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Constrained design

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Abstract

This paper aims to develop a more rigorous and holistic understanding of the role of constraints in design practice, moving beyond narrow interpretations to examine design in its functional environment(s)[1]. This expanded notion of context will be used to uncover the more covert or obscure constraints that act to hinder the transition to more appropriate and sustainable forms of practice.

Résumé

Cet article vise à développer une compréhension plus rigoureuse et holistique du rôle des contraintes dans la pratique du design, en dépassant les interprétations étroites pour examiner le design dans son (ses) environnement(s) fonctionnel(s)[2] . Cette notion élargie de contexte sera utilisée pour découvrir les contraintes plus cachées ou plus obscures qui entravent la transition vers des formes de pratique plus appropriées et plus durables.

Keywords

Constraints, design practice, transition, reconstraints, complexity.

Mots-clés

Contraintes, pratique du design, transition, re-contraintes, complexité.

Introduction

This paper aims to develop a more rigorous and holistic understanding of the role of constraints in design practice, moving beyond narrow interpretations to examine design in its functional environment(s). This expanded notion of context will be used to uncover the more covert or obscure constraints that act to hinder the transition to more appropriate and sustainable forms of practice.

The subject question of constraints was addressed by Madame. L'Amic, the curator of the 1969 exhibition *Qu'est ce que le design? (What is Design?),* in her interview with Charles and Ray Eames. She began by asking Charles (speaking on behalf of the couple):

Q: « Does the creation of Design admit constraint? »

A: « Design depends largely on constraints. »

Q: « What constraints? »

A: « The sum of all constraints. Here is one of the few effective keys to the Design problem: the ability of the Designer to recognise as many of the constraints as possible; his willingness and enthusiasm for working within these constraints. Constraints of price, of size, of strength, of balance, of surface, of time, and so forth. Each problem has its own peculiar list[3] ».

This enquiry follows Eames' counsel in recognising the crucial role of constraints, but builds on this by acknowledging the existence of larger, more complex or covert constraints. The obscure nature of these constraints means that they are commonly not recognised by the designer who simply designs *for* or *within* the system.

Constraints will be examined through *context,* another keyword in the lexicon of design practice, perhaps best summed up by Eero Saarinen's oft-quoted advice:

> *« Always design a thing by considering it in its next larger context—a chair in a room, a room in a house, a house in an environment, an environment in a city plan. » As with constraints, the notion of context is often reduced to to what is tangible and immediate—If designing is understood through this simplified version, then it follows that many designers practice under an equally simplified notion of constraints. In expanding the notion of context (to reveal the covert constraints), the paper will draw on different fields and theories, in particular biology and ecosystems[4], Sociotechnical Imaginaries[5], the Device Paradigm[6], ANT[7], analogies with evolution[8], and history and society[9].*

The objective is to demonstrate that by practicing from this limited perspective, the potential of design is diminished by the narrowing of possible paths and modes of action. Developing a broader awareness of constraints has the effect of better informing the designer of their place and potential in the functional environment(s), in turn, revealing the constraints that hinder the transition to more appropriate and responsible modes of practice. More importantly, once identified, these constraints be exposed, challenged, nullified or simply worked around to change the way designers think and act.

1. What are constraints?

Design practice is always guided, restricted or informed by a particular set of forces or conditions, commonly known as constraints. These constraints may be straightforward and indisputable, such as a physical or material quality—the force of gravity or the tensile strength of a structural beam; they can be the subject of discussion and compromise, such as a financial cost or a timeline; they can relate to aesthetic or cultural considerations, such as a fashion trend or social movement. Whilst constraints are considered to be a key factor in design practice and education, their influence remains somewhat unconsidered—typically reduced to the familiar and tangible factors that Eames listed in his interview (price, size, strength, balance, surface and time). In *The Design of Everyday Things*, the behavioural scientist Donald Norman explores the subject in more detail, distinguishing between *affordances*, « which convey messages about their possible uses, actions and functions », and *constraints*, which « limit the number of alternatives[10] ». He goes on to divide constraints into four categories: physical, semantic, cultural and logical, using examples from human–computer interaction (HCI) to describe them.

Tim Brown, the executive chair of the global design consultancy IDEO, also emphasised the role of constraints in an approach (to innovation) he calls *design thinking*. Following Eames, he notes that the willing and even enthusiastic acceptance of competing constraints is the foundation of design thinking. He proceeds to visualise constraints in terms of three overlapping criteria: « feasibility (what is functionally possible within the foreseeable future); viability (what is likely to become part of a sustainable business model); and desirability (what makes sense to people and for people)[11] ». In explaining the design challenges of harmoniously balancing these three criteria, Brown suggests the following: « It is actually much more difficult for an accomplished designer such as Michael Graves to create a collection of low-cost kitchen implements or Isaac Mizrahi a line of ready-to-wear clothing than it is to design a tea kettle that will sell in a museum store for hundreds of dollars or a dress that will sell in a boutique for thousands ».

The first challenge is to avoid attempting to distil constraints into a neat taxonomy that can be applied to all situations. This follows John Chris Jones' related observation on the definition of design itself, that « there are as many kinds of design process as there are writers about it[12] ». Jones' examination into the need for new design methods begins with the recognition that traditional methods are essentially too simple for the growing complexity of the man-made world[13]. This complexity has given rise to numerous new forms of design practice, each with its own methods, tools and expectations and each with different constraints—the list is continuously expanding. Nevertheless, there is a need to start with a more formalised approach to identifying and exposing constraints and constraint categories; to simplify this process, it is helpful to break down practice into its basic components. In '*Qu'est ce que le design?* Eames described design as « a *plan* for *arranging elements* to accomplish a *particular purpose* » in general terms:

A *plan* is teleological, introducing design's relation to the future—the realisation of something that as yet doesn't exist, typically developed to address a pre-defined problem or issue. It is informed by different forms of knowledge and skills depending on the problem and context. The general plan can exist as a design brief – a key factor in setting the rules and expectations of the project and defining the relationship between designer and client (or design student and teacher). According to Tim Brown, « the brief is a set of mental constraints that gives the project team a framework from which to begin, benchmarks by which they can measure progress, and a set of objectives to be realised: price point, available technology, market segment, and so on[14] ».

Arranging suggests the techniques, tools or methods available to the designer at a particular moment in time. Constraints are directly related to the type of *elements* being arranged and can be overcome (to some extent) by the creation of new tools or approaches. In simple terms, arranging might refer to the shaping, organising and joining of different elements to make, for example, an Eames moulded plywood lounge chair. In the context of strategic design, arranging could relate to the connecting or re-structuring of disparate social elements or power structures in communities or businesses. Constraints can therefore take many forms, from political control to access to tools.

Elements are the materials or factors that are *arranged* during the design process. They can be physical and tangible, such as an aluminium casting or a piece of fabric; abstract and representational, such as data or language; biological such as microbes (in the context of synthetic biology) or social such as a community or network. The choice of element(s) is usually informed and constrained by notions of performance (that relate to the *particular purpose*) and availability – the current political conflicts that focus on access to rare minerals are a timely example of how this constraint informs design decision-making (and how design choices impact on politics).

The *particular purpose* is the pre-defined goal that relates to the problem to be solved – this is increasingly the most complex constraint to identify due to various overlapping and conflicting factors or expectations. The purpose may be simple when the subject is an engineering component. For example, the design of an aeroplane engine bracket is constrained by the opposing performative needs to be both light and strong[15]. Optimisation can be achieved through complex mathematical approaches such as finite element analysis and iterative testing on sophisticated prototyping rigs. Purpose was equally straightforward in the formative years of industrial design, when the advances brought about by electrification led to basic labour-saving domestic appliances that significantly improved human comfort and wellbeing. The key issues facing design today centre on this notion of purpose which has become increasingly conflicted from numerous perspectives. The next section will examine these in more detail.

2. The limits of current attitudes towards constraints

Contemporary attitudes towards constraints can be constructive when examined in specific and relatively narrow contexts. However, while Norman's advice is helpful in the specific field of HCI, its focus on human-scale interactions drastically limits the possibilities, for example, cultural constraints are « conventions shared by a cultural group. The fact that the graphic on the right-hand side of a display is a "scroll bar" … is a cultural, learned convention[16] ». Eames' description also suffers from this oversimplification with each constraint acting at the scale of the object (size, strength, balance, surface) or on the relationship between designer and client (price, time), all without mention of the context in which the project takes place. Design thinking shows more promise, indeed the examples provided in Brown's book suggest an expanded perspective[17], however, it is clearly an approach with a specific orientation towards business and innovation. Whilst this factor is important, the constraints imposed by the designer-client relationship and the demands for profit tend to limit ideas to near-term and relatively non-radical solutions.

The fundamental problem was eloquently exposed by the philosopher Bruno Latour in his 2008 lecture for the Design History Society « … four hundred years after the invention of perspective drawing, three hundred years after projective geometry, fifty years after the development of CAD computer screens, we are still utterly unable to draw together, to simulate, to materialize, to approximate, to fully model to scale, what a thing in all of its complexity, is[18] ». Too often, the history of design is told through a series of fetishised objects and the celebrity (European or American) designers who created them, failing to relate design to the complex social, political and economic contexts in which it exists. As with constraints, the notion of context is reduced to what is tangible; compare Saarinen's description (a chair in a room …) to John Steinbeck's advice to ecologists:

> « One merges into another, groups melt into ecological groups until the time when what we know as life meets and enters what we think of as non-life: barnacle and rock, rock and earth, earth and tree, tree and rain and air. And the units nestle into the whole and are inseparable from it ... all things are one thing and one thing is all things – plankton, a shimmering phosphorescence on the sea and the spinning planets and an expanding universe, all bound together by the elastic string of time. It is advisable to look from the tide pool to the stars and then back to the tide pool again[19] ».

Steinbeck's description of marine life poetically captures the complexity of scales, timeframes and interactions that operate in a natural ecosystem, a complexity that is echoed in the artificial systems that host a designed artefact. This expanded notion of context will be used to uncover the obscure constraints that act to hinder the transition to more appropriate and sustainable forms of practice.

3. Constraints and their implications

In developing the analysis of constraints further, this chapter will follow Herbert Simon's description of an artefact as « a meeting point … between an "inner" environment—the substance and organisation of the artefact itself, and an "outer" environment, the surroundings in which it operates[20] ». For Simon, the surroundings relate to the object's immediate physical conditions, for example, the sunny climates in which a sundial can function[21]. An ecological approach will be used to expand this notion of the outer environment. The word ecology is derived from the Greek oikos, meaning « house » or « place to live ». Literally, ecology is the study of organisms « at home [22] ». Charles Elton, one of the pioneers of natural ecology, provided the following counsel:

> *« When an ecologist says 'there goes a badger', he should include in his thoughts some definite idea of the animal's place in the community to which it belongs, just as if he had said, "there goes the vicar" [23] ».*

The analogy equally works with design artefacts, for example what if a designer says « there goes a Tesla Cybertruck ». The contemplation would reveal the complexities and nuances of its *outer* environment, or the more appropriate term, *functional* environment(s) (to use the ecological terminology). These might comprise, economic systems, cultural systems, systems of resource, infrastructural systems, technical systems, social systems and so on. Each of these influence, constrain and explain the specific existence of the Cybertruck and the approach(es) to its design.

A second section will then examine, through a series of short observations, how the outer environment influences the practice of design – Simon’s inner environment[24].

3.1. Constraints that act via the outer environment

« *The styling of motorcars, and the American motorcar in particular, has always struck me as tremendously important, bringing together all sorts of visual and psychological factors. As an engineering structure the car is totally uninteresting to me. I’m interested in the exact way in which it brings together the visual codes for expressing our ordinary perceptions about reality. For example, that the future is something with a fin on it. And the whole system of expectations contained in the design of the car. Expectations about our freedom to move through time and space, about the identities of our own bodies, our own musculatures. The complex relationships between ourselves and the world of objects around us. These highly potent visual codes can be seen repeated in every aspect of the 20th century landscape. What do they mean? Have we reached the point now in the 70s where we only make sense in terms of these huge technological systems. I think so myself, and that it is the vital job of the writer to try to analyse and understand the real significance of this huge metallised dream*[25] ».

All of the elements that make up the assemblage (of the motorcar) are present in Ballard’s opening statement to the BBC short film *Towards Crash* – the relationship between the human and the designed artefact, the artefact and its related systems (technological, cultural and social), expanded notions of function, myth, desire and the future. This section examines these various factors and the role they play in shaping and constraining the practice of design and the existence of the designed object.

3.1.1. Value systems

For the purpose of this article, the understanding of a ‘value system’ draws heavily on Jasanoff and Kim’s notion of the Sociotechnical Imaginary (STI). STIs are particularly helpful because they encode not only the visions of what developments in science and technology might bring, but also an entrenched notion of a society's **shared value system** – the invisible forces that inform and shape pathways to the future[26]. Jasanoff and Kim begin by analysing the key values of modernity, with a particular focus on the belief in (technological) progress and the fundamental conviction that the future will be better than the present. The question at the core of this paper relates to the need for transition (to more sustainable modes of practice)—it is therefore pertinent to understand how the last major transition took place. In the opening pages of his book *Modern Social Imaginaries* Charles Taylor asks « how did modernity come about, with its distinctive complex of new practices and institutions, new ways of living, and new forms of malaise? » His explanation can be summed up in two words « imaginaries changed[27] ». At the turn of the last century, modernity brought about a significant shift in the socio-technical imaginary, facilitating an unchecked approach to the future driven by belief in the progress of technology.

Inspired by Ballard’s opening text, the analysis of value systems and related constraints will mostly focus on the 20^th^ century socio-technical imaginary of modernity, through a potted history of the motorcar. The aim is to better understand how value systems shaped and informed design practice over the last century (and vice versa) and, more importantly, how this led to the emergence of constraints that impede the transition to more (genuinely) sustainable forms of practice.

The first machine age

> « We declare that the splendour of the world has been enriched by a new beauty—the beauty of speed. A racing car with its bonnet draped with exhaust pipes like fire—breathing serpents—a roaring racing car, rattling along like a machine gun, is more beautiful than the winged victory of the Samothrace[28] ».

The architectural critique Reyner Banham wrote about the importance of Futurism as a turning point in modern theories of design noting that its qualities were « primarily ideological, and concerned with attitudes of mind, rather than technical or formal methods[29] ». Banham described the scale of the transition taking place in northern Italy at the beginning of the 20^th^ century, which had been sheltered from the gradual shift toward industrialisation that had taken place, for example, in the United Kingdom, suggesting that it was this « manifest and radical change-over to a technological society which animated the whole of Futurist thought[30] ». The Futurists set the tone for what would become the attitude and value-system of motor-culture for the rest of the century – the celebration of speed and power, and the annihilation of space and time. What also followed was a significant change in the sentiment towards the past and the dismissal of tradition-bound technology or as the Italian sculptor Umberto Boccioni phrased it: « The era of the great mechanised individuals has begun, and all the rest is palaeontology … [31] »

Stylistic change

Alfred P. Sloan, General Motors chief executive, observing that the sales of new cars in the United States were stagnating under the standardised approach of manufacture and design, devised a strategy to encourage consumers to purchase new vehicles on an annual basis. Sloan pioneered the concept of frequent cosmetic modifications, strategically designed to motivate car owners to purchase new vehicles on an annual basis, effectively establishing the business model of planned obsolescence. In his biography, Sloan articulated his vision, stating « The changes in the new model should be so novel and attractive as to create demand … and a certain amount of dissatisfaction with past models as compared with the new one[32] ». This historical juncture can be regarded as a pivotal step in cementing design's relationship to capitalism, and marking a conscious shift from the more social values embodied in, for example, the Arts and Crafts Movement, towards a more ostentatious form of consumption.

Streamline Moderne

In *Objects of Desire*, Adrian Forty affirms that for a product to be successful it must incorporate the ideas that will make it marketable. This results in manufacturing goods « embodying innumerable myths about the world, myths which in time come to seem as real as the products in which they are embedded[33] ». He goes on to suggest that in industrial societies, design has been used to habitually disguise or change the true nature of artefacts and to play tricks with our sense of chronology[34]. Streamline Moderne emerged in the late 1930s as a response to the Great Depression, bringing an increasingly sophisticated symbolism to the stylistic changes that had been promoted by Sloan. Perhaps unsurprisingly, the movement's key designers (in relation to car design) were based in the west coast of the United States, and influenced by culture of Hollywood, for example, the designer Harley Earl spent his formative years learning from his father at Earl Automotive Works, a customs-built shop that made bespoke car bodies for Hollywood celebrities such as Fatty Arbuckle and Tom Mix. Norman Bel Geddes began his career as a designer in Los Angeles, creating sets and costumes for film and theatre and working with key figures of the era such as Cecil B. DeMille and Max Reinhardt.

Fig.1: 1959 Cadillac Tailfin

During this period, the scientific study of aerodynamics was becoming increasingly influential as a way of optimising aircraft design through wind tunnel testing. The resulting shapes were characterised by flowing lines, rounded corners and the iconic tapering teardrop. From an engineering perspective, this was a simple case of form following function, however, Bel Geddes, Earl and Raymond Lowey (who had recently arrived in the US from France) saw the potential in reversing the modernist standard to exploit the symbolism afforded by aerodynamic's relationship to air travel and the associated notions of speed, progress and futurism. Streamline Moderne, came to symbolise the American dream of freedom and escape, with designers playing a pivotal role in forging the link between technological advancement and the promise of a brighter future. According to the design curator David A. Hanks, American Art Deco and Streamline Moderne differed from the European functionalism of the Bauhaus in that, while the former « arose from an artistic vanguard', streamlining was 'aimed at the widest possible public and was based on an admiration for industry and speed[35] ».

To New Horizons

Myths of progress and the machine age value system were perfectly captured in General Motors promotional film, *To New Horizons*[36], which was commissioned to accompany their *Highways and Horizons* exhibit at the 1939 New York World's Fair. The film begins by invoking 'the mystery and the promise of distant horizons [that] always have called men forward' with the promise of a brighter future; a future driven by technological progress. The imagery accompanying the voiceover is the settlers' view of America, complete with covered wagons and frontier forts: moving West to conquer and colonise new territory, finding new ways to subjugate nature and apply the logic of extractive capitalism, always enabled by the advent of new technologies. In the film the frontier becomes a network of futuristic highways 'for men to go places', symbolising American freedom and dominance. The core message of *To New Horizons* is that this new world is in a constant state of flux, 'opening before us at an ever-accelerating rate of progress' with the related imaginary representing 'a greater world, a better world, a world which always will grow forward.' Norman Bel Geddes was again instrumental in the creation of this future utopian vision, highlighting the potential of design to shape grander imaginaries – beyond the scale of the artefact to national scale infrastructure. All the time remaining faithful to the general ideology of faster, more efficient and more dominant of nature.

Fetishised and Superlative Objects

In Mythologies, Roland Barthes describes the elevation of an object's status through the example of the Citroën DS, the « Goddess » — « a superlative object ». He comments on the seamless perfection of the vehicle, likening it to the « unbroken metal" of science-fiction spaceships and even to the smooth and seamless robes worn by Christ. Barthes' emphatic words somewhat anticipated the state of objects today[37], in the sense that seams, he argued, « reveal the hand of the (human) maker », therefore suggesting that the DS is beyond human—an immaculate conception (the closest French translation of design) and the ultimate dislocation of the object from its manufacture[38]. This potential of designed objects (and their designer) to achieve this elevated status was remarked on by Bel Geddes in his book *Horizons*:

> « When automobiles, railway cars, airships, steamships or other objects of an industrial nature stimulate you in the same way that you are stimulated when you look at the Parthenon, at the windows of Chartres, at the Moses of Michelangelo, or at the frescoes of Giotto, you will then have every right to speak of them as works of art. Just as surely as the artists of the fourteenth century are remembered by their cathedrals, so will those of the twentieth be remembered for their factories and the products of these factories[39] ».

This worship of designed artefacts has the effect of dislocating their existence from the means of production, as described by Karl Marx in his theory of commodity fetishism, and also from the means of resources. The ingrained value system of design culture (and the resulting approaches to education) continues to deify the superlative object and the designer responsible for its creation, while the means are relegated to whatever it takes to produce the object.

Post-petroleum and legacy constraints

The obsession with petroleum, speed and progress continued throughout the century following the *always moving forward* mantra of the 1939 World's Fair. In the 1950s the invention of the jet engine allowed for supersonic flight, in turn expanding the horizons and moving the technological dream outwards and into the 'final frontier' of space (note again the colonising terminology). This provided the impetus for countless new visions including the Moon mission and related Cold War imaginaries[40]. It also represented the final extrapolation of the petroleum dream, in the sense that within a few years these utopian visions would be exhausted. As J.G. Ballard observed in a 1979 interview titled *The Space Age Is Over*:

> « The world of 'Outer Space', which had hitherto been assumed to be limitless, was being revealed as essentially limited, a vast concourse of essentially similar stars and planets whose exploration was likely to be not only extremely difficult, but also perhaps intrinsically disappointing … The number of astronauts who have gone into orbit after the expenditure of this great ocean of rocket fuel is small to the point of being ludicrous. And that sums it all up. You can't have a real space age from which 99.999 percent of the human race is excluded[41] ».

This could be seen as the symbolic end of machine age, or at least of the era of the petrol engine, its mythical potential having finally been exhausted. Its time was also coming to a more pragmatic finale—since the early Industrial Revolution, there had been a steady resistance to the logic of burning things in the pursuit of progress, but as the realities of climate change and air pollution became increasingly apparent, many governments began to initiate legislation that encouraged a transition to more environmentally friendly forms of transport, such as electric vehicles (EVs)[42].

Such paradigm shifts place tangible constraints on the engineers and designers working in the motorcar industry, with the need to research and develop alternative solutions to the normalised model. The designers of early electric cars, such as the Enfield 8000, fabricated at Syros Island in Greece or the Florida based Vanguard Citicar, embraced the new value system exploiting the opportunity to rethink what movement could be when constrained by these new challenges. Ultimately, however, these novel and pertinent solutions would surrender to the conflicting legacy constraints of the machine age as consumers remain susceptible to the ego-inflating (old) ideas that make the products marketable. This problem is exemplified by the latest generation of EVs such as the Tesla Cybertruck, the Range Rover EV and GM's Hummer EV. The Hummer EV weighs more than 4000 KG, nearly twice the weight of the petrol-powered version. Its battery alone weighs roughly 1400 KG and contains enough lithium, nickel and other high-demand minerals to power nearly 400 e-bikes.

Fig.2: Enfield 8000, Fig.3: GM's Hummer EV

In the same interview, Ballard provided his perspective on what might replace the petroleum dreams of the space age, perceptively predicting the rise of computer technology:

> *« The ability to pass information around from one point in the globe to another in vast quantities and at stupendous speeds, the ability to process information by fantastically powerful computers, the intrusion of electronic data processing in whatever form into all our lives is far, far more significant than all the rocket launches, all the planetary probes, every footprint or tyre mark on the lunar surface[43] ».*

Visions of *automation* represent another key theme for 20^th^ century sociotechnical imaginaries. As early as 1891, in *The Soul of Man Under Socialism*, Oscar Wilde declared: « On mechanical slavery, on the slavery of the machine, the future of the world depends[44] ». By the 1930s the vessel for this utopian future had taken the form of the humanoid robot, with a seminal performance taking place at the Westinghouse Corporation's pavilion at the 1939 New York World's fair. Although the robot's role as a key symbol of the future remains pervasive, the focus for the related technologies of sensing and computing diverged in the 1950s, taking on more realistic forms through the promise of the smart home and driverless car. Here, Ballard's prophecy of the coming computer age fills the void left by the end of oil—the (more) realistic dream of automation of everyday life.

Fig.4: 1964 GM Firebird-IV Concept[45], Fig.5: Google's in-house driverless car

3.1.2. Infrastructure and legacy

Infrastructures are the hidden networks, systems or structures that enable a society to function. They covertly constrain almost everything we design as (through time) their existence becomes so normalised that designers simply design for and within the system. In *The History of the Future*, Donna Goodman describes how the invention of electricity was instrumental in laying the groundwork for the coming machine age[46]. By the 1940s 90% of American homes were connected to the electricity grid. This in turn led to many new domestic products—all electrically standardised via the sockets they plugged into and therefore all dependent on the infrastructure, a legacy that continues to this day. The philosopher Albert Borgmann described the problematic consequences of the ‘below’ nature of infrastructures through his *device paradigm*. Making a differentiation between things and devices, he suggests that « *things* are inseparable from their context: we engage and interact with them in their worlds ». *Devices*, on the other hand, « unburden us of their contexts through the operation of complex background machinery; the more advanced the technology, the more invisible or concealed the machinery ». Borgmann uses the hearth as an example of a *thing*: it provides a focal point for the household, links people to the local terrain through the gathering of firewood, and demands an idea of how much wood is required to get through the winter. In contrast, the central heating system ‘procures mere warmth and disburdens us of all the other elements’, while the means become invisible, intangible, controlled and managed by others[47].

Infrastructure represents an increasingly critical factor in the outer environment of designed objects with many contemporary products being reliant on systems far more complex and covert than the electricity grid; for example, the GPS system on mobile phones is owned by the US Government and operated by the United States Air Force. Anything from thermostats (e.g. Nest) to EVs are totally reliant on, and controlled by, connection to the internet. The design of almost all modern products is constrained by the reliance on complex infrastructure, this leads to standardised and generic solutions and increasing exposure to external issues, from software bugs to global conflicts.

3.1.3. Unconstraints

The problem with the Futurists was that they believed too much in the future. As Marinetti himself put it: « Contrary to established practice, we Futurists disregard the example and cautiousness of tradition so that, at all costs, we can invent something *new*, even though it may be judged by all as madness[48] ». This mindset largely continues today through what Richard Barbrook described as the California Ideology which blends radical individualism, libertarianism, neoliberal economics and perhaps most importantly techno-utopianism. Their attitude was captured in Peter Thiel’s essay, *The Education of a Libertarian*. He places hope for the future in companies like Facebook, which « create the space for new modes of dissent and new ways to form communities not bounded by historical nation-states ». Our fate, Thiel concludes, « may depend on the effort of a single person who builds or propagates the machinery of freedom that makes the world safe for capitalism[49] ». While the end of nation states might sound appealing enough, to replace elected governments with the CEOs of private companies is less palatable–a fear presciently outlined by the Eurasia Group consultancy who, at the beginning of Donald Trump’s first term as US president, described the rise of technologists as one of the top risks of 2016 –due to the fact that « highly influential non-state actors from the world of technology are entering the realm of politics with unprecedented assertiveness[50] ».

The critique of 'unconstraint' could also be applied to the more recent approaches of design fiction and speculative design—while both typically represent a polemically opposite ideology to that described by libertarianism, the decoupling of practice from direct market imperatives often leads to projects that are too detached from reality, resulting in provocative and hyper-stylised outcomes that simply feed the voracious new mechanisms of social media, facilitating too easy dissemination while neglecting the more rigorous critiques associated with established forms of design research.

Conclusion on the expanded study of the outer environment

In the late 1960s, Guy Debord noted that « in societies dominated by modern conditions of production, life is presented as an immense accumulation of spectacles. Everything that was directly lived has receded into representation[51] ». In his essay for Aeon, Venkatesh Rao describes the contemporary version of this through the example of the « American Cloud, the vast industrial back-end of our lives that we access through a theatre of manufactured experiences ». He describes the example of the Whole Foods store, where « sale items peek out of custom-made crates, distressed to look like they've just fallen off a farmer's truck », and every detail, from the font used on the signs to the rustic finish of the countertops, is designed to create the illusion of a nostalgic country market[52]. This description, in many ways, sums up the messiness of post-modernity—the essential (political and corporate) values of modernity continue to motivate largely unchecked developments in technology[53], however, these are now disguised behind a thick façade of nostalgia – either through the symbolism of simpler, more innocent times, or the revisiting of last century's technological dreams, such as the tech industry's current (re)obsession with space colonisation and the automation of domestic life (for e.g. robots, *smart* homes, cars, and toasters).

While Silicon Valley continues to present aggrandised versions of 20th-century techno-utopias, some observers have begun to « comprehend that we live in a world that is taking away futures for ourselves and non-human others[54] ». Franco Berardi described the « slow cancellation of the future[55] » as a consequence of diminishing trust in scientists and policy-makers. In many ways this describes the scale of the problem—design's teleological imperative and the expectation of a *preferable* outcome—the dominant extractive approach of modernity was immensely successful in the creation of both performed and consumable visions of the future. Improvements in the quality of life were tangible and measurable with the negative (numerous) side-effects being temporarily supressed. Whilst the need for a fresh transition is becoming increasingly apparent, the designed outcomes may not be preferable when measured by the existing metric systems.

3.2: Constraints that act on the inner environment

This section will continue the analysis of the factors in Charles Eames' description of design but analysed via the value lens described in the previous section – how value systems, myths and legacy constrain contemporary design practice.

3.2.1: Constraints that are complicated by the *particular purpose*

Eames's use of the word *particular* suggests that purpose is reducible to a singular and distinct goal. According to Simon, « the fulfilment of purpose or adaptation to a goal involves a relation among three terms: the purpose or goal, the character of the artefact, and the environment in which the artefact performs[56] ». He uses the example of the clock, the purpose of which « is to tell time », the character is made up of « arrangements of gears and the application of the forces of springs », and the importance of the environment is illustrated by the case of the clock being used on a rolling and pitching ship to solve the problem of longitude. The fundamental issue comes back to the designers focus on *objects* rather than *things* – a legacy of both modernism and engineering approaches to design. By acknowledging the existence of the multiple environments in which the object functions, more complex or conflicting purposes can be identified.

Using Simon's approach to ask « what is the purpose of a smartphone » – it is primarily a device that can be used to communicate remotely (its legacy purpose). The addition of internet access and screen afforded the addition of increasingly diverse applications that extend its function almost infinitely; the phone is at once, a shopping centre, a cinema, a dating service, a library, a music player, a camera and an almost infinite number of other things. It has a different purpose for each of its outer environments:

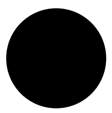

Fig. 4: Diagram of smartphone's outer or 'functional' environments.

Its character is made up of arrangements of exotic materials (see 3.2.4) and complex software allowing it to function in its technical environment (energy provision and network). A secondary outer environment could be described by its role in the economy and the need to create profit for numerous actors; third could be its cultural purpose—the role of the phone in a specific community[57]; a fourth is its semiotic environment and what the phone represents to consumers via its brand and lastly is the actual multifarious functions of the phone.

Design constraints essentially relate to the increasingly complicated and diverse purposes of many contemporary products (we could say that their *thinginess* is constantly expanding). A well-defined purpose is essential for even a rudimentary evaluation of the device—the expanded approach to the outer environment begins to reveal the limitations of established methods, for example, while the sales of a smart phone might create huge profits for shareholders (well-functioning semiotic, economic and technical environments) the negative psychological impacts of its social media suggest a more nuanced appraisal of its functional purpose(s)

3.2.2: Constraints that act on the *planning*

In design's formative years materials were tangible and designers were makers—the knowledge and skills required to plan design activities were easily defined and relatively narrow (though difficult to acquire). As industrialisation replaced the arts and crafts, the materials used, the processes required to shape them and the wider design ecosystem became increasingly complex (as described in the Outer Environment diagram above). After the Fourth Industrial Revolution, materials may exist at the nanoscale, be biological, or stored in terabyte datasets, with approaches to their manipulation outside the typical knowledge set of the designer. Developments in artificial intelligence represent perhaps the greatest disruption to design planning since the reforms of the 19th century, largely related to its exposure to advances in image generation techniques[58].

This raises important questions for both design education and practice – as John Chris Jones pondered: « is in necessary, or even possible, to understand completely the complexities of the product and of its operation when one is designing?[59] ». This pressing problem demands the need for new approaches to knowledge generation and forms of collaboration between disciplines—and whilst *inter / multi / trans / pluri* disciplinarity is extremely en vogue across certain sectors, deeper affiliations are typically constrained by the historical siloing of knowledge, language and metric systems in academia.

3.2.3: Constraints that act on arranging

Debates on how to arrange elements goes right to the core of design culture. Such discussions on the object, its relation to manufacture, and the balance between decoration and utility existed at the core of the Arts and Crafts Movement. Of particular relevance here are the arguments that focused on the use of machines as the process of making became increasingly mechanised. For some key figures, such as John Ruskin and Walter Crane, the making of an object should happen totally under the hand of the designer, while others (including William Morris) believed that mechanisation was not negative in itself, and machines used well could improve the quality of the designed object.

Building on the ideas of the more progressive members of the Arts and Crafts movement, Norman Bel Geddes described a design approach that completely incorporated the manufacturing process, advocating that the designer should « visit the client's factory and determine the capacity and limitations of the machines and workers[60] ».

Many designers today remain as connected as Bel Geddes in their connection to the machines that manufacture their products, however, the complexity and expense of the machines that do the making have grown exponentially. In a video showing the manufacturing process of the iPhone 5, designer Jony Ive describes how « with the parts on a conveyor, two high-powered cameras take pictures of the [phone] housing, an instantaneous analysis is done and then the best match out of a possible 725 cuts is determined ». He goes on to state that the Apple belief is that « going to such extreme lengths is the only way that we can deliver this level of quality[61] ». Such an approach clearly facilitates the manufacture of superlative objects but how many designers have access to such tools? There is a tangible correlation between consumers' escalating expectations regarding the aesthetic quality of objects and the increasingly advanced technological means required to meet these demands.

3.2.4: Constraints that act via elements

The designer's choice of materials can be traced back to attitudes formed during the colonial era. As Arthur Chandler observes, at the time of the 1855 Paris World's Fair, « the French attitude was a mixture of pure greed and the dawning sense of the "civilizing mission" of France: Africa will supply the raw materials; and in return, France will supply the most precious of all commodities: French civilization[62] ». In this case it was the exotic hard woods being used by the royal manufactories to construct what we might call the superlative objects of the day—the highly ornamented and sculpted furniture represented by the Napoléon III period (1848-1870).

Turning again to the Apple iPhone, it incorporates 75 of 118 elements from the periodic table (the human body is made up of around 30). In an article for the Los Angeles Times, Brian Merchant (2017) recounts pulverizing an iPhone and analysing the resulting dust using mass spectrometry, X-ray fluorescence and infrared analysis. He notes that to obtain the 100 or so grams of minerals found in a single iPhone, miners around the world have to dig, dynamite, chip and process their way through about 75 pounds of rock on nearly every continent.[63]

The problematic constraints today arise from the expectations, placed on the designed object, by its relation to both the functional and symbolic outer environments. Performance expectations require the use of rare earth elements and specialised minerals to achieve high screen fidelity, computational power and battery life. Other material choices, such as aluminum alloys capable of being machined to a mirror finish (also described by Jony Ive in a 2012 video), are driven by aesthetic considerations. Meanwhile, elements are increasingly taking on less tangible forms, such as data—raising new questions of access and availability—or biomaterials, which require laboratory conditions for safe and ethical manipulation.

3.2.5: Dependence – The contexts in which design happens

According to the philosopher Alain de Botton, « the rationale of almost any commercial organisation can be broken down into a simple and arid equation:

INPUT OUTPUT

Raw Materials + Labour + Machinery = Product + Profit

Every organisation will attempt to gather raw materials, labour and machinery at the lowest possible price to combine them into a product that can be sold at the highest possible price[64] ». Whilst this formulation overlooks the critical role of design—and its capacity to enhance profitability by amplifying the perceived value of products—it nevertheless reveals the stark realities of the situation: when profit maximisation is a company's primary objective, the designer's actions are inevitably constrained by the values of the organisation. These values were candidly articulated by the American economist Milton Friedman, who, in 1970, famously called for the liberation of business from any pretense of social responsibility, arguing that such responsibilities conflicted with the fundamental interests of shareholders. Friedman argued that companies that did adopt “responsible” attitudes would be faced with more binding constraints than companies that did not, rendering them less competitive.

This dynamic constitutes perhaps the most profound and problematic constraint facing designers today, and remains the proverbial "elephant in the room" in discussions about transitioning toward more sustainable approaches. Although the magnitude of this challenge is undoubtedly formidable, some measure of hope can be drawn from Victor Papanek’s preface to the second edition of *Design for the Real World*. Reflecting on the initially hostile reception of the book, Papanek recounts how, over time, the work gained acceptance, citing crises such as Detroit’s economic decline, rising unemployment, oil shocks, extreme winters, severe droughts, and global energy shortages as pivotal factors. He ultimately suggests that "maybe we learn best from disasters," implying that systemic change, while difficult, often finds its catalyst in moments of profound disruption[65] ».

3.3: Constraints that inform the evaluation of the designed artefact

Approaches to the evaluation of designed artefacts have been significantly complicated by the artificial separation of form and function. The Purist’s[66] approach to design offered a temporary resolution to this dilemma through the application of what they termed the "Law of Mechanical Selection." Drawing on biological metaphors, this perspective advocated for an evolutionary method, positing that relentless iteration in response to specific functional requirements would naturally lead to a convergence of forms toward a universal standard. Examples of such *objets-types* included stereotyped, mass-produced objects such as the tobacco pipe, the guitar, and the Parisian café drinking glass.

While there is a *purist* engineering logic to this approach, it suffers from the same issues that stem from the reduction of outer environment to the purely functional. Once the constraint of profit-making is introduced the purist model quickly becomes inadequate. A further critical flaw arising from this simplified understanding of designed objects is the tendency to celebrate ends (the fetishised object) at the expense of means. As Aldous Huxley observed in *Ends and Means* (1937), « Good ends … can be achieved only by the employment of appropriate means. The end cannot justify the means, for the simple and obvious reason that the means employed determine the nature of the ends produced[67] ».

These examples underscore the pressing need for a critical rethinking of approaches to design evaluation. The interplay between the various factors outlined in the preceding sections creates a network of constraints that are complex and intertwined, complementary or conflicting, dynamic, and temporal. A fundamental re-evaluation and re-valuation of these relationships is urgently required.

Conclusion

It is hoped that this broad surface analysis will offer valuable insights into how current constraints limit the potential of design practice and narrow the pathways of possibility. This article represents, for the most part, the theoretical half of the discussion—its practical counterpart remains to be explored, particularly regarding how design can be "re-constrained."

By cultivating a deeper understanding of these constraints, designers can gain a clearer sense of their position within the functional environment(s). This awareness, in turn, illuminates where the boundaries of agency are situated, the nature of those boundaries, and the potential strategies for challenging or transcending them. This process—what we might call reconstrained design—aims to uncover and leverage those possibilities.

Illustrations

Fig.1: 1959 Cadillac Tailfin by Christer Johansson is licensed under CC BY 4.0:

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Fig.2: Enfield-Neorion 8000 Electric car by Skartsis is licensed under CC BY 4.0: https://commons.wikimedia.org/wiki/File:Enfield_Neorion_8000.jpg The original

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Fig.4: 1964 GM Firebird-IV Concept by Bill Lile is licensed under CC BY 4.0:

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Fig.5: Google self-driving car in Mountain View by Grendelkhan is licensed under CC BY 4.0: https://en.wikipedia.org/wiki/History_of_self-driving_cars#/media/File:Google_driverless_car_at_intersection.gk.jpg

1. The term « functional environment » borrows from « functional ecology », a subcategory of ecology that is concerned with the functions that species perform within the communities and ecosystems in which they are found.
2. Le terme « environnement fonctionnel » “ est emprunté à l'« écologie fonctionnelle », une sous-catégorie de l'écologie qui s'intéresse aux fonctions que les espèces remplissent au sein des communautés et des écosystèmes dans lesquels elles se trouvent.
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12. Chris Jones, Chris, *Design Methods*, London, David Fulton Publishers, 1992, p.3.
13. *Ibid.* p.28
14. Brown, Ibid. P.21
15. I originally trained as a stress analysis engineer at Rolls-Royce Derby - the manufacturer of aero-engines and worked for several months on the prototyping of engine brackets. The computer analysis revealed over-engineered areas that could be refined to lighten the component or weak areas that would need re-designing.
16. Norman, Donald, *Affordance, Conventions and Design,* Interactions, Volume 6, Issue 3, 1999/>https://doi.org/10.1145/301153.301168,> consultée le 25 mars 2025.
17. Brown describes a project for the Japanese bicycle part manufacturer Shimano which analysed and identified general shifts in bicycle culture and exploited consumers nostalgia for simpler, less technical bicycles.
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21. This is explored further on p.19.
22. Odum, Eugene, *Fundamentals of Biology*, Philadelphia, W B Saunders Company, 1971, P.3.
23. Elton, Ibid, p.64.
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