for a certain purpose that technical artefacts influence the world but also through their side effects."

Therefore, how we may live in our world is very much tied to how the design of technical artefacts shapes our environments by curbing the undesirable side effects.

3.4. Concluding Remarks

To conclude this chapter, the significance of the properties is that they display causal powers in given circumstances, thus enabling the particular structural compositions and the functions of technical artefacts. Properties with causal powers are dispositional and as such they afford known desirable effects, which are always intended, and known and unknown undesirable side effects, which are unintended in the design of technical artefacts. Obviously, in terms of known/ unknown and desirable/ undesirable, four types of effects are logically possible: (1) known desirable, (2) known undesirable, (3) unknown undesirable, and (4) unknown desirable. Effects of type (1) are the ones we plan to achieve; the other three we do not plan for, hence they are called side effects. The type (4) does not concern this study, although it might be interesting to consider in the light of repurposing materials and substances not as intended by the design, nonetheless when making technical interventions sustainable.

The production of side effects comes about as materials and substances have dispositions affording effects irrespective of the intentions behind the design or what is specified by design requirements. When we understand, for instance, durability of materials as a disposition, in addition to perceiving it as merely a desirable property that serves an intended function of a technical artefact, we begin to recognise that dispositions of the materials and substances retain their powers also in conditions where we no longer need them to do so. Such an understanding supports the conditions for making the design of technical artefacts sustainable.

In the following chapter, I will continue to explicate the sustainable design of technical artefacts by discerning how the values carried by the effects help us to qualify the design as the sustainable kind.

4. Effects and Values in Design

> "… When it comes to creating things, one is faced with the question of responsibility …. Responsibility is the decision to answer for things to other people. It is openness to other people, if I decide to answer for something in creating my design, then in the object of use designed by me I emphasise the inter-subjective and not the objective. And the more I direct attention towards the object in the creation of my design (the more irresponsibly I design it), the more the object will obstruct those coming after me (Flusser, 2009:59).

In the previous chapter I discussed that the technical artefacts are designed for a purpose, and that the materials and substances selected for the structure of the artefact have certain dispositions which then help us to attain that purpose. However, the dispositions residing in the physical structure of the artefact may also harbour undesirable side effects. In this chapter, I discuss the values rendered by the dispositions and the hazards carried by the side effects. I explain how the utility value is rendered by the dispositions of materials and substances and how this contributes to the discerning the 'sustainable design'. I end the chapter with a discussion on value conflicts.

4.1 Desirable Effects and Values in the Design of Technical Artefacts

The effects of design carry values. Due to the values attained with the design of technical artefacts, the effects manifesting themselves through a technical intervention can be said to be desirable or undesirable, or perhaps even determining if an intervention should take place. Broadly speaking, we relate to objects because of the values they enable us to attain. Our primary concern with a technical artefact is its instrumental value, that is, how valuable we find the artefact as an *instrument* (Franssen, 2009, also van de Poel, 2009). Like knives, telephones, cars and buildings, technical artefacts are evaluated for how well they serve our needs.

The instrumental value is why we design a technical artefact in the way we do, although there may be other reasons why we choose one technical artefact (or a material or component for that matter) over another with the same function. This, I argue, is due to the technical artefacts having dispositional properties, which afford all sorts of known desirable effects. While some of the dispositions directly support the function of the technical artefact and therefore render its instrumental value, others may be valuable in other ways, as illustrated by the Eames Fibreglass Chair in the previous chapter. Meaning, some dispositions make the artefact valuable for some particular reason relative to other artefacts with the same function (Vissonova, forthcoming). For instance, some dispositions make some tyres safer at high speeds, and some dispositions make some packaging sustainable if made of biodegradable materials.

The general pattern thus is that dispositions afford effects and effects carry values (see Figure 1). It is due to the values rendered by the dispositions that we may assess the various benefits, or their lack, of the technical artefacts, and hence the technical interventions their design gives rise to. Due to the unbalanced technical interventions, i.e. those where nature's coping mechanisms with our interventions are challenged, I find that in the design we may discern as sustainable, a particular focus is placed not only on the undesirable side effects, but also on the values carried by the known desirable effects. It appears to be so that with the increased focus on the flows of materials, resource exhaustion and resource waste in the design of technical artefacts, more focus is placed on values rendered by the dispositions of the materials and substances (Vissonova, forthcoming). Due to certain dispositions, the materials and substances can be used so as to add other desirable effects to the function of the artefact. Furthermore, some dispositions persist through the disposal phase of a technical artefact, endowing the materials and substances with a value to be potentially utilised. I call the (positive) values rendered by the dispositions of materials and substances the *utility values* (Vissonova, forthcoming).

I choose the term 'utility value' because all materials and substances can have a utility value given their intrinsic characteristics (see discussion on an instrumental value by van de Poel, 2009). Materials and substances selected for the structure of a technical artefact may be 'technical', if their structure is designed by humans for a purpose; as well as, they may be found in our biosphere, such as various gases and minerals, and used in designing the technical artefacts.

4.2 Utility Values of Materials and Substances, Hazards and Value Retrieval

The utility values can be said to be deliberately accommodated in the technical artefact's structure, yet not necessarily be the primary reason why a user acquires the artefact. Accordingly, a technical artefact may accommodate several utility values, so to say, complimentary to its function (Vissonova, forthcoming). Let me explain with an example of a roofing membrane Noxite developed by Icopal [13]. The product is a bituminous waterproofing sheet covering a roof surface. Besides this function, the membrane purifies air by ridding it of nitrogen oxide pollutants called NOx. The NOx are atmospheric pollutants and are born as a side effect of fossil fuel combustion from cars, incinerators, manufacturing and such. The air purification works by the Noxite membrane containing granules coated with titanium dioxide on its surface, which through exposure to the sun alters the NOx molecules converting them into harmless levels of nitrates, carbon dioxide and water. The process is activated by ultraviolet radiation from the sun hitting the titanium dioxide particles and releasing energy for processing the NOx molecules. The converted air pollutants are washed away with the rain. The effects afforded by the dispositions of substances within the membrane can last the lifespan of the product, as it is claimed by the manufacturer [14]. Thus, a technical artefact may have a benefit deliberately designed into the structure of the artefact, which does not alter in any way the function of the artefact, in this case waterproofing the roof, and thus how we may characterise the artefact as a particular kind. The Noxite is an example of how with certain utility values of selected materials and substances, side effects manifested through unsustainable interventions may be curbed.

While the dispositions of materials and substances have their utility values, which we readily exploit in the design of technical artefacts, they also may pose hazards. Dispositional properties that have the power to afford effects, of which the consequence may be harmful to living beings and the environment, it can be said,

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[13] The Noxite is one of the products of Green Solution House retrofitting to attain the project's goal to be a sustainable building

[14] As bitumen is not an environmentally friendly material, I would like to add that this particular manufacturer also reclaim bitumen roofing for recycling into new roofing materials.

are hazardous. As Nitrogen Dioxide is a pollutant with a hazardous disposition to affect respiratory systems of humans, for instance. Hazard, we understand, is either a risk potential, or a negative value carried by an undesirable effect that has manifested itself (see Hansson, 2009:1073). Consequently, building manufacturing plants and planning for heavy traffic in an urban area is a high risk potential for a hazardous accumulation of Nitrogen oxide emissions. Whereas a designed and built combustion engine that emits Nitrogen oxides has an undesirable side effect carrying a hazard. However, Hansson (2009:1073) points out that what is hazardous may be applicable under vague conditions. For instance, an airplane flying its regular route above your head is not considered hazardous, while an airplane about to crash close to you is a hazard. Thus, Hansson continues with the argument, where we are potentially exposed to a hazard, yet the potentiality is very slight, we tend not to think of it as a hazard.

Dispositions may pose a hazard, however, in general we do not consider an entire technical artefact to be hazardous. For instance, a wine glass is disposed to shatter, as a result of which wine may be spilt leaving nasty marks and the shattered glass may cut someone's hand. The disposition thus is hazardous, but the actual wine glass is not. This is because the hazards, as considered here, are posed by dispositions of the structure of a technical artefact and thus only certain properties and not the entire artefact are hazardous. However, it is worth noting that technical artefacts can be hazardous by function, weapons being the primary example.

Nonetheless, I consider it useful to separate the theoretical understanding of hazardous dispositions from hazardous artefacts. This is because technical artefacts often contain materials and substances that have a longer life span than the artefact and their effects remain in the technical intervention, as is the case with the wind turbine blades discussed in chapter 3. After the technical artefact has reached its disposal phase or is partly consumed, these materials and substances no longer purposeful for the artefact become hazardous, if not somehow repurposed or otherwise handled. Perhaps a stronger example of dispositions posing hazards is nuclear waste.

Continuing the subject of dispositions posing hazards, some technical artefacts contain substances which bear hazardous qualities while the technical artefact is still in consumption cycles. These are referred to as toxic compounds.

Toxic compounds are widely integrated not only in our technologies, but also in everyday products. Let us look at one such example. The phthalate substance, a type of plasticiser, is commonly used in plastics to increase their durability, flexibility and transparency. Due to these dispositions the substance is widely contained, among other things, in packaging, toys, casings of electronic goods such as mobile phones and computers, raincoats, wall coverings, lubricants and detergents, according to EurActiv Network (Jacobsen, 2012). Some types of phthalates are also present in cosmetics such as some hair products. Along with their utility values rendered by the dispositions, phthalates are known to be endocrine system disrupters in humans, for this reason, according to EU's REACH regulations (2007), cosmetic products containing the substance and the compound use in toys has been banned in Europe. Thus, dispositions can pose hazards while rendering a utility value, which illustrates the complexity of the choice of dispositional properties in the design of technical artefacts.

In design, a disposition may be treated as a property to withstand various conditions while sustaining its utility value. With an example of elasticity, we see that what is designed to be elastic, is desired to remain so. The same observation we may apply to properties such as breathable, soluble, thermal, hydrophobic or hydrophilic, fire resistant and so forth. Because it is so, dispositions make artefacts safe for us to use, or quite on the contrary, hazardous while in use or in their disposal phases (Vissonova, forthcoming). Nonetheless, if a technical artefact breaks down beyond repair and hence is no longer functional or otherwise approaches its disposal phase, a disposition of a material or substance in its structure may still continue to render the particular utility value. So for instance, the utility value of plastic bottles and containers of short-life products such as e.g. cosmetics does not end when the cosmetic substance is consumed. The properties of the particular plastics, irrespective of our needs, retain their utility value while safely holding the cosmetics for us, as well as when disposed of.

One of the conditions for qualifying a design as sustainable, is that materials and substances with well sustained utility values are available for some extent of re-use when the artefact is no longer functional. A simple example is a car that has been in an unfortunate accident and hence no longer functions as a car. Yet, the parts in a good (or repairable) condition can be reused and hence would be made available for another similar vehicle. However, more often than not, a reuse of materials and substances is significantly more complex than components such as car parts. Let us look at two examples, one of PVC plastic materials and one of a nearly depleted substance - phosphorus.

Firstly about the plastics. Due to their durability disposition, several types of plastics are used in components for the building industry. According to a report on recyclability of plastics in the building industry by the Centre of Sustainable Textiles in the Construction Industry (Jerichau, 2013:16), from 47 million tons of plastic used in Europe in 2011, 20% were consumed in the building industry, which was the third biggest consumer of plastics. Diverse types of plastic materials are used in many applications. However PVC is the primary type of plastic used within this industry, as in pipes, different types of profiles, also window frames, and other applications. Clearly, the disposition to be durable, that is unchanging and withstanding various typical conditions in the building without breaking, dissolving or otherwise disabling its utility value, is why the material is used as a structural element in the design of products for the building industry.

For instance, a utility value of PVC plastic is so it can be formed for a use as a pipe. When the pipe is no longer needed, the utility value of the PVC may be retrieved and, albeit requiring severe processing, serve in a new technical artefact such as a pipe. According to Jerichau (2013:21), in Denmark 75% of accessible PVC is retrieved from construction waste and recycled. Other types of plastic are retrieved where possible for use as a raw material in another type of structure, depending on the type of the plastic in question. The retrieval of plastic happens in waste sorting plants, where for example NER (Near Infra Red) laser technology sorts out finer hard and soft plastic materials, or RENescience technology, developed by DONG Energy in Denmark, where enzymes separate organic and other materials in the process of retrieving the plastic (Jerichau, 2013:21). Either way, this is to say that plastic requires rather advanced technologies for the retrieval of its value, precisely because of its certain dispositions. However, from 500.000 tons of all plastic used in Denmark a year (27% of this from the building industry), 70% of the material is retrieved for incineration for energy recovery (Jerichau, 2013:23). This means that a significantly smaller share of the material is retrieved for its utility value and returned to the consumption cycles. Nonetheless, if not retrieved, the plastic material is known to pervade the environment where it is discarded, and as far as we know, remains there for a very long time and disrupts the eco-systems, thus becoming hazardous.

As a second example of value retrieval, let us look at a case with phosphorus leaked into water reservoirs around agricultural areas of the Baltic region. Common fertilisers are produced containing phosphorus, which is an essential nutrient for a growth of crops and plants. Applied in agricultural fields, the substance eventually leaks into ground waters and is flushed into lakes and seas. The phosphorus is bound to soil particles and therefore it is found in abundance in seabeds, where it has over time become a hazardous element to the regular marine sediment conditions as it promotes eutrophication. It is an oversupply of nutrients inducing a rapid growth of algae and plankton, which in their decay cause depletion of oxygen and thus significantly impede on existence of other marine life forms. Thus, the eutrophication reduces the water quality to a level where it has become a major problem of the dying of the Baltic Sea. Nonetheless, the phosphorus is readily available for retrieval as its utility value is compatible to its virgin resource counterpart. Teknikmarknad, a Swedish research and development company, developed a phosphorus retrieval technology, essentially targeting a new supply of phosphorus, since the substance in its natural settings is nearly depleted (see chapter 2). In addition, with the retrieval process the side effect of the eutrophication is also addressed and, as a result, the water reservoir is revived.

What we can draw from the two cases described above, is that a disposition of a material or substance harbouring a side effect may be treated in such a way that a new utility value may be obtained. Value retrieval is increasingly associated with design being sustainable, perhaps particularly emphasised with Cradle to Cradle and Circular Economy principles. The notion refers to various material, substance and an entire component looping methods where a utility value is somehow retrieved and the material or substance in question is reused in the same loop or in a new design (Vissonova, forthcoming). Value retrieval to a lesser extent also applies to energy recovery in incineration plants, where waste is processed for energy production.

Value retrieval essentially is based on the nature of dispositions. Since dispositions afford effects carrying utility values irrespective of intentions with the design of a technical artefact, the dispositions may enable new schemes for designing new technical artefacts rendering the utility values. As such, the notion of value retrieval supports minimising the sourcing of virgin resources and a need for production of new materials. Therefore, the value retrieved and the material or the substance returned to consumption cycles add to the characteristics of the sustainable design of technical artefacts.

4.3 Side Effects, Value Conflicts and Trade-offs

As discussed above, values are attained with an artefact design. These can be instrumental values attained with a technical artefact by its user, as well as, they can be different utility values rendered by dispositions of materials and substances. However, in the design of technical artefacts, not all values are equally attainable as these might be conflicting and a compromise might be required. For instance, the value of comfort for an airplane passenger can conflict with the value of economy for the airline shareholders. A higher number of seats designed in the airplane cabin leads to better economy, but also leads to less space per passenger and thus less comfort. The two values are conflicting.

Most, if not all, design requirements unavoidably contain a potential for value conflicts (For a discussion on value conflicts and trade-offs see van de Poel, 2009, and van de Poel and Royakkers, 2011). Value conflicts may arise where by enabling one desirable effect, other values are compromised. Lets take an example of domestic laundry washing machines. Nowadays it has become possible to acquire a washing machine that will measure the load and adjust its detergent and water consumption accordingly. To do that, the user, in my case, has to press a button on the operating panel marked with “E” which indicates an economy program. As one does that, the time of the washing cycle increases. By doing so, I have succeeded in saving water and detergent consumption, but by the same token I have increased the electricity consumption. So here, the design has solved a concern for water consumption yet has significantly compromised the concerns for energy consumption.

Value conflicts, in essence, concern choices by the designer faced with the design's functional and structural requirements. As proposed by van de Poel and Royakkers (2011:177-178), values can be said to be conflicting in conditions when: (A) minimum of two values are relevant as a choice from a minimum of two options. (B) the minimum of two diverse values inform two diverse options and these options appear to be the best from choices known to the designer. (C) The values are equally valuable, there is no one better than the other (as then we can simply order the values respectively). Resulting from value conflicts, values may be reduced, as the earlier mentioned laundry washing machine's eco function for energy saving. Alternatively, the value may even be dismissed entirely from the design. Furthermore, the value conflict may lead to the creation of an undesirable side effect. A well known example of this is the household refrigerator case, also used in their value conflict discussion by van de Poel and Royakkers's (2011:178-180). Household refrigerators are known for their hazardous properties, particularly of its refrigerants. An updated refrigerant (after a ban of an earlier version of refrigerant in the 90's) had to meet three essential values - safety (in terms of non-flammability), health (in terms of non-toxicity), and sustainability (in terms of ozone depletion and global warming potentials). The case with the refrigerant option found to be the best is such that by increasing the properties that will afford a better sustainability value, flammability is increased and thus the value of safety is sacrificed.

Value conflicts result in *trade offs*. Emissions, all sorts of leakages, pollution and waste are all side effects resulting from trade offs in the design of technical artefacts. Trade offs also pertain to utility values of materials and substances which surpass the functional life of the technical artefacts they constitute, as illustrated earlier by the plastic packaging for cosmetics, and also with the wind turbine blades. Trade offs are the concerns with dispositional properties of technical artefacts. They can only be made between values which are known to the designer and considered for the artefact design, hence the factor of the designer's choice made when faced with value conflicts. Unknown effects carrying unconsidered values therefore cannot be referred to as products of trade offs.

In the closing of the discussion on value conflicts, for technical artefacts to meet as close as possible the various value requirements, as for instance safety, efficiency and sustainability, various criteria assessment methods are used in the design of technical artefacts, such as the Life Cycle Assessment (for criteria assessment methods and their evaluations see van de Poel and Royakkers, 2011:163-194). The challenge of dealing with conflicting values and trade offs, as opposed to attaining all positive values, however, remains in the design of all technical artefacts, including those designed for sustainability.

4.4 Concluding Remarks

To summarise the chapter: overall, technical artefacts may have several utility values complementary to their function. Dispositions may pose hazards to the technical intervention while a technical artefact is functional, as well as in its disposal phase. Furthermore, materials and substances may be reprocessed and reused provided their utility values are retrievable once a technical artefact has reached its disposal phase. Thus, the presence of several utility values which may help to curb side effects ramifying through technical interventions; and the potential of the value retrieval of materials and substances may help to qualify the design of technical artefacts as sustainable. Nevertheless, the common problem of value conflicts results in trade-offs, even in the deliberate efforts to design for sustainability.

5. Explication of Sustainable Design of Technical Artefacts [15]

> “The proper study of those who are concerned with the artificial is the way in which that adaptation of means to environments is brought about - and central to that is the process of design itself.” (Simon, 1996:113)

In this chapter 5, I return to the discussion about the value of sustainability. I discuss what may constitute a sustainable technical intervention, referring to the side effects and utility values discussed in the chapters 3 and 4. I continue the chapter with classifying empirical examples of sustainable design with a clear correlation to making technical interventions sustainable. I then offer to the reader a definition of *sustainable design of technical artefacts* by the conditions of which *sustainable technical interventions* can be maintained.

5.1 Sustainable Design of Technical Artefacts

In discerning if the sustainable design is a kind of design, and not simply a design dealing with the kind of ‘wicked problems’ occurring in eco-systems [16], I come to argue that there are some conditions which will help us to qualify the design as the sustainable kind. To get to the identification of the conditions and hence the definition of the sustainable design of technical artefacts, I first ought to review the relations of the dispositions, the effects, the values and the hazards, and what all these have to do with the technical intervention I would like to propose as being ‘sustainable’.

The empirical examples of the design of technical artefacts dealing with the matters of sustainability express shared concerns for the reconciliation of the industrial and natural processes. I believe, however, the most common misconception is that with the design thought to be sustainable, the impermissible

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[15] This chapter is an elaborate version of a summarised text (Vissonova, forthcoming), which has been submitted for publication in the volume “Philosophy of Design”, edited by P.E. Vermaas and S. Vial, to appear in the Springer book series “Design Research Foundations”.

[16] See chapter 2 for a discussion on the ‘wicked problems’

solutions are those out of balance with the eco-systems and with equality in social structures. The aforementioned shared concerns do not guarantee a resolved balance. Rather, the design of the technical artefacts is aimed at resolving a selected issue in a selected eco-system or a social structure. It can be asserted, the design is thus instrumental in bringing about sustainability in a selected eco-system and hence preserving the goodness of that eco-system.

The value of sustainability is carried by the known desirable effects afforded by the dispositional properties of the technical artefact. I argue that 'good' effects carrying the value of sustainability are primarily attained by curbing 'bad' effects, i.e. the undesirable side effects ramifying through technical interventions. In seeking to design for sustainability, the act of designing encompasses a broader scope of considerations towards the undesirable side effects. The scope is not only broader than in a 'conventional design', as it were, but it is also focussed specifically on reconciling the industrial and natural processes. Consequently, as the design aims for such reconciliation, the specific materials and substances are selected for their dispositions to afford the effects which carry the value of sustainability; as well as for their dispositions not to pose hazards. Sustainability is thus translated into the design requirements.

Saying that, would it be fair to assert that the sustainability is translated into the design requirements and is a design problem just the same as in addressing safety, for instance? It proves not to be so. A car designed for safety would have clearly marked properties that render safety relative to what it means for a car to be considered safe. Whereas solutions pertaining to sustainable design are more difficult to evaluate and, more often than not, are only comparable to their alternatives bearing more side effects carrying hazards, which we find to be impermissible. We ought to take into account that the 'goodness' attained by curbing the 'badness' is a process not free from value conflicts, nor from occurrence of undesirable side effects.

5.2 The Four Classes of the Sustainable Design of Technical Artefacts

While it is not very common (or perhaps even possible) for design to address all undesirable side effects, all technical artefacts designed to be sustainable, regardless of the method applied during their design, are done so relative to the extent side effects are addressed. Accordingly, I find that in design of technical artefacts which we consider sustainable, a deliberate curbing of various side effects is done and hence the subsequent technical interventions are more sustainable. Moreover, I find that in order to achieve sustainable technical interventions, the design is done in four fairly distinguishable ways.

Firstly, designs of technical artefacts that can be classified as sustainable are instrumental in attaining sustainability by their function. These artefacts, so to say, exist only to deliver sustainable ends, or are an alternative to an artefact with the same function. To start with, technical artefacts that address cutting emissions that cause climate change belong to this class of sustainable design. For example, all renewable energy technologies replacing the consumption of fossil fuels, electric vehicles reducing the use of fossil fuels for transport; also autonomous solar powered lights, and lights reducing energy consumption. Second in this class are those addressing pollution and saturation of biocapacity by design, such as reprocessing plants for chemicals and other hazardous gases and substances, and designs for the separation and processing of waste. Lastly in this class of sustainable designs of technical artefacts are artefacts that are designed to address resource depletion, for instance designs considerate towards the availability of fresh water, such as various autonomous and centralised desalination technologies, as well as newer toilet designs saving the consumption of fresh water. These are just a few examples to illustrate the leading characteristics in this class of technical artefact designs of the sustainable kind. The aim of these design solutions is to replace more polluting or otherwise hazard posing technical artefacts, and to reconcile the issues of resource depletion. However, the common trait of these artefacts is that their structural compositions contain abiotic and often non processable materials and substances, as well as rare earth minerals and metals demanding their mining. Therefore, while they are instrumental in attaining sustainability, the technical intervention subsequent to the design is often unsustainable.

Continuing with class two of sustainable design of technical artefacts. The design of technical artefacts which may have utility values aimed at making technical interventions sustainable falls into this class. The utility values are delivered by deliberately selecting materials and substances with certain dispositions for the design of that particular technical artefact. One example is the aforementioned Noxite roofing membrane, which cleans pollution out of the air. Another similar example is Airmaster carpet produced by Desso company, which is designed to specifically filter finer dust particles out of the air thus maintaining a healthy indoor climate. In addition, both of these products are recyclable. Another example for this class of sustainable design of technical artefacts is a pyrolysis plant producing renewable energy. There are many types of the plant, but essentially the technology retrieves value from all carbon waste by recovering energy, and produces biochar from solid sediments in the process, which is a highly nutritious fertiliser. And the last example in this class is called Desolanator, invented by an organisation under the same name, which is an autonomous solar powered unit for producing clean water, boiling water, and powering lights. What can also be considered to belong to this class of sustainable design are technical artefacts with which waste is addressed by being designed for optimised transportation, such as flatpack, or packs of concentrates instead of liquids. The technical artefacts in this class are substantially alternated in their physical structure in order to deliberately accommodate the type of utility values. The design of the technical artefacts of this class may not necessarily be ’sustainable’ by their function, and their physical structures and the subsequent technical interventions are not necessarily free from side effects. Nevertheless, the utility values make the technical artefact instrumental in attaining a sustainable technical intervention.

The third class of sustainable design of technical artefacts consists of the artefacts having specific structural compositions, such as those made of biodegradable, retrievable, recyclable and reusable materials, substances and entire components. This means that the materials and substances used to compose the structure of the artefacts, one way or another, will not create a hazard by ramifying side effects in their subsequent interventions. For instance, biodegradable plastics, and insulation materials within the construction industry; and artefacts being designed for an extended product life such as repairable, modular, modifiable and upgradable. Hence, all technical artefacts built-for-disassembly will fall under this class of sustainable design of technical artefacts, as well as designs reducing the use of virgin materials and substances, such as wood, metals and rare minerals and hence helping in managing the resource flows. A utility value retrieved and thus the material or the substance returned to consumption cycles add to the characteristics of the sustainable design of technical artefacts. The utility value retrieval minimises the sourcing of virgin resources and a need for the production of new materials. Therefore, this class of artefacts also directly address the waste and depletion of resources.

The forth class of the sustainable design of technical artefacts is the most focused on limiting the technical interventions themselves. The designs permissible in this class have a high concentration on the local sourcing of materials, local use and enhancing welfare in social structures, have a high rate of reuse of materials, and otherwise pose very little or no hazards. A very substantial position in this class of design of technical artefacts should be given to locally sourced biodegradable materials selected for a function enabling a better life for the local communities. One such an example is WarkaWater - a tower for collecting condensation from the air for the consumption of clean and readily available water, developed by the Warka Water Organisation. The project is ongoing, but it was first tested in Ethiopia, where it was approved and built by local communities together with the designer and the founder of the Warka Water Organisation, Arturo Vittori. The tower is made from bamboo, metal pins, hemp, bioplastic netting and polyester ropes. The last two materials are clearly not sourced locally, but their reuse or otherwise their utility value retrieval is possible. Interestingly, this last example of the sustainable design of technical artefacts also falls oddly into the group of all the designs of its kind: WarkaWater tower does not express addressing any side effects of the design of technical artefacts. It is not a more sustainable alternative to any similar designs, because there were none. Perhaps, we could say that the design of the WarkaWater is an example of a design giving rise to an inherently sustainable technical intervention. Thus, perhaps it is an ultimate sustainable design, as the intervention is to a high degree free of undesirable side effects.

I classify the design of technical artefacts in the four classes for the purpose of evaluating what is being attained by the design we commonly already qualify as sustainable. It seems that if the emphasis is placed on the function of the technical artefact, i.e. as it is in the first class, the structure is made to concern only the desirable effects pertaining to the function. Hence, the sustainability value being attained is relative to not attaining the specific goals at all. Moreover, the design of the technical artefact of this class is aimed at curbing some side effects that rise through technical interventions of other designs. However, the technical intervention subsequent to the design in question is almost always unsustainable, and almost always relies on other perhaps future technologies to curb the ramified side effects. Arguably, we could possibly identify this class of design as dealing with the specific kind of wicked problems that occur in eco-systems, as discussed in chapter 2. That is to say, the design of the technical artefacts of the first class is aimed at offering a resolution to the sustainability issues at hand, and the guiding principle is the cumulative effect.

The second class of the sustainable design of technical artefacts is not so much concerned with what the technical artefact is for, but rather how its structure can be altered to accommodate multiple utility values which help to curb some undesirable side effects of some designs resulting in unsustainable technical interventions. Due to the attention given to the dispositions of the technical artefact's structure, the subsequent technical intervention can be said to be sustainable to the extent the undesirable side effects are being curbed.

The third class has the highest concern for the dispositions in the structure of the technical artefact from the above two. Hence, it is also concentrated on sustainable technical interventions subsequent to the design, addressing the mining, manufacturing and the taking back of materials and the value retrieval, freeing the interventions from some of the side effects of design.

The fourth class of the sustainable design of technical artefacts contains those solutions that are most concerned with the technical interventions to which their design gives rise. These technical artefacts ought to be 'sustainable' by their function as well as by their structure to the extent side effects are curbed in the subsequent technical intervention. It is my conviction, developed as a result of my study, that the last class is the one which comes closest to meeting criteria for solutions designed for sustainability.

With reference to the above, it can be said that the technical artefacts which are instrumental in attaining *sustainability 'by function'* are designed to address side effects pertaining to other unsustainable technical interventions. Whereas artefacts that are designed to be instrumental in attaining *sustainability 'by structure'* are designed to address side effects in the subsequent technical intervention. Either way, the resulting benefit is evaluated against making the technical interventions sustainable rather than isolated values attained with specific technical artefacts. This is why the side effects play such a fundamental role in qualifying the design of technical artefacts as the sustainable kind.

An evaluation of effects afforded by dispositions appears to be one of the fundamental aims with the sustainable design kind, as it is addressing the effects that makes the technical interventions sustainable. That is to say, where more value can be created with the given dispositions, and less hazards are carried by side effects, the more sustainable the technical intervention can be said to be. Therefore, an evaluation of sustainable design against the different ideas about what is desirable to attain, is replaced by an evaluation of the specific utility value of materials, substances and entire components of the technical artefacts, and the specific curbing of side effects caused by design.

Lastly, in discerning what qualifies the design of technical artefacts as the sustainable kind, there are no implications of the design kind being free from the undesirable side effects, although, arguably, freedom from undesirable side effects may be stated as an ultimate goal of designing for sustainability. I observe that the design can be qualified as sustainable *to the extent* the side effects are curbed. The extent ought to concern the utility values of the materials and substances, the hazards posed by the materials and substances selected for the structure of the technical artefacts, and the entire technical intervention starting from the mining, sourcing, manufacturing and transporting of the materials and substances and ending with the disposal phase and value retrieval mechanisms so designed.

5.3 The Sustainable Design of Technical Artefacts - the Explicatum

The task of explicating the concept of sustainable design of technical artefacts may be completed on the basis of discerning that some design is of the sustainable kind constituted by certain criteria. I have argued that a view of the kind of design being qualified by an application of a type of a design method ought to be abandoned. Also, I have suggested that by simply dealing with the conservation of eco-systems or equality issues does not guarantee a reconciliation between the industrial and natural processes and, hence, also does not qualify the design as the sustainable kind. The above merely suggests that the design is concerned with the notion of sustainability and it still very well may be a part of the problem rather than the solution. In chapter 2, I referred to sustainable design as the 'explicandum' as it is based on unsystematic terms.

The 'explicatum' introduces the necessary conciseness by what we mean 'sustainable design'. The 'explicatum' is the definition of the sustainable design as how we may consistently conceive it. According to Carnap (1950), the explicated concept should be as good as to be used in formulations of scientific laws or otherwise integrated into well constructed systems. For these reasons, as Carnap proposes, the definition must incorporate (1) similarity to the explicandum, (2) exactness, (3) fruitfulness, and (4) simplicity (Carnap, 1950:5). Thus the concept can be said to be explicated, when it has been given a definition that meets the above criteria and specifies certain necessary and sufficient conditions for something to fall under the concept.

In the light of the above, firstly, the definition I offer shortly is not employing a changed term: we still refer to the 'sustainable design' as the design kind. Instead, I offer a stricter rule of thumb criteria for what are the permissible design solutions under the concept, all of which are based on the design practice we refer to as being sustainable. Secondly, the definition I am proposing offers two conditions which are satisfied when certain exact criteria is being met. Thirdly, I believe that by having such a definition, any references to sustainable design will be made easier for researchers and practitioners, as potential misconceptions are avoided on what may be sustainable and what may not. I also believe that this will lead to improved solutions under the concept. This makes the definition to be fruitful.

And lastly, the definition I offer is built on two conditions we are well aware of from the design practice, making the definition simple to grasp and hence the concept easily usable.

5.4 The Definition of the Concept of the Sustainable Design of Technical Artefacts

Having earlier discussed the undesirable side effects and values attained with the design, for qualifying the design of technical artefacts as sustainable it is necessary to discern the kind of design by the extent to which it is able to curb the side effects, along with the goodness attained with the design. Undoubtedly, to evaluate what is being attained by the design of technical artefacts we may consider as 'sustainable', we ought to consider the entire technical intervention to which it gives rise. If the design of a technical artefact reconciles a given situation in the industrial and natural processes, yet is disposed to affording side effects that carry hazards, thus upsetting another eco-system, then we have an unsustainable technical intervention. Hence, I would hesitate to qualify the design of the technical artefact in question as sustainable, as the condition is necessary yet insufficient. I thus claim that sustainable design can only be so characterised if the known undesirable effects are curbed throughout the associated intervention. I argue that sustainability with reference to the design of technical artefacts cannot be isolated to the design methods, to being a property of the artefact, or even to the value the design aims to attain. Rather, sustainability must be considered as pertaining to the technical intervention. Only then can we be confident that what is being attained by the design of technical artefacts is part of the sustainability solution and not still part of the problem.

In reflection of the considerations presented in this study, my proposition is:

> The design of technical artefacts may be defined as *sustainable* to the extent that:
>
> 1) *side effects are resolved in the technical intervention to which the design gives rise* and
>
> 2) *dispositions inherent in the structure of the artefact render certain utility values which benefit the reconciliation of industrial and natural processes.*

When these two individually necessary and jointly sufficient conditions are satisfied to a high degree by a design of a technical artefact, the design and the subsequent technical intervention can be said to be sustainable.

A challenge with the definition I have proposed, which I would like to point out, is to determine the minimum extent to which the two conditions are satisfied in the design requirements so that we may qualify the design as sustainable. My proposition is based on an understanding that by reconciling the industrial and natural processes involving one eco-system, the design ought to minimise the potential of posing hazards to other eco-systems and social structures. Otherwise, we are simply transferring a design problem to be resolved elsewhere. For this reason some design solutions, perhaps particularly in the class one of the sustainable design of technical artefacts, are still somewhat difficult to evaluate as being sustainable. I find this point of my conceptual analysis still open for improvement to my proposition.

5.5 Concluding Remarks

This chapter concludes the sense-making exercise I endeavoured to achieve with this study of what is the 'sustainable design' kind and what it attains. I have argued that by having a concise definition of the sustainable design of technical artefacts we are enabled to adequately evaluate what are the right or wrong solutions so as to discern what is 'sustainable' concerning the design. Hence, what is being attained by sustainable design, I have argued, ought to pertain to the entire technical intervention the design gives rise to, rather than sustainability being treated as a selected goal of the design. I have addressed the impacts of sustainable design, as the design kind is not free from undesirable side effects. Lastly, I have specified conditions that define a design of technical artefacts as the sustainable kind.

6. Conclusion

> “We assuredly know objects, but we now better realise what knowing is and what it grasps. We may say that after its kind, human knowing has no fixed limits. It can explore and decipher the characteristics of physical systems as far as man’s patience and technique will carry him.” (Sellars, 2008:22-23)

The aim of the study was to offer an explication of the sustainable design of technical artefacts. I have done so by offering a definition based on the two individually necessary and jointly sufficient conditions which, when satisfied (to a high degree), qualify the design as the sustainable kind. I believe I have overcome the challenges associated with the ambiguities of the notion of sustainability itself, by proposing the conditions which are present in the best-practice sustainable design, irrespective of the various interpretations of the notion of sustainability. Meaning, regardless of whether the design is aimed at conservation of an eco-system for its intrinsic or instrumental value, or whether it promotes inter- and intragenerational justice, resolving side effects while benefiting the reconciliation of the industrial and natural processes is what characterises the sustainable design across its broad range of solutions.

The definition, I believe, is long overdue in design studies. The explication of the concept and the subsequent definition adds to our knowledge of the design and its relations to the world, thus, resulting in an enrichment of the field of epistemology of design. The definition may be a useful tool in design research and the design practice alike; as well as it may be useful in other sciences where a reference to a sustainable design might be necessary. For instance, these might be ecology or conservation studies, as well as possibly concerning environmental policy making. However, primarily, I consider the explication of the sustainable design of technical artefacts as a contribution to the field of design research.

The explication of the sustainable design of technical artefacts would not result in the proposition of the definition without the proposition of the concept of *technical intervention*. The concept of technical intervention is my second contribution to design studies. It has been somewhat challenging to define the criteria of sustainable design due to the kind of design dealing with side effects more extensively than we typically do. I find that the concept of technical intervention relieved the challenge and turned out to be a fundamental element of the study. In this regard, I have claimed that the criteria for qualifying the design as the sustainable kind must extend to the technical interventions to which the design has given rise. The materials and substances selected for the design of technical artefacts may be the cause of undesirable side effects brought about due to their mining, or they may emit hazardous pollutants when being manufactured, or when being used, as well as when being disposed of. Therefore, I have argued, sustainability in design may not be confined to being a property of a technical artefact, specifics of the design methods, or even to the value being attained by the artefact's design; but must pertain to the entire technical intervention to which the design gives rise.

The concept of technical intervention, perhaps, may even offer broader implications for studying any type of interventions which are 'technical' and where known and unknown, desirable and undesirable effects may occur, hence where the conceptual model I have proposed might be applicable.

Furthermore, and as the last of the contributions resulting from my study, I found that the conceptual analysis I was conducting had some practical applications. Namely, just as in the design studies, the design practice lacks consistency when referencing the design as a sustainable kind. The implications are that the ambiguities associated with the notion of sustainability in design transpire into a lack of motivation to reconcile the industrial and natural processes by design. Therefore, perhaps a broader audience of design practitioners may find the concept and the definition helpful in qualifying their solutions as sustainable. Undoubtedly, the more practitioners consider the design of technical artefacts for qualifying as sustainable, the more goodness and hence the desirable state of affairs - the sustainability may obtain.

In this regard, this last contribution in particular may appeal to a larger audience. It is a common belief that doing little by little of good for selected eco-systems, many a system will be made sustainable. It is time we abandoned such a belief, as undesirable side effects hazardous to eco-systems and living beings are produced indiscriminately – also by the design we call 'sustainable'. Only by curbing the undesirable side effects, which arise through the design's total interventions in the natural processes, while creating a benefit by balancing industrial and natural processes, are we justified in claiming to design sustainably.

Bringing the thesis to its conclusion, I would like to offer some recommendations for further research.

Through my study, I found that conceptual analyses of side effects are uncommon in the design research. The closest field of study of the evaluations of side effects I have come across is Technology Assessment (see Grunwald 2009). However, typically industrial and product design is often exempt from such assessments, presumably due to the complexity of the technology not being as high as associated with engineering design. I think this point is disputable in contemporary design practice, as materials and substances with hazardous side effects occur in the products of industrial design. Therefore, it may be of relevance to investigate further if there are some parallels with the Technology Assessment studies which may help in obtaining a better understanding of side effects of all design forms, not just related to technology engineering.

Furthermore concerning the study of side effects, it also might be valuable to investigate further whether the principle of double effect (McIntyre 2014) may offer some better explanation of the situations when the production of side effects is permissible. The principle of the double effect represents the notion that causing harm as a side effect of bringing about some desirable effect may be permissible as long as harm is not being caused as a means to bringing about the desirable effect (McIntyre 2014). At the very least, our understanding of side effects in the design of technical artefacts might be enhanced with the help of the principle of double effect.

In addition to the above, a valuable insight to sustainable design could be offered by looking at the role of the agency. I found it particularly interesting to consider what the designer may know at the time of designing, and how her knowing may be helped or enhanced in a given timeframe at the early design phases. Enhanced 'knowing' would clearly be more helpful for the timely uncovering of any unknown undesirable effects. One of the perspectives, I believe is of relevance to further research, would be to look at ‘inference’ from a philosophical perspective. Namely, to conduct a conceptual analysis of the notion of inference in relation to addressing more comprehensively the potential effects of design. I found Kleinberg’s (2011) work offers a valuable overview of the principles of inference, which, given time, I would have liked to research further with an application to our knowledge on side effects.

Furthermore, with regards to the principles of inference, another way to proceed further would be to make closer relations between design discipline and the computing world allowing experimental investigations of higher sophistication of statistical analysis and simulation entering the world of designing. Such a perspective would offer practical applications more directly than the conceptual analysis suggested just earlier. There appears to be a rather recent upsurge of simulation modelling in design, specifically observed in architecture and construction engineering. Besides being used for assessing aesthetics of one or other design solution in a three dimensional image, simulation modelling enables the testing of material durability and reactions to a variety of elements to the extent there are available known quantifiable factors. Another simulation type allows the assessment how a change in volumes or types of materials in a system, such as a manufacturing plant, flows of other materials, processes, overall or specific costs, etc. These simulation assessments may be used for inferring impacts of design on the environment. Simulation in design is most certainly not a new field of study. Yet I think it is relevant to investigate further the methods by which the sustainable design of technical artefacts may resolve side effects and reconcile industrial and natural processes.

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Summary

The aim of the study is to offer a definition of *sustainable design of technical artefacts*. This is achieved by a conceptual analysis and philosophical reasoning, based on ample empirical examples. The process leading to the definition is what in philosophy is known as explication. Essentially, I argue that – despite certain ambiguities concerning the notion of sustainability, which I discuss in the thesis – there are some necessary and sufficient conditions, which characterise design of the sustainable kind.

The study has resulted in two propositions which constitute my contribution to the design discipline. Firstly, I claim that a 'sustainable design' is a design that reconciles some specific industrial and natural processes; meaning, where industrial activities have exhausted the coping mechanisms of eco-systems thus bringing the two processes out of balance. The design does so in two ways: A) by resolving the undesirable side effects of design; and B) by creating a value which somehow benefits a restored balance between the industrial and natural processes. I construct this claim in the following way: Materials selected for a structure of a technical artefact have *dispositional* properties, which afford both *desirable effects* and *undesirable (side) effects*. The desirable effects carry values; the undesirable side effects carry hazards.

Secondly, I claim that the effects of design – the desirable as well as the undesirable ones – manifest themselves when an intervention by design takes place in the natural processes of eco-systems. I call such an intervention a *technical intervention*. The design of technical artefacts gives rise to technical interventions through the selection of materials, since these are mined, transported, processed, and determine the manufacturing of the technical artefacts themselves, as well as their use and disposal. Consequently, the materials determine whether the entire technical intervention may be sustainable.

I conclude the thesis by defining the sustainable design of technical artefacts. Doing so, I argue that the design may be considered sustainable to the extent the undesirable side effects are curbed in the entire technical intervention to which the design gives rise, and to the extent it creates a value benefiting the reconciliation of the industrial and the natural processes.

Hopefully, this analysis (explication) of the concept will find applications in design practice, where its improved understanding of what constitutes sustainable design may produce more coherent solutions for the benefit of people and the environment.

Bæredygtigt design af tekniske artefakter: en begrebsanalyse.

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Resumé

Målet med studiet er at foreslå en definition af bæredygtigt design af tekniske artefakter. Dette opnås gennem en begrebsanalyse og filosofiske ræsonnementer, baseret på adskillige empiriske eksempler. Den proces, der fører frem til definitionen, er, hvad der i filosofien kendes som eksplikation. I det store og hele argumenterer jeg for, at der – trods visse usikkerheder, som diskuteres nærmere i afhandlingen – findes et sæt nødvendige og tilstrækkelige betingelser, som karakteriserer design af den bæredygtige slags.

Studiet har resulteret i opstillingen af to principper, som udgør mit bidrag til designdisciplinen. For det første hævder jeg at et "bæredygtigt design" er et design, som forliger specifikke industrielle og naturlige processer; nemlig hvor industrielle aktiviteter har udtømt økosystemernes evne til at fungere, og dermed har bragt de to processer ud af balance. Designet opnår dette på to måder: (A) ved at modvirke designets uønskede bivirkninger; og (B) ved at skabe en værdi, som på en vis måde bidrager til at genoprette balancen mellem de industrielle og naturlige processer. Jeg konstruerer denne påstand som følger: Materialer og stoffer, der udvælges til at indgå strukturelt i et teknisk artefakt, har dispositionelle egenskaber, der frembyder såvel ønskede virkninger som uønskede (bi) virkninger. De ønskede virkninger udgør værdier; de uønskede bivirkninger udgør risici.

For det andet hævder jeg, at virkningerne af design – de ønskede såvel som de uønskede – manifesterer sig, når design fører til en intervention i økosystemernes naturlige processer. Jeg kalder en sådan intervention en teknisk intervention. Design af tekniske artefakter giver anledning til tekniske interventioner gennem valget af materialer, eftersom disse udvindes, transporteres, forarbejdes, og bestemmer fremstillingen af selve de tekniske artefakter, samt deres brug og bortskaffelse. Det er altså materialerne, der er afgørende for, om den samlede tekniske intervention er bæredygtig.

Jeg afslutter afhandlingen med en definition af bæredygtigt design af tekniske artefakter. I den forbindelse hævder jeg, at et design kan anses som bæredygtigt i den udstrækning, de uønskede bivirkninger begrænses og holdes under kontrol i den samlede tekniske intervention, som designet giver anledning til, og i den udstrækning det bidrager til at forlige de industrielle og de naturlige processer.

Denne analyse (eksplikation) af begrebet vil forhåbentlig finde anvendelse i designpraksis, hvor dens forbedrede forståelse af, hvad der udgør bæredygtigt design, kan skabe mere sammenhængende løsninger til gavn for mennesker og miljø.

Appendix A

Cumulus Mumbai 2015:
In a Planet of Our Own – A Vision of Sustainability with Focus on Water
http://www.cumulusmumbai2015.org/

Insidious Side Effects of Design

and how to turn them into values of sustainability in design

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Abstract:

The purpose of this paper is to propose a way of using the concept of sustainability in design of technical artefacts. Given the recent efforts in designing a more sustainable environment of the artificial, there is a need for an explication of the concept of sustainability as characteristic to the design of technical artefacts. I argue that technical artefacts are designed as sustainable based on the extent side effects are addressed with the design. I present necessary and sufficient conditions in the presence of which the design of technical artefacts falls under the concept of sustainability in design, and argue for the usefulness of the resulting conception of sustainability. The proposed paper is a philosophical approach to a conceptual analysis and as such is aimed at contributing to the epistemology of design.

Key words: sustainable design, side effects, technical artefacts, values.

1. Introduction

Sustainability in design of technical artefacts is a concept richly represented by empirical examples, and explanations are offered in scientific literature about the value of sustainability delivered by design. Technical artefacts tend to be considered 'sustainable' whenever they are designed so as to respond to depletion of virgin resources, overload of the Earth's capacity to absorb wastes (i.e., its biocapacity), and emissions of hazardous pollutants affecting climate change, to mention a few examples. Thus, commonly, sustainability is associated with a positive value delivered by the artefact and this is being considered a sufficient condition for sustainability in design of technical artefacts. My concern is that the aforementioned condition may not be as sufficient as generally assumed. While it certainly seems necessary for design to deliver such positive values in order to count as sustainable, that in itself is not sufficient, as I shall argue in this paper. We appear to have a relatively good mutual understanding of what is intended by the term sustainability. However, the term tends to be informal and the design solutions only loosely correspond to the intentions. Therefore, the concept of sustainability in the design of technical artefacts, I find, needs to be clarified. To do so, I will attempt to explicate the concept in terms of necessary and sufficient conditions for design of technical artefacts to count as sustainable.

An explication, as defined by Carnap, takes place when we give more exact terms based on logic or empirical explanations to an imprecise and a pre-scientific concept (Carnap 1950:3-8). My aim here is to propose a way we may explicate sustainability in design, and I submit, it directly concerns the extent to which side effects are addressed by design.

2. Effects of Design

The significance of an object is in its properties the effects of which help us to realise our goals. If we perceive technical artefacts as mere physical objects, we are, to an extent, limiting the scope of analysis where visible and easily imaginable characteristics are the defining qualities of an artefact. We then exclude the functions, uses, dispositions to various effects, and lastly values that are willingly or unwillingly attained with the technical artefacts. All these pertain to the technical artefact but are, strictly speaking, not a part of the physical object. Vermaas et al. argue that besides the physical object, the technical artefact is constituted by a function and a use plan (Vermaas et al. 2011). My study particularly concerns the effects afforded by the object; and the object, I propose, renders more than its intended functions and the uses we ascribe to the technical artefact.

When it comes to an analysis of designing artefacts, their functions and structures, their capacities to affect other objects, or their propensity to be affected by the other objects, our understanding is obtained through the powers of properties to cause effects. Such properties are dispositional. Dispositions make an artefact what it is (Mumford 1998:9, Groff 2008:2). For a technical artefact to fulfil its intended function, materials and substances with certain dispositions are selected as elements, which then constitute the structure of the artefact. Dispositions afford the effects that endow technical artefacts with their instrumental values, such as the sharpness of a knife, and the permeability of a filter. An instrumental value refers to that intended function which is valuable to the user. The instrumental value remains valuable whether the technical artefact is in function or not, although the value is lost when it no longer has the capacity to perform as intended (also see Vermaas et al. 2011:15). Therefore, the instrumental value is what is obtained as the ends, and as van de Poel proposes - as the good end with a positive value (van de Poel 2009:980).

Furthermore, dispositions render utility values. Utility values are afforded by properties selected for the technical artefact, which make the artefact useful (and beneficial) besides its intended instrumental value, such as breathable, soluble, hydrophobic or hydrophilic, fire resistant, elastic, durable, biodegradable and so forth. Most, if not all, mass produced artefacts are instrumental and have more than one utility value. So, for instance, bathroom tiles water-proof the walls (their instrumental value) and are also easily cleanable (a utility value); similarly, a window permits natural light into the room while also enabling views and natural ventilation. (A toothbrush, in comparison, has a very simple value profile - it can only be used for cleaning small objects such as teeth). Dispositions display the true characteristics of a technical artefact and essentially are there to support the specific and purposed utility values of the technical artefacts. It is by recognising the dispositions that we can design artefacts with certain utility values. Unlike the instrumental value, the utilities can remain valuable when a technical artefact is no longer able to fulfil its intended function.

Consequent to the above, I propose to consider the effect which delivers a value and is afforded by a dispositional property a *known desired effect.* To design technical artefacts is to ascribe certain utility values to the known desired effects which contribute to the artefact's instrumental value. This means, the known desired effects deliver certain utility values which are definitive to the characterisation and structuring of the artefact, thus supporting its function.

3. Dispositions and Side Effects of Design

Properties are dispositioned to participate in certain causal processes associable with the particular disposition, and no other way can be expected from the property (Ellis 2008/2002:82). It follows that physical objects, and the elements they contain, are subject to physical laws, and therefore harbour dispositional properties to cause effects irrespective of the intentions of the designer. The object, to put it simply, affords effects which are designed into the artefact, which may or may not be known, or be of any use to the designer, or the user; yet these effects may escape a critical evaluation of the artefact (Franssen 2009:923). Such effects are generally referred to as *side effects*. And side effects, I propose, have everything to do with dispositions.

To support my claims, firstly, dispositions are accepted within the structure of a technical artefact although they are not necessarily desirable properties of the artefact. Properties of such kinds are present in most industrially produced technical artefacts. A wine glass possesses the disposition of fragility, among other properties, but surely we cannot refer to this disposition as a desirable one. The same applies to the toxicity of the nitrogen dioxide emitted from combustion engines. Another example: an average water flushing toilet is designed to flush up to 6 litres of water per flush of around 0.025 litres of urine. Large volumes of wastewater, without further utility value in this design, are literally produced within the structure of the artefact.

In addition, some dispositions manifest themselves even though the artefact no longer fulfils its function. The materials and substances continue to exist, so to say, without their previous utility values. Plastic containers of short-lived substances such as cosmetics have the power to remain durable even a long time after disposal. The properties of the plastics, irrespective of our needs, manifest their powers when safely holding the cosmetics for us, but just as well when ending up as debris in our landscapes and oceans. Another example of a high environmental impact is phosphorus in water reservoirs around agricultural areas of the Baltic region causing hazardous eutrophication. Common fertilisers are produced containing virgin phosphorus, which is an essential nutrient for a growth of crops and plants. Applied in agricultural fields, the substance eventually leaks into the groundwater and is flushed into larger water reservoirs such as rivers, lakes and seas. The phosphorus is bound to soil particles and therefore is found in abundance in sea beds. There, it promotes eutrophication, which is an oversupply of nutrients inducing a rapid growth of simpler plants such as algae and plankton. When decaying, these simpler plants deplete the oxygen in the water thus significantly impeding the existence of other marine life forms. Thus, the eutrophication reduces the water quality to a level where over time it has become a hazardous element to the regular marine sediment conditions causing the dying of the Baltic Sea. Nonetheless, the phosphorus as a valuable substance is readily available for retrieval from the sea beds, as its utility value is entirely the same as its virgin resource counterpart. With the retrieval process the hazardous eutrophication side effect is also addressed and the water reservoir is revived.

The significance of the above is that when we conceive of the durability of plastics and the nutritiousness of phosphorus as a disposition in addition to perceiving it as merely a desirable property which bears a desired utility value, we recognise a causal model where the plastic, for instance, is dispositioned to be durable also in conditions where we no longer need it to be. (It is this understanding of the properties, I believe, that has led to an integration of the value of sustainability in design.)

Based on the above, in the design of technical artefacts, properties are selected for a purpose of the desired effect during the function of the artefact. Any powers of the properties to cause effects other than intended, i.e. which do not serve the functional purpose, may render values or disvalues which wouldn't be considered during the initial process of designing the artefact (for discussion on disvalues see van de Poel 2009). Hence, what then is achieved as a result of the structure having dispositional properties, is not exactly defined within the conception of the technical artefact. Dispositions, therefore, are a significant point of analysis of technical artefacts and of the relation between technical artefacts and the environments they occupy while in use and after. Dispositions and the effects they afford 'extend' the perceived technical artefact, as conceptualised by Vermaas et al (2011). Technical artefacts offer more than what their design asks for. And what is offered, in some cases might be more significant than what was intended.

To summarise, in addition to the known desired effects afforded by the dispositions, some dispositions are selected by the design of the artefact: however, the effects they afford are suspended from the evaluations of the artefact. These effects I refer to as *known undesired effects.* (This however does not exclude them from being evaluated as waste or by-products elsewhere). Lastly, with regard to the effects, I find, as much as we may attempt to know the causal production of each property, some causal powers we fail to recognise. Therefore properties may generate *unknown undesired effects.* Thus, through the instrumental nature of technical artefacts, what is being made useful carries along both known and unknown side effects.

However, it is particularly the side effects that give rise to ways of seeking solutions through design. As I further explore, artefacts resulting from such design are what we have come to characterise as sustainable technical artefacts.

3. Side Effects and Sustainability

Sustainability, as a general concept, is commonly referred to as a fair treatment of the natural environment and fellow humans of this and the coming generations. As mentioned above, it takes into account the depletion of resources, environmental degradation, an array of pollution hazards, or basically anything that may impede the sustaining of all life on Earth. The way we create the artificial, therefore, has a lot, if not everything, to do with our role in the sustaining. For this reason we have developed several methods to assist in making a more sustainable environment of the artificial. These are, to name but a few of the most recognised, Life Cycle Assessment, DGNB and Cradle to Cradle certification systems, and lately, Circular Economy principles.

Technical artefacts that have characteristics of a sustainable artefact, regardless of the method applied during its design, are usually either instrumental in attaining sustainable ends, for instance renewable energy technologies, LED lights, electrical vehicles, and lately, technologies for object sharing; or having specific structural compositions such as biodegradable, recyclable and reusable elements. And so, those artefacts that are not instrumental for sustainable goals, or are not structured as characteristic of sustainable objects, are not referred to as sustainable artefacts.

Nevertheless, if not to categorise the different interpretations of sustainability in design, but to pinpoint the common denominator in all such artefacts, we will find that sustainability in design pertains to addressing side effects. A wind turbine is an instrument in addressing the side effects of fossil fuel based energy production, while biodegradable plastics address the hazardous side effect of regular plastics, and so forth. And so, an effect bearing a negative value or a disvalue, is countered with dispositional properties rendering either a positive instrumental or utility value.

3.1 Trade-offs and Value Retrieval

In the design of technical artefacts not all values are equally attainable as these might be conflicting. For instance, the value of a renewable energy producing wind turbine conflicts with the value of biocapacity due to the perdurability of the turbine blades. Therefore, while the functional effect of the wind turbine renders value of sustainability, its structure creates hazards to the environment. Most, if not all, designs unavoidably contain a potential for value conflicts which result in trade-offs. (For a more detailed discussion of value conflicts and trade-offs see van de Poel 2009, and van de Poel and Royakkers 2011). Trade-offs arise where by enabling one desired effect, another effect is maintained that is undesirable.

Trade-offs produce some of the side effects of the design of technical artefacts: those that are known to the designer and in essence deliver undesirable conditions associated with the artefact. These are the emissions and leakages and such kinds. In addition, as considered here, the side effects of artefacts no longer evaluated as usable when consumption cycles are completed are also a product of trade-offs, such as a wind turbine blade, a disposable plastic knife, etc.

In the light of trade-offs resulting in known undesirable effects, how does the instrumental value of a wind turbine justify hazardous dispositional properties of its blades, for instance? The answer lies in the notion of value retrieval. Value retrieval essentially is based on the nature of dispositions, as exemplified earlier by the phosphorus as a nutrient retrieved from sea beds. Since dispositions can afford effects bearing utility values irrespective of intentions of a designer, the dispositions enable new schemes in design attaining new utility values. As such, the notion of retrieval supports minimising the sourcing of virgin resources and a need for production of new materials. Therefore, the value retrieved and the material or the substance returned to consumption cycles add to the characteristics of sustainable technical artefacts.

Based on the above discussion, it would seem that the concept of sustainable design can be captured by the following three necessary and sufficient conditions: firstly, an instrumentality of artefacts in generating a positive value, mentioned earlier as generally considered sufficient for design to be sustainable; secondly, dispositional properties designed into the artefact and endowing the artefact with the specific utility values are helping to reduce side effects; and lastly, equitability of the artefact and all the processes associable with its designing, as the first two categories above would be no good if during design and use harmful side effects are induced to any parties within and external to the particular concerns of the design.

4. Conclusions

With this paper, I have introduced my work thus far in explicating the concept of sustainability. I have aimed to further the studies in sustainability in design by giving a more formal definition of what satisfies the conditions that characterise the concept of sustainability in design of technical artefacts.

I have argued that besides the desirable effects afforded by the dispositional properties of the object, the properties afford effects that are undesirable yet known, and undesirable though unknown. Thus, what is achieved by the structure of the designed artefact having dispositional properties during and post consumption cycles, carries along known and unknown side effects. Side effects stem from properties that are either intentionally or unintentionally suspended from evaluation processes in the design of technical artefacts. In addition, the design of technical artefacts may give rise to value conflicts, which in some cases are resolved with a retrieval of the traded off value.

I propose to characterise the design of sustainable technical artefacts in terms of the extent to which side effects are addressed with the design of the artefact. Based on the considerations in this paper, my initial attempt at explicating the concept of sustainability in design of technical artefacts results in the following definition:

> An act of design of a technical artefact is sustainable if and only if the following three necessary and sufficient conditions are appropriately satisfied:
> (1) Instrumentality of a technical artefact in addressing various side effects present in the artificial environments. The aim here is to replace designs producing unsustainable effects, or to retrieve value from side effects. This condition is satisfactory in relation to technical artefacts which do not fit any of the characteristics of sustainable artefacts. Examples: renewable energy technologies, LED lights, electric vehicles.
> (2) Dispositional properties within the structure of the technical artefact afford utility values not necessarily directly associable with the artefact's instrumental function; the dispositions to harbour side effects producing disvalues are addressed. This condition concerns the structural composition of the artefact and the effects rendered by the design of the object. Examples: all recyclable, biodegradable, reusable/ retrievable materials and substances.
> (3) The processes associable with the design of the artefact are equitable towards the natural environment and living beings. Meaning, these are known to not impose hazards to any parties, including parties initially not part of the design plan (e.g. future generations). Examples: eliminating use of rare minerals, addressing pollutants and biocapacity overload.

This is my initial proposal of how we should use the concept of sustainability so that we come closer to having an exact meaning of the concept leading to an exact translation of the intended values into design solutions.

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