In light of the climate crisis and using Cedric Price as a recurring reference, this dissertation seeks to analyse;

Is there a growing need for Architectural 'Lightness' today, and what are the Cultural Impacts it May have?

By

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A Dissertation

Submitted to Manchester School of Architecture

In Partial Fulfilment of the Requirements

For the Degree of Master of Architecture (MArch)

May 2022

Contents

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Introduction.

The concept of weight and the role it can play within Architecture has always been a fascination of mine. In the initial years of my Architectural studies, my intrigue was more drawn towards heavyweight constructions; My early university projects often resembled ridged, monolithic forms inspired by the works of Tadao Ando and Peter Zumthor, much of these designed with concrete and stone. As I have progressed through my studies my interests have shifted to the other end of the scale towards this concept of Architectural 'Lightness'. Lacaton & Vassal, the acclaimed French architectural duo had a notable impact on my shift in mindset with their philosophy towards Architecture which promoted, 'social justice and sustainability by prioritizing a generosity of space and freedom of use through economic and ecological materials.' (The Hyatt Foundation, 2021) Oftentimes their work comprising of lightweight, translucent materials such as polycarbonate in steel frames, their designs encompass many features of what I would consider Architectural Lightness. This dissertation will focus on the concept of lightness through the works of the renowned architect Cedric Price, who in many ways shares close parallels with Lacaton & Vassal, namely this shared advocacy for Architectural lightness, a concept which he takes even further.

> "Because the structure is light, you don't feel the weight of the architecture.
> you feel free."
>
> ~ *Anne Lacaton*

Running the debate through Cedric Price, who as previously mentioned I have chosen as a prominent figure who advocated for architectural lightness, this dissertation firstly seeks to lay the foundations of the dissertation by attempting to define the term 'architectural lightness', a subjective description of architecture which can be both qualitative and quantitative. This is followed by a theoretical analysis into the relationship between key traits of architectural lightness, this includes the relationship between lightness and; **technology**, **nature**, **adaptability**, and **temporality.** Four elements that this dissertation argues were prevalent in the works of Cedric Price.

The next stage of the dissertation starts to look at the relevancy architectural lightness may hold in present-day; this is done by looking at the most significant challenge the Architectural profession has ever had to face, the climate crisis, and postulating how this has the potential to be resolved or lessened through architectural lightness using examples of Cedric Prices' work as case studies. Topics covered during this section include; **tensegrity structures** and **the circular economy**.

The final section rounds off the dissertation by looking at the potential cultural implications of architectural lightness through the analysis of the theoretical relationship between **time & identity** in order to propose what impacts a transient architectural landscape may cause.

The Most Famous Architect You Never Knew.

Figure 1: Cedric Price abstract portrait (Medina, 2017)

The way Price signed his work was with a self-portrait caricature, rather than a conventional signature.

Why Cedric Price?

The reason I have chosen Cedric Price in this dissertation regards the clear connections which can be made between Price's work, ethos and opinions with the concept of lightness which I will discuss throughout this dissertation; be that in physical or metaphorical form, Prices obsession with light-weight structures and indeterminacy makes him a key figure in the advocation of Architectural 'Lightness'.

Cedric Price

Cedric Price, born on the 11th September 1934, was one of the most influential, yet heavily polarising Architectural thinkers of the twentieth century and is considered one of the great pioneers of the modernist movement. With most of his work left confined to the notepad (now kept sealed in boxes at the Canadian Centre for Architecture in Montreal (Murphy, 2018), the majority of Price's influence and notoriety came from his outlandish theories and unbuilt projects, his visions often being too radical, ambitious or vague to be practicable. (Rose, 2005)

Through the use of vague, 'representational forms' in his work to encourage 'ideological debates' (Herdt, 2017) on architectural values, Price was more committed to pursuing the implementation of ideas (Mathews, 2007) rather than the forms themselves, 'championing an architecture of autonomy, impermanence and social wellbeing over personal glory and monumentalism' (Rose, 2005) and inspiring the world with the concepts and ideas he wholeheartedly believed in.

"Technology is the answer, but what was the question?"

~ *Cedric Price*

Enthralled by the recent advancements of cutting edge technology at the time and being a great enthusiast for the 'systems thinking[1]' approach to design, specialising in 'a certain holistic expertise of a non-scientific scientism' (Murphy, 2018) shared by his friend and mentor Buckminster Fuller, Price recognised the city as a 'socio-technical system'. (Herdt, 2017) Utilising recent advancements in technology and cybernetics[2], Price sought to make empirical connections across a vast expanse of information and knowledge (Murphy, 2018), things that were thought to be too subjective or complex to manage in any standardised, logical way, ultimately to improve the social condition through his Architecture.

Cedric Price can be seen as one of the most authentic Modernist Architects ever to have lived, given that the majority of his work attempted to confront one of the paradoxes observed in modernist architecture, *'that true fidelity to the ideas of Modernism means the disappearance of the building'*

[1] *A method used to make sense of the complexity of the world by looking at it in terms of wholes and relationships rather than splitting it down into its parts and looking at each in isolation.* (Ramage & Shipp, 2020)

[2] *Cybernetics is 'The study of communications systems and of system control in animals and machines.'* (Simpson, et al., 1989) *Cybernetic Architectures therefore, 'argues that such frameworks have been constructed in direct reference to cybernetic thinking, a thought model that emerged concurrently with the origins of informatics and that embodies the main assumptions, values, and ideals underlying the development of computer science.' (Quin, 2021)*

(Murphy, 2018) through his ‘anti-building’ approach to Architecture. Further proof of his authenticity was shown though-out his career whereby he actively fought against his own monumentalism with regards to both his reputation and projects, demanding the obsoletion of the few realised projects he built; When approached by English Heritage in the late 1990s to try list his ‘Inter-action’ centre, ‘a multipurpose community centre built in London’s Kentish Town in 1977 with an intended lifespan of 20 years’ (Milmo, 2014), Price fiercely opposed the idea leading to its eventual destruction in 2003, the year of his death. (Herdt, 2017)

> “The value of permanence must be proven not merely assumed.”
> ~ Cedric Price

Holding little importance over superficial gains such as ‘glory’ or ‘monumentalism’ and describing himself as an ‘anti-architect’, Price was a ‘persistent critic of normative architecture’ (Moon, 2017) and the tendency in the UK to continually list and preserve buildings (St John's College, University of Cambridge, 2014), believing the traditions within the architectural field at the time were static and archaic, too stiff to adapt to future change in fast-paced environments stating, “Architecture is too slow in its realisation to be a 'problem solver'.” (Cedric Price, 2002)
Many of Price’s critics believe his projects are better-off unbuilt for reasons relating largely to the extreme way in which he prioritised adaptability, functionality and efficiency over aesthetic prowess; although to an extent, you could argue Price would agree with them given his staunch, dogmatic view on indeterminacy and temporality within the Architectural landscape; Price once jokingly proposing to demolish the Palace of Westminster to replace it with a “pop-up Parliament”, (St John's College, University of Cambridge, 2014) this stemming from his, ‘deep scepticism of political institutions and their tendency to use grand, monumental buildings as a means of consolidating power’. Instead, Price being the life-long socialist he was, advocated for ‘temporary and mutable structures which would be open and accessible to all.’ (St John's College, University of Cambridge, 2014)

Figure 2: Cedric Price, Pop-up Parliament, 1965 (Price, 1965)

Cedric Price: Anti-architect, designing for Indeterminacy

One of the earliest pioneers of 'anticipatory architecture' (Admin, 2016), much of Price's projects were designed to be responsive to the ever-changing requirements of both user and environment, putting heavy emphasis on the idea of designing for indeterminacy. (Fox, 2016) The project that epitomises this style of anticipatory Architecture and is considered by many as his magnum opus is the Illustrious 'Fun Palace'. Although unrealised, the fun palace has gone on to inspire many Architects and projects around the world including Richard Rogers & Renzo Piano's Pompidou Centre in Paris, as well as Diller Scofidio + Renfro's 'Shed' in New York, a 18500m^2 deployable Exhibition Centre built-in 2019 which achieves a level of radical adaptivity seen in the Fun Palace;

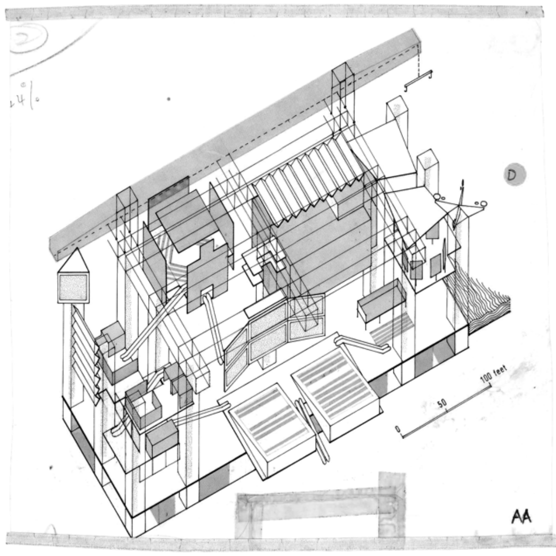

Figure 3: Fun Palace Axonometric, Cedric Price, 1960-1964 (Price, 1962)

"With an open ground-level deck and with multiple ramps, moving walkways, moving walls, floors, and ceilings, hanging auditoriums, and an overall moving gantry crane, the physical volumes of the spaces could be changed as different usages were adopted. The kit of parts for these operations included charged static vapour barriers, optical barriers, warm air curtains, a fog dispersal plant, and horizontal and vertical lightweight blinds. (Mathews, 2005)"

Cedric Price was said to have 'hated' any visuals which attempted to capture the Fun Palace into any 'concrete form', in particular, the image in fig 4, which is said to be the image he 'hated most' (Wigley, 2017). Believing this type of representation gave the projects too much of a 'literal density' in the way they resembled something 'too close to a building' (Wigley, 2017), Price was far more attuned to the illustrations like the one seen in figure 3, which depicts the temporary equipment dictating the use of the space within the Architecture in a much brighter light than the Architecture itself. This again shows Prices' high level of authenticity to the cause of flexible, dynamic Architecture.

Figure 4: Fun Palace Exterior Perspective (Price, 1962)

Lightness.

This section of the dissertation will define what is meant by the term 'Architectural Lightness'. Also, in this section I will be explaining the relationships Lightness shares with technology and nature, two recurring themes running through the dissertation, acting as a precursor for the following chapters in particular; Tensegrity Structures and Modernism & The Circular Economy.

What is Lightness?
Similarly, to the ambiguous way in which Price portrayed his projects, the notion of lightness refers more to a concept than a concrete form or quantitative measurement, 'its basic sequence founded on intuitive association rather than a tight and ridged system.' (Adriaan Beukers, 2005)
'Lightness' may concern the physical weight and property of materials, but can also relate as much to the visual appearance of structures and spaces, as well as be used as a metric for describing the intrusive nature a structure may have on its environment, 'It is a quality that comes from the form, composition and economical use of materials.' (Wilkinson & Eyre, 2001)
The key characteristics of what is thought of as 'Architectural Lightness' that I will be focusing on in this dissertation include architecture which can be deemed; Ephemeral, Lightweight or non-invasive.

"Lightness is not a technical term and cannot be measured in a finite way. It can be neither quantified nor specified but is a qualitative ingredient of modern architecture which is gaining momentum"
(Wilkinson & Eyre, 2001)

The Relationship Between Lightness & Technology
As well as having a lifelong obsession with technology which fuelled his passion for novel design, Price was a firm believer in interdisciplinary design, serving as a 'facilitator for interdisciplinary and extraprofessional innovation…advocating for the sharing of knowledge and expertise across fields and continents, he brought together seemingly disparate entities.' (Moon, 2017) Throughout his exploration into the newfound worlds of Pneumatics and tensegrity, Price believed there was a lot that the world of Architecture could learn from the aerospace/aeronautical engineering industries. 'Lightness deals with many different subjects that, somehow, are all interrelated by analogies, in shape, structure, process or the idea behind them. Likeness transcends time, origin and professional specialism. (Adriaan Beukers, 2005)

The concept of lightness and the Incessant advancement of technology are two closely linked paradigms, both with deep roots in our human history. As a species we are, and always have been striving for innovation and progression. This subconscious draw towards innovation is not only seen in the realm of Architecture but in all areas of life, the insatiable desire to learn, discover and invent is ingrained in the human DNA; this can be witnessed in microcosm through the never-ending 'smart-phone arms race' (Fry, 2011); the relentless drive to produce smaller, lighter, stronger, more powerful smartphones with built-in obsolescence forcing non-stop advancement.

"The starting point is that we have to look to novel ways to make things lighter. This is simply inevitable..." (Adriaan Beukers, 2005)

The Relationship Between Lightness & Nature: Biomimicry

Although Price was a keen lifetime advocate for multidisciplinary collaboration (Moon, 2017), there has been no better in this field than mother nature. Designers, including Cedric Price, have always looked towards nature for inspiration through a process called *biomimicry, simply summarised as,* 'the implementation of good design based on nature' (F.V, et al., 2006). No matter what field or industry we are designing in, there is often much to learn from the way nature conducts itself, whether it be mimicking the forms, processes or whole eco-systems, there's no denying that we as a species have a lot to learn from nature. After all, *it has had a 3.8-billion-year head-start.*

"SINCE THE EARLY STARTING OF UNIVERSE AND CREATION, MAN AND CREATURES WERE ENCLITIC BY NATURE AND WELL ORGANIZED IN HARMONY."
(HELMY & ABOULNAGA, 2020)

The ingenuity in design and form found in nature is derived from billions of years' worth of evolutionary refinement, driven by a competitive environment and the need for survival, natural selection has been able to achieve astonishing efficiency (Pawlyn, 2016), efficiency that humanity greatly requires right now. In the book, 'Lightness: the inevitable renaissance of minimum energy structures' Julian Vincent draws attention to the efficiency of the natural form and the economical way in which nature establishes its structures through sophisticated, adaptive manufacturing of shape and structure stating, 'in nature, shape is cheaper than material'. Vincent goes on to explain how adaptability plays an important role in the efficiency of nature's form-finding using the growth of a tree as an example;

> *'The shape of a tree is the history of the forces which were acting on it while it grew. These same sensory mechanisms, allied to a more mobile effector system as found in animals, lead to structures whose lightness and apparent fragility are made robust by the ability to adapt shape and structure quickly to changing loads. This adaptiveness not only reduces the energy input into the production of the structure but also allows it to adapt to changing forces and circumstances during its lifetime, many of which may be unpredictable. Such adaptiveness has also been called smart or intelligent behaviour.' (Adriaan Beukers, 2005)*

Clear connections can be observed between the engineering and natural world through this concept of 'minimum use of energy' via adaptability, and in a world of diminishing resources and a necessity to drastically cut carbon emissions, it is no surprise that this is becoming an increasingly important design driver within the Architectural realm. Later in the dissertation, I will return to these notions of 'minimum-energy-structures' and adaptability where I will be looking at how Cedric Price attempted to combine natural principles with technology to achieve this through implementing the novel concepts of Pneumatics[3] & Tensegrity[4] into structural form.

"THERE IS A DUALITY BETWEEN ENGINEERING AND NATURE WHICH IS BASED ON MINIMUM USE OF ENERGY."
(ADRIAAN BEUKERS, 2005)

If lightness is prevalent in the natural world as well as many other disciplines, perhaps the question Price was always trying to answer was, *then why not Architecture?*

3 *'Pneumatic envelope systems are tensile structures, based on the use of membrane skins, which are stabilized by the differential pressure between their inner and outer sides; in order to acquire enough stiffness to maintain an equilibrium position and to be able to support external loads.' (Alberto Gómez-González, 2011)*

4 *'The term tensegrity, first used by a friend and mentor of Price 'Buckminster Fuller', was described by Fuller as, "self-tensioning structures composed of rigid structures and cables, with forces of traction and compression, which form an integrated whole."' (Pires, 2021)*

Space, Weight & Time.

In the next section of the dissertation, I will be examining the relationship shared between weight and time through history in order to gain a deeper understanding of Architectural Lightness and the cultural implications it can have. This will give me a better insight as to the reasonings behind Cedric Prices' obsession with ephemerality as well as act as a foundation for some of the topics covered later in the dissertation.

The Relationship Between Lightness & Temporality
Architectural weight and the life span of a building are two closely correlated entities, this has been known throughout history, 'In most cases, weight relates to Vitruvius's principle of firmitas (sturdiness, stability), and is, therefore, an architectural factor that influences life span.' (Roorda, 2014) Since the beginning of human civilisation, Architectural weight has long since been used as a tool to promote power and status through Architectural monumentalism. Recurring examples of this style of architecture can be seen throughout history by prominent political empires and religions to portray illusions of strength, unity, immortality, intimidation or everlasting power. Fighting against the inevitability of time and striving for unattainable permeance, these empires attempted, 'to build something of significance that will outlast the human lifespan and stretch through generations', (Booth, 2017) deluding themselves with the notion that buildings withhold any real permeance.

"And on the pedestal these words appear:
"My name is Ozymandias, king of kings;
Look on my works, ye Mighty, and despair!"
Nothing beside remains. Round the decay
Of that colossal wreck, boundless and bare
The lone and level sands stretch far away."
(Shelley, 1977)

Figure 5: Ozymadias Illustration, Nick Derington, 2008 (Derington, 2008)

Well known examples of these attempts at defying time itself include; the Ancient Egyptians, Ancient Greeks, Aztek, Roman and more recently the Nazi empire to name but-a-few, 'In Albert Speer's[5] megalomaniac vision of future Berlin 'Germania[6]', massive stone structures were meant to provide, even after hundreds or thousands of years, impressions of overwhelming beauty and sublimity' with Speer suggesting that, the use of sturdy construction materials ensuring that even in a state of decay, as ruins, the colossal new buildings of future Germania would "more or less resemble Roman models."' (Koepnick, 2001).

Lutz Koepnick in his essay '*Redeeming History? Foster's Dome and the Political Aesthetic of the Berlin Republic'* goes on to examine the relationship between Architectural materiality and the politics they can portray, framing Foster + Partners radical redesign of the Reichstag dome, in which they used Glass as the primary material, as a political statement;

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[5] *'Albert Speer, (born March 19, 1905) Was a German architect who was Adolf Hitler's chief architect (1933–45) and minister for armaments and war production (1942–45).'(Britannica, 2022)*

[6] *'Germania was Hitler's renewal of Berlin, planned to be a megacity at the centre of his Thousand Year Reich, which started construction prior to the outbreak of WWII in 1938 until it was abandoned in 1943.'*

'The modernist use of glass was marked by a curious dialectic between the sacred and the secular, the monumental and the ephemeral… for the use of glass, one might contend, defies Speer's theory of ruin value. Neither can glass-like Speer's monumental stone designs assault perception, overwhelm the senses, and deny the private body as an autonomous site of corporeal pleasure; nor can it ever decay in an aesthetically pleasing fashion, whether tomorrow or in one hundred years' time.' (Koepnick, 2001)

The type of egotistical monumentalism displayed by Speer was the exact thing Price was directly opposed to; The design of Foster + Partners Glass dome emphasises the social and political value that Lightness can have when implemented through Architecture, in this case, a glass dome, and is a clear example of why it resonated with Prices socialist values, 'Foster's use of transparent glass is consequently understood by many as testimony to the spirit of pluralistic openness of German politics after Hitler and Honecker and casts Germany's new constitutional patriotism into a plain architectural expression.' (Koepnick, 2001)

Price was far more attuned to how the Bonn Republic conducted their governmental architecture following the Nazi era, whereby they, 'placed a tacit taboo on all conspicuous forms of political symbolism, on the figurative repertoire of statesmanship and any excessive imagery of democratic will formation.' (Koepnick, 2001) This led to the new institutional buildings to favour a 'modernist anti-monumental' style which followed form over function by, 'creating government buildings in the unassuming guise of provincial banks, municipal administration centres, and commercial management compounds' (Koepnick, 2001) in the hopes of creating, 'an emotional connection between people and parliament … one where the government stood humbly before its citizens.' (Nielsen, 2014) This was something Price strived for though-out his career with Price once suggesting that York minster should be 'flattened' in an interview which shocked Architects around the world. (Price, 2003)

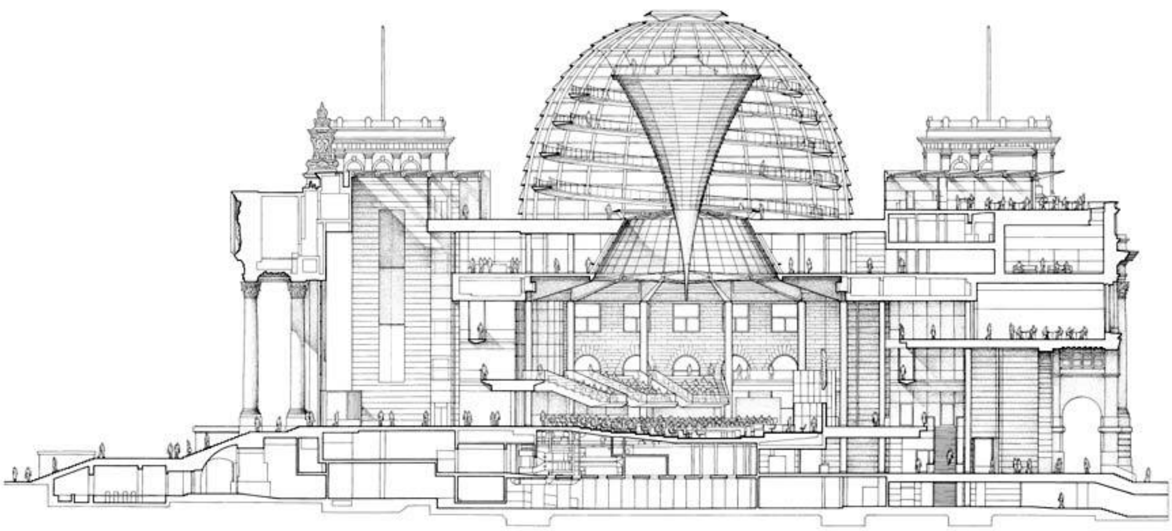

Figure 6: Foster + Partners, New German Parliament, Reichstag, 1999 (Foster + Partners, 1998)

Adaptability.

Introduction
As previously mentioned, the notion of adaptivity was a key proponent of Cedric Prices' design ethos, a notion which this essay attempts to argue shares strong ties with the concept of architectural lightness; as a result of this, the notion of adaptability is a key topic discussed in this dissertation. In this next section, I will attempt to gain a deeper understanding of the human condition towards 'adaptivity' by looking at both the human history of adaptability and at recent, notable examples where human adaptability can be clearly observed. This section intends to form a greater understanding as to the reasonings behind Price's motivations and to gain a deeper insight as to the relevancy this notion may hold today.

The history of Human Adaptability: It's in our DNA
Humans are a profoundly adaptive species. Not only is the human biology hardwired to adapt biologically to the changes in the physical environment e.g., by acclimatizing to a wide range of temperatures and humidity or by adjusting cells so that we still receive sufficient oxygen when travelling to high altitudes (O'Neil, 2012), humans also have an instinctual ability to adapt quickly to routine changes in life as well as our physical environments, '"Humans are extremely adaptable and modify their surroundings more than any other species." (Potts, 1999). In recent years new discoveries on the subject of human evolution, which was once thought to have been solely due to Darwinian natural selection, have put more emphasis on human adaptability for the evolution of the human genome; (Brooks, 2009) this form of natural selection is known as 'The Variable Selection Theory' (Potts, 1999) and frames human adaptability during periods of significant climate change as playing a key role in our evolution as opposed to 'consistency in the effects of Darwinian selection'. (Potts, 1999) In his Theory which involves climate change as an instrumental factor, making it more relevant today than ever before, Potts attempts to explain the, 'repeated, dramatic shifting in Darwinian selection over time', proclaiming in his comprehensive study that, 'adaptive-flexibility' is correlated with 'wider environmental oscillation and uncertainty', going on to point out that, 'new ways of living and interacting with the environment' emerged with, 'increases in technological innovation' also being recorded during these climatic shifts (Potts, 1999). These observations seemingly resemble strong connections with the novel, technologically orientated, adaptive way of living Price sought to achieve through his Architecture which was spurred on by our current climactic uncertainty.

> "Adaptation, the process by which organisms change to better fit their environment, is indeed a large part of human genomic evolution."
> (Brooks, 2009)

Ephemeral Normalcy: Recent Examples of Human Adaptivity
In the book 'Ephemeral Architecture: The Routledge Companion to Critical Approaches to Contemporary Architecture', Swati Chattopadhyay explores the construction of pandals (pavilions) in Kolkata for the religious festival of Durgapuja; In doing so Chattopadhyay critiques the 'ideology of permanence' and highlights the adaptive nature of the human condition through an ethnographical approach, 'When a Pandal is located in a daily market area which does not have a permanent infrastructure, the pandal under construction might provide that infrastructure - the platform is used by vendors and the bamboo structure used for displaying wares. In other words, the pandal structure is simply incorporated into the daily life and rhythm of the residents who come to view it as much an accordance to inhabitation as an obstacle to movement.' (Chattopadhyay, 2019) This not only serves as a good example of the human ability to swiftly adapt to changes in our environment, but

points towards the notion that our Normality may feel concrete and immovable, but is in fact like everything, ephemeral in nature.

The Covid-19 pandemic serves as a recent reminder about the precarity of life, how fast the simulation of stability can be disturbed and how suddenly life can change, but also about how fast we as a collective and as individuals can adapt to change and the resilience of the human condition; work-from-home setting, parents home-schooling their children in a new blended learning setting, lockdown and quarantine, and the mandatory wearing of face mask and face shields in public. (Corpuz, 2021) People have been affected in varying levels of magnitude by the devastating effects of the pandemic which has caused untold suffering and dislocation (More In Common, 2017), but overall, out of pure necessity and with a deeply ingrained survival instinct, as a collective we have been able to accept the fast-paced ever-changing 'new normal', learning from the experience as we adapt and overcome adversity. 'Covid has made us more aware of our shared humanity, the value of strong local communities and the importance of our connection to nature.' (More In Common, 2017) Climate change is a far greater challenge to the human race than any pandemic, the effects of it however not as instantaneous, resulting in a seemingly gradual shift in normalcy; the shift is still apparent nonetheless and is growing momentum at an unprecedented rate in terms of human history. Much like the Covid Pandemic in macrocosm, humanity will adapt and transform in our changing environments out of necessity and instinct, but the critical question everyone is trying to work out is, *how?*

Conclusion

There can be no doubt that we are currently living in a transformative period of time, one that is moving at speeds far greater than any other, with this said we start to look at what the future may hold and perhaps begin to question whether this notion of adaptability will continue to play an ever-growing part in it, more specifically it's architecture. In the same way, history has often proven itself to repeat, and given the current unprecedented climate emergency with 'planetary warming occurring at a breakneck pace', human adaptability is likely to face its biggest test. (Massey, 2013) The question that then begins to emerge from these observations is:

Humans are and always have been an adaptive species, ***so shouldn't our Architecture be too?***

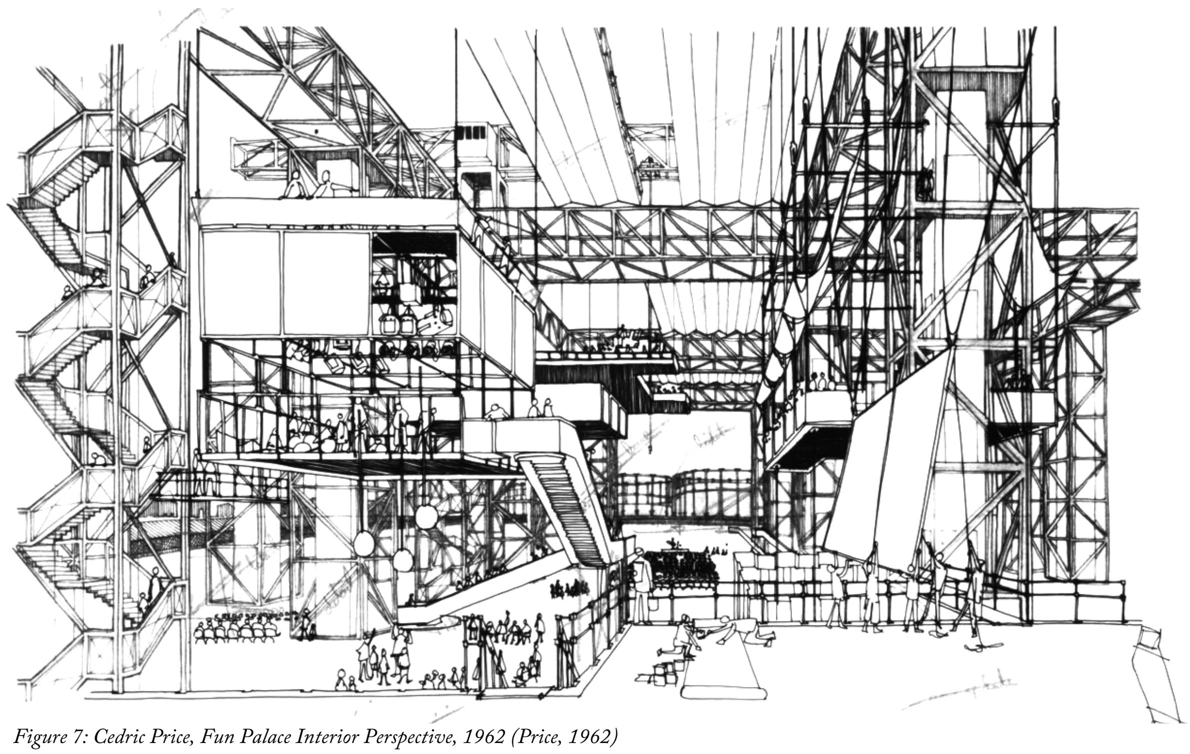

Figure 7: Cedric Price, Fun Palace Interior Perspective, 1962 (Price, 1962)

The Climate Crisis.

Eight Years to Save The Planet

The central challenge in not only the architectural realm but all industries and sectors today is the ever-looming, omnipresent climate crisis, a crisis which has been escalating since the introduction of human civilisation and has reached exponential rates of increase in the last century due to industrialisation. Recent studies have shown that the average global temperature has risen by at least 1 degree since preindustrial levels (World Meteorological Organisation, 2021) due to increased CO2 levels in our atmosphere, this seemingly small rise in the average global temperature is fuelling notable increases in, 'environmental degradation, natural disasters, weather extremes, food and water insecurity, economic disruption, conflict, and terrorism.' (United Nations, 2019) As time continues to pass, the global temperature continues to rise which in turn is resulting in increased environmental repercussions with catastrophic consequences for humanity. With the Intergovernmental Panel on Climate Change recently predicting that we have a 50% probability of exceeding a 1.5°C temperature threshold within the next few decades, and data from the latest UNEP Global emissions gap report suggesting that, 'if nations only implement unconditional climate commitments as they stand, we are likely to hit global warming of approximately 2.7 degrees Celsius by the end of the century' (United Nations Environment Programme, 2021) we can start to understand that the word 'crisis' is no understatement and that there is a serious and imminent need for radical action.

"To be clear: we have eight years to make the plans, put in place the policies, implement them and ultimately deliver the cuts. The clock is ticking loudly."
(Inger Anderson, United Nations Environment Programme)

profligacy | noun *[mass noun]*
1 reckless extravagance or wastefulness in the use of resources:
there is no conceivable justification for such fiscal profligacy

How is The Climate Crisis affecting Architecture?

The Climate Crisis is a result of a collective effort from almost all aspects of modern-day life, meaning that there is a need for change across-the-board. The built environment however accounts for approximately 40% of total global emissions (UKGBC, 2022) currently making it the largest source of global CO2; this has placed new demands and pressure on the Architectural discipline in particular. The role of the Architect is now more important than it ever has been and is critical to the fight against climate change; to do this the current and future Architects of the world must radically increase the value held on materials, buildings and energy consumption to, 'eliminate all CO2 emissions from the built environment by 2040.' (Architecture 2030, 2022)

The fact that building materials and construction (embodied carbon) accounted for 11% of annual global emissions in 2018 (EIA, 2018) tells us that there is rampant human profligacy apparent in the modern-day construction industry which needs to be addressed. In Barnabas Calder's 'ground-breaking' new book *'Architecture: From Prehistory to Climate Emergency'* he explains the history of Architecture through the lens of energy consumption, explaining how Architecture has been shaped throughout history by humanities ever-increasing access to energy.

'In architecture, and in the rest of life, **form follows fuel**'
(Calder, 2021)

Calder puts forward a new narrative in regards to the way Architecture is taught and makes it vitally clear the importance low energy structures will have on Architecture's next stage of evolution, suggesting an adaptive, pragmatic approach may be part of the solution, 'Low-energy societies make highly rational decisions on how much energy to invest in building in proportion to the level of use they intend to make of the structure.' (Calder, 2021)

Infrastructural Damage

We live in a world that is optimised for the climate that currently exists. Our infrastructure is subsequently built to withstand and operate within expected current climactic ranges; this includes all aspects of weathering such as temperature, precipitation and wind etc. We are at a point now where we are beginning to depart from key tolerances designed into existing infrastructure with climate change breeding, 'conditions where these parameters are exceeded more often and to a far greater degree. Some changes, like higher average air temperatures and humidity will become permanent… what were previously considered once in a century floods may become a regular occurrence'. (Boydell, 2021) This will inevitably have increasingly significant consequences on the existing built infrastructure with the effects already making themselves apparent; on the day of me writing this, 'a bridge in Pakistan has collapsed, after a heatwave caused a glacial lake to release large amounts of water into a stream.' (BBC News, 2022) Bridges and transport infrastructure such as railway lines are likely to be one of the heaviest effected; transport Infrastructure spread themselves across 'vast areas and connect remote communities' and 'often have limited flexibility, making it difficult to avoid climate hazards' (Woetzel, et al., 2020), this will not only have direct economic ramifications, but will cause, 'large socioeconomic effects as critical services are disrupted.' (Woetzel, et al., 2020) The most damning effects to be seen however is likely to be seen through the determination of concrete infrastructure. In the 2010 report *'Climate Change Impact and Risks of Concrete Infrastructure Deterioration'* a study was conducted to analyse the probable effects climate change will have on reinforced concrete due to the fact, 'Atmospheric CO2 is a major cause of reinforcement corrosion in bridges, buildings, wharves, and other concrete infrastructure in Australia, United States, United Kingdom and most other countries.' (Stewart, et al., 2011) The tests conducted in Australia found that due to rising CO2 levels, 'carbonation induced damage risks can increase by over 400% over a time period to 2100', (Stewart, et al., 2011) these results are highly significant and give us one more empirically grounded reason to move away from using heavy concrete as a construction material, the other major reason being it's high embodied carbon and the fact cement attributes to 'about 8% of the world's carbon dioxide (CO2) emissions' (Lehne & Preston, 2018). As a result of these infrastructural damage caused by climate change (plus many more I have not mentioned), it is no wonder that it is estimated to account for 'between 60 and 80 percent of total climate change adaptation spending globally', that could average £120 billion to £365 billion per year on infrastructure in 2050. (Neufeldt, et al., 2018) The points covered show that climate change is indiscriminate and the fragility of our built environment calls for a restructured approach to the way in which we design it. There is a need for innovation in the ways we navigate its effects and adapt to changing environments; arguing for the demise of static, immovable, heavy infrastructure and perhaps a return to a more minimal approach, 'the modern buildings of developed countries have more things in them that can go wrong than simpler traditional structures.' (Boydell, 2021)

Displacement Crisis

When designing for climate change we cannot solely focus on its mitigation, this is due to the fact it has already begun and escalation at this point is a sad inevitability. We must design *with* climate change, not just against it, this requires steps to be taken to combat the increasingly extreme climatic conditions it is causing. As direct and indirect consequences of climate change, we are experiencing unprecedented levels of displacement. The United Nations reported that 84 million people are currently deemed 'forcibly displaced' worldwide, 'UNHCR estimates that global forced displacement has surpassed 84 million at mid-2021.' (UNHCR, 2021) With growing numbers of devastating conflicts, increased sea levels and crop failures, the necessity for emergency housing is 'increasingly being recognised as one of the foundational challenges of the twenty-first century.' (Langar, 2020) Currently there is 'several million properties in areas at risk of flooding' in the UK alone with the risk of overheating remaining 'very high' (UKGBC, 2022). Refugee camps are no longer being deemed 'temporary spaces intended for transition' in many cases, they are now more permanent in reality, 'with the average length of stay in a UNHCR camp being 17 years, the nature of a refugee camp tent as a hostile site of impermanence is in reality a permanent home for many.' (Maganga, 2022) Modern-day refugee camps are more accurately taking the form of 'informal cities' as in the case of Al Za'atari, a refugee camp which has an approximate population of 80,000. Al Za'atari has 'become the second largest camp in the world after the Dadaab camp in Kenya which houses 329,811 refugees' (Ledwith, 2014), with the majority of the refugees escaping conflict in Syria, 'Jordan is presently experiencing an increase in the flow of Syrian refugees. Made even harsher by the climate change and related desertification.' (Aburamadan, et al., 2020) In the study, *'Designing refugees' camps: temporary emergency solutions, or contemporary paradigms of incomplete urban citizenship?'* the authors discuss the problems stemming from the "impermanent permanence" of modern-day refugee camps caused by escalating displacement; calling for more recognition of the fact these camps are less transient than first anticipated and signalling a need for improved living conditions for the residents which often are living in unstable shelters, unfit to provide suitable shelter from extreme climatic conditions, 'makeshift tents manufactured out of wooden frames covered by billboard advertisements offer little protection from the elements'.(Maganga, 2022) As the climate continues to rise, so will the numbers of displacement; this is consequentially putting more responsibility on the built environment to, 'allow us to adapt to these changing and increasingly extreme climatic conditions.' (UKGBC, 2022)

Conclusion

The points that have just been covered call for the urgent evolution into the next phase of Architecture, 'If in the past the world has changed so much, so often and so fast, it only needs enough sincere effort for it to change again, this time towards sustainability' (Calder, 2021). The next evolution of Architecture needs to be both highly adaptable and of minimal energy; also calling for the innovation of flexible Architectures to aid infrastructural damage and displaced populations.

In the next chapter, I will be using case studies of Cedric Prices' projects to propose how Architectural lightness could aid and/or mitigate the detrimental effects of climate change covered in this chapter. [7]

[7] Side note*: It is important to note that a significant factor in the fight against climate change will involve the retrofitting of existing buildings, '80% of buildings in 2050 have already been built'* (UKGBC, 2022)*, meaning the decarbonisation of existing buildings will play a large role in the reduction of CO2 caused by operations which are, 'responsible for 28% of global emissions annually' (EIA, 2018). For this essay I will not be focusing on the retrofitting of new buildings, but on the new ways of designing and thinking about the Architecture of future buildings and structures.*

Tensegrity Structures.

During this chapter, I will firstly be introducing the principle of tensegrity and its relationship with nature to then begin looking at how the principles of tensegrity could be significant in addressing climate change, infrastructural damage and the displacement crisis covered in the previous chapter.

Tensegrity and its relationship with Nature

'Price established himself as a pioneer of novel and innovative environments, and in so doing radically reframed architecture in terms of lightness' (Moon, 2017). One of the ways in which he did this was through experimenting with the ground-breaking structural principle of tensegrity which sought to use the structural principle of tension instead of the usual compression (Buckminster Fuller Institute, 2022). Tensegrity structures are highly efficient structures which are 'mechanically stable not because of the strength of individual members but because of the way the entire structure distributes and balances mechanical stresses.' (Ingber, 1998) This is highly significant in the quest for minimum energy structures as it relies more on the structural form for strength as opposed to the strength of the structural material, hence 'tensegrity structures offer a maximum amount of strength for a given amount of building material.' (Ingber, 1998) In the mid-1970s the scientist Donald Ingber some-what 'reverse engineered' the biomimicry model to make a breakthrough scientific discovery about all living organisms, doing so by using man-made structures as a precedent to inspire new knowledge about the natural world, as opposed to the other way around. Through observing the use of tensegrity in the Architectural realm, Ingber was able to make correlations to the tensile and compressive anatomy of a mammal i.e., tendons and muscles for tension and bones for compression. From these findings Ingber went on to discover the use of tensegrity structures down to the cellular level whereby 'individual cells define their shape in the same way', going on to hypothesise that, 'It is possible that fully triangulated tensegrity structures may have been selected through evolution because of their structural efficiency – their high mechanical strength using a minimum of materials'. (Ingber, 1998)

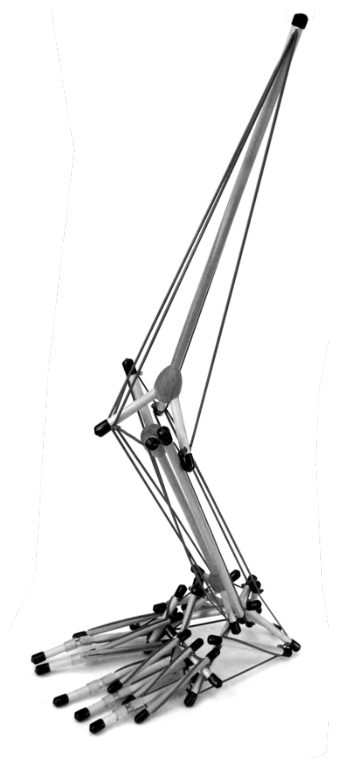

Figure 8: Tensegrity in the human leg (Flemons, 2018)

"ALL STRUCTURES, PROPERLY UNDERSTOOD, FROM THE SOLAR SYSTEM TO THE ATOM, ARE TENSEGRITY STRUCTURES. UNIVERSE IS OMNI~TENSIONAL INTEGRITY."
(FULLER, 1975)

Tensegrity Structures

There are two types of structures which fall under the umbrella of 'tensegrity', both of which 'share one critical feature, which is that tension is continuously transmitted across all structural members.' (Ingber, 1998) The first type I will talk about involves a phenomenon known as 'prestress'; whereby 'Even before one of these structures is subjected to an external force, all the structural members are already in tension or compression', this can be seen in fig 8,9 and 10. (Ingber, 1998) These structures are separated into two distinct material elements; materials that are solely under tension (cables) and materials which are solely under compression (struts). As a result of this, these structures are optimised for both strength and lightness. The earliest application of using tension to create structural form is the tensioned tent structure, one that has existed for thousands of years and was likely the first structure ever to have been built by humans with its origins likely dating back to Mesopotamia (Faegre, 1978). It can then be argued that the tent served as a precedent for all

permanent housing which followed. (Adriaan Beukers, 2005) The fabric tent structure is arguably the most authentic application of what is thought of as lightweight, minimum energy structures, 'as tension can generally be guided through light threads of material, the emphasis on light constructions is on tension' (Adriaan Beukers, 2005) and is still more prevalent today than it ever has been due to the displacement crisis covered previously. Although tents do not conform precisely to the strict laws of pure tensegrity, they often share a lot of its principles whereby, 'textiles of different kinds are stretched with cables on supporting structures that take care of the compression forces'. (Adriaan Beukers, 2005) Although still widely used for recreational use and to provide 'temporary' shelter, the tent structure has been evolving rapidly in recent decades and is becoming increasingly adopted into the works of Architects and engineers with the help of advancements in material sciences.
A key supporter of this type of 'tent structure' includes Frei Otto, a 'leading authority on lightweight tensile and membrane structures' (Tensegritywiki, 2019) who 'After the rigid, weighty formalism of the Third Reich, post-war architecture in West Germany strove above all for lightness and openness, transparency and elegance.' (Meyer, 2015) Otto's architectural career shares many striking resemblances to that of Cedric Price; founding the 'development centre for lightweight construction' and later included in 'the institute of light surface structures at the university of Stuttgart' (The Hyatt Foundation, 2022) Otto was, like Price, hugely influential in the development of lightness in architecture. Also Inspired by biomimicry, Otto used structural fundamentals found in 'soap films, spiderwebs and vertebral spines' (Drew, 1976) to create lightweight structures which were transient, made efficient use of materials and had low environmental impact, (The Hyatt Foundation, 2022) supporting the notion that lightweight is the true measurement of structural effectiveness. (Drew, 1976)

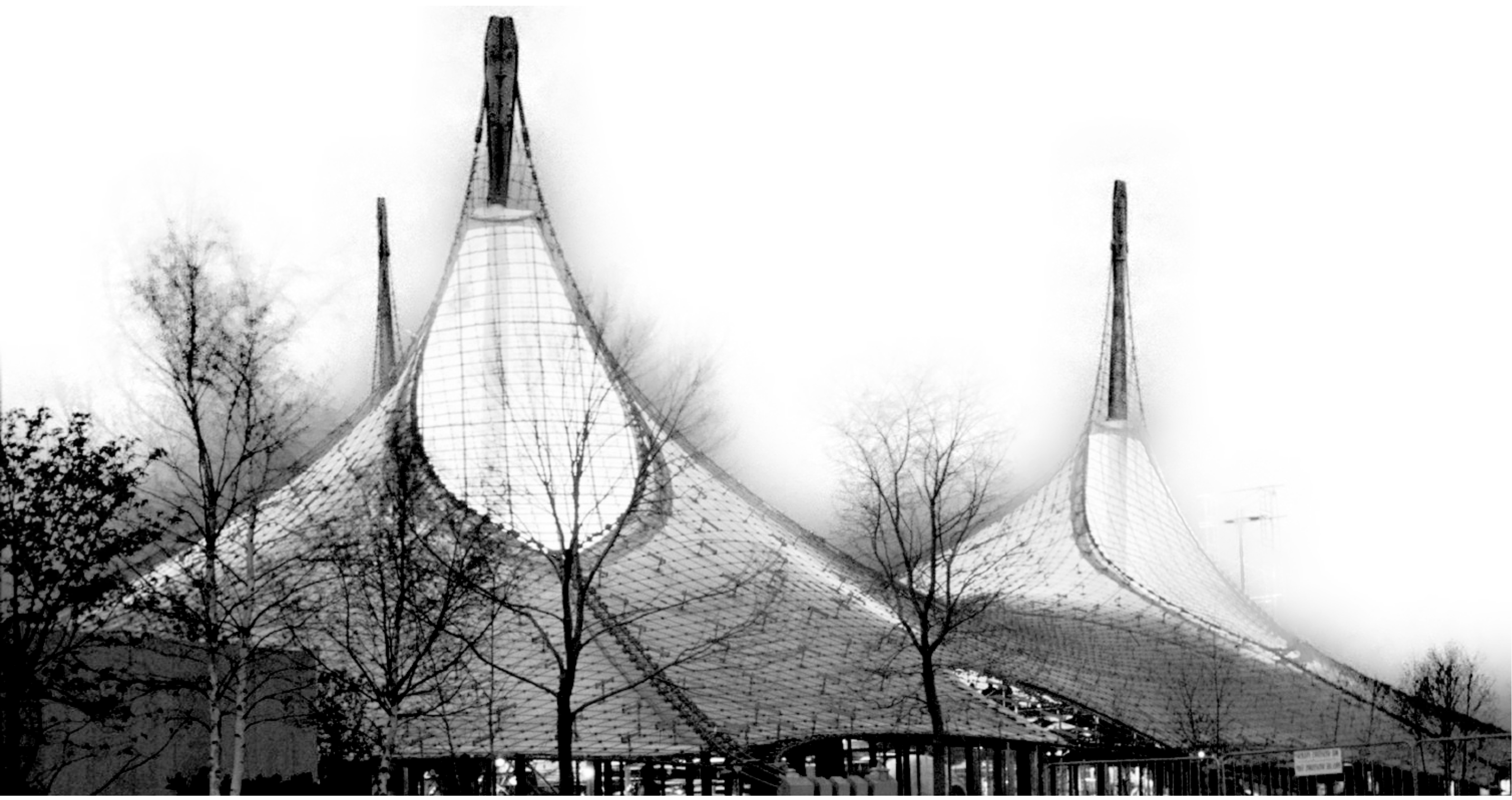

Figure 9: Frei Otto & Rolf Gutbrod, German Pavilion, Expo 1967 (Otto, 1967) The first large cable net structure with fabric cladding

'The pavilion's construction was based entirely on a cable network, prefabricated in Germany, which could be erected in a very short time on site in Quebec. The result was a modern, innovative and aesthetically epoch-making presentation of Germany at the world's fair' - (Meyer, 2015)

None of Frei Otto's projects could be considered fully authentic tensegrity structures; a prime example of an authentic tensegrity structure, in true Price fashion, is Snowdon Aviary. Designed and built by Cedric Price and Frank Newby, Snowdon aviary was a load-bearing system, 'consisted of two tetrahedrons made from aluminium bars anchored in the ground, and connected by tension cables…the structure distributed the loads dynamically'. (Herdt, 2017) Being one of the few realised projects of Prices', and working with his monitor Buckminster Fuller, the zoo 'afforded price an opportunity to experiment, which he hoped would Foster further progress on integrating technical systems and developing prefabricated components' (Herdt, 2017)

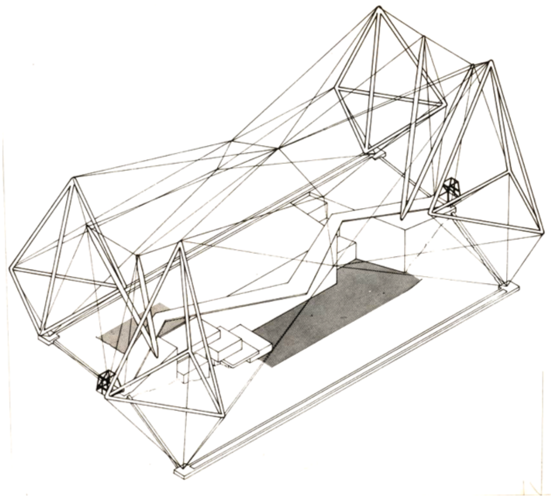

Figure 10: Snowdon Aviary Axonometric (Price, 1962)

Since then, this type of tensegrity structure has continued to evolve offering even greater potential, particularly in the form of deployable and foldable tensegrity structures. Still regarded as cutting-edge technology, deployable and foldable tensegrity structures are still in their infancy but are offering a lot of promise for the future. Specifically promising uses include earthquake-resistant emergency shelters and bridges; 'The fact that these structures vibrate readily means that they are transferring loads very rapidly, so the loads cannot become local. This is very useful in terms of absorption of shocks and seismic vibrations' (Gomez-Jauregui, 2004), this redeeming quality of this type of tensile structure which operates under prestress means they have great potential to offer emergency shelter in hostile environments suffering climactic disasters such as earthquakes to aid displaced populations. This coupled with the fact, 'a tall project would be relatively easy to construct since the sculptures are self-scaffolding' (Whelan, 1981), suggests the application of bridges seems a desirable possibility in a world facing increased risks of infrastructural damage (Fig 14). Tensegrity bridges can be seen all across the world with Arup being the first to pioneer it in October 2009 'Kurilpa Bridge'. (Arup, 2009)

With Antonio Sant'Elia setting out in 1914 what he believed would be 'futurist architecture' as; 'revolutionary, elastic, light, expandable, active, mobile and dynamic.' (Sant'Elia, 1914), it's hard not to see the striking similarities between these traits and the traits tensegrity structures can promise.

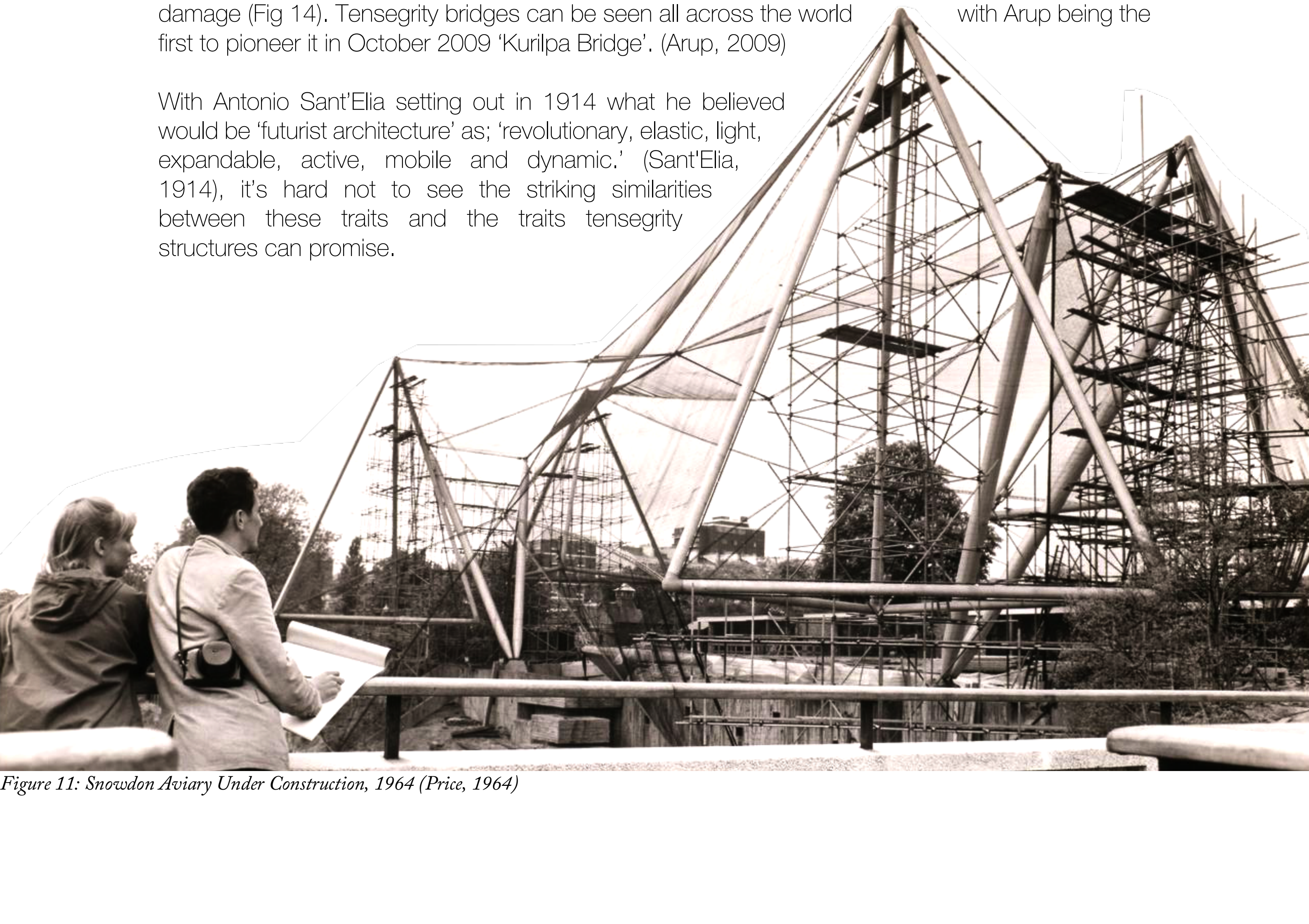

Figure 11: Snowdon Aviary Under Construction, 1964 (Price, 1964)

The Geodesic Dome

The next structural form produced through the principles of tensegrity is the geodesic dome. the American Institute of Architects described the geodesic dome as, “the strongest, lightest and most efficient means of enclosing space yet devised” when they awarded Fuller with a gold medal for his USA Pavilion (Fuller & Kuromiya, 1992). The geodesic dome achieves this impressive status by combining what is known as the strongest structural form, the sphere, with the strongest most efficient shape to exist in the triangle through its ‘Omni-triangulated surface’. (Synergetic Lattice Field Theory, 2021)

Although Price’s work did not extensively include the use of geodesic domes, the flexible geodesic dome auditorium he did design ‘Claverton Dome’ (Fig 8) was said to have, ‘anticipated the Millennium Dome by decades’(St John's College, University of Cambridge, 2014), and was a prime example of the type of avant-garde, pioneering mentality Price had towards achieving lightness in design. The Geodesic dome was developed by Buckminster Fuller in the 1940s to ‘create affordable and efficient housing that could be built quickly from mass-produced parts’ (Buckminster Fuller Institute, 2022). The form of the dome lends itself to a vast array of benefits when it is translated into an Architectural form, this includes;

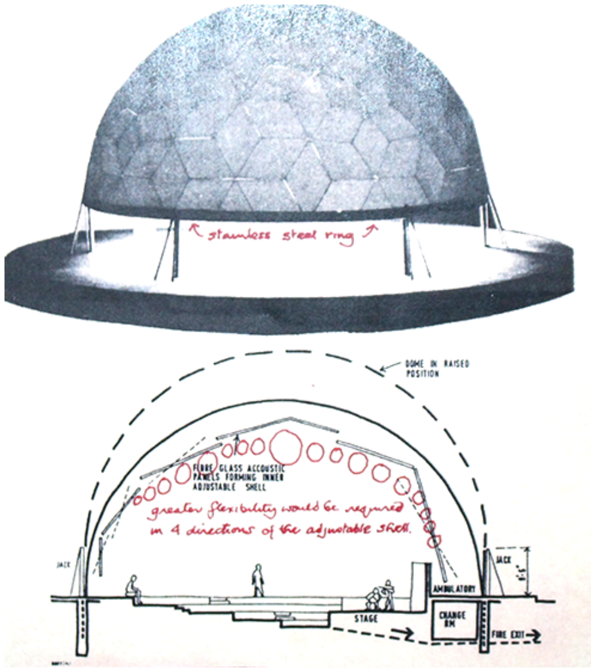

Figure 12: Geodesic Dome Auditorium 1963 (Price, 1963)

- Built with Less Material: Due to the efficiency of the spherical shape and tensegrity structure, geodesic dome structures have up to 30% less surface area than a conventional square structure would have. This means it requires less material and is less expensive to construct while maintaining up to 5 times the strength of a square construction, making it arguable the most efficient minimal energy structure to exist. (Bio Domes, 2022)

- Energy Efficient: Having 30% less surface area also results in a 30% reduction in heat transfer. The unobstructed curved interior space also means that climate control systems are more effective, again cutting operational costs. As the structures grow in size, so too do these efficiencies. (Bio Domes, 2022)

- Extreme Weather Resistance: Perhaps one of the most significant aspects of the geodesic dome, as previously mentioned, is the dome's strength to weight ratio due to its ‘Omni-triangulated surface’. ‘According to the United States Federal Emergency Management Agency say Geodesic dome homes can withstand EF5 tornadoes and category 5 hurricanes’ as well as winds up to 320km/h and loads of ‘up to 20 tonnes per node of structure’. (Bio Domes, 2022) The dome structures are also said to be ‘virtually earthquake proof’, even when constructed from conventional materials such as wood. (Clark, 2014)

“THE SMALLEST LIVING ORGANISM CANNOT SURVIVE WITHOUT MINIMIZING INNER STRUCTURAL STRESS UNDER ALL CIRCUMSTANCES, AND EARTHQUAKES ARE OUR OWN PLANETS PROZAC."

(ADRIAAN BEUKERS, 2005)

The geodesic dome had a surge in popularity in the 1970s in the form of 'dome homes' and has experienced another surge recently throughout the Covid pandemic, whereby the whimsical 'Garden dome' in the shape of 'transparent polycarbonate hemispheres' can now be observed outside an ever-growing number of homes; providing much needed additional indoor floor space in a novel and exciting way during Lockdowns as well as 'outdoor dining pods for the hospitality industry'. (Burroughs, 2020) There is also a large and increasing number of geodesic dome shelter manufacturers, with a new large scale 2004 start-up (Fig 13) offering 'Carbon-Neutral Geodesic Dome Homes' (Koetsier, 2020) which are 'affordable, resilient, modular, green, and long-lasting'. (Koetsier, 2020) Constructed using Bioceramic, a 'new type of chemically-bonded ceramic that forms strong molecular bonds like a polymer. Crucially, bio-ceramic has the ability to mix itself into a slurry and pour it into a mould without using high heat making it cheap (and green) to manufacture, while enabling it to be much stronger than concrete' (Koetsier, 2020);

> *'Geoship domes merge geodesic geometry with crystal chemistry and are built with all-ceramic composite panels, struts, and hubs. the lightweight ceramic parts are fused on-site with ceramic mortar. the domes are low cost, low maintenance and quick to install. The buildings are zero-carbon, 100% non-toxic and resistant to mould, fire, floods, earthquakes and hurricanes. the ceramic domes come in two sizes and can be used for various functions: from a backyard studio to part of a community of dome dwellers.'* (Myers, 2020)

Seeing the geodesic dome achieve this level of mass production through the examples shown may point towards the idea that the 'futuristic' minimal energy structures that the likes of Price and Buckminster Fuller enthralled themselves with back in the 1960s are now coming of age for reasons relating to wider accessibility of advanced computer-aided tools and software as a consequence of 'the digital revolution' which started in the 1990s (Veltkamp, 2007) and the advancements of material sciences, "the right geometry but the wrong materials." (CEO Morgan Bierschenk)
A revolutionary innovation, the geodesic dome is not limited to garden domes and houses but lends itself to a wide range of uses and possibilities; Sports stadiums, theatres, homes, greenhouses, exhibition halls, radomes and more poignantly emergency shelters. (DesigningBuildings, 2022) The geodesic dome structure is already proven as an effective emergency shelter, even more so than the first type of tensegrity structure covered due to the reasons previously covered relating to their; resistance to harsh climates, structural resilience, economical use of material, buildability and energy efficiency. The geodesic tents which are starting to gain popularity (Fig 15), 'do a better job at heat retention and offer more structural support against the wind than the standard backpacker's tent or traditional A-frame' (Beyman, 2018) that are still the favoured type of disaster relief temporary shelter due to cost and efficiency. Relating this back to the 'impermeant permeance' of modern-day refugee camps, the geodesic dome could be an effective substitute for the traditional temporary shelters used today to bridge the gap between temporary and permeant 'With a vast majority of refugee camps being placed in faraway, poorly connected areas, tents in this scenario act as a visual marker of asylum-seeker status, where the tents function as an architectural distinction from the "urban" area of a settlement, leading to further ostracization of immigrants living in these refugee tents.' (Maganga, 2022)What this shows is there is not only is there a growing need for lightness, there is a growing need for the innovation of lightness, to make Architectural lightness not only achievable but more effective and attainable. There are clear signs of increased adoption of the early works of Cedric Price and Buckminster Fuller regarding the use of tensegrity as an instrument of Architecture and as such an increased adoption of architectural lightness. With the world continuing to suffer from widespread climate change, displacement and infrastructural damage, taking into account the many benefits offered by tensegrity structures that I have covered, it is hard not to see this type of Architecture playing a much more significant role in the future. Whether this is in the form of emergency shelters, bridges or more permeant housing, this revolutionary geometric principle coupled with advanced material sciences has the potential to give architectural lightness an exciting future.

New Age Form Finding to minimise structural form

The programs available, such as parametric software like Rhinos and grasshopper (Pereira, 2018), now are far more advanced than that of the 1960s and allow for the comprehensive testing and optimisation of far more complex structures than just the geodesic dome, often called ‘free form Architecture’. The organic ‘free form’ shapes seen in this style of Architecture can now be achieved far more easily and efficiently through generative design, a new design method in which iterative designs are formed through a program which aims to satisfy constraints outlined by the Architect e.g. spatial requirements, strength requirements, material usage, manufacturing methods, and cost constraints. (Autodesk, 2022) The designer can then refine the iterations by adjusting selected output or input values to meet the desired outcome, oftentimes going on to further increase efficiency through ‘rationalisation’, a process used by many mainstream large-scale Architectural institutions that participate in free form architecture such as Zaha Hadid Architects, Foster + Partners and Gehry Partners. The process of rationalisation, ‘is the process of information reduction or compression of an architectural design with the goal of simplifying and optimising its geometry towards manufacturing and construction’, (Fischer, et al., 2012) this type of technological innovation is revolutionising how minimal energy structures are conceived. Although revolutionary regarding material efficiency, oftentimes it is used with monetary gains acting as a key motivator as opposed to environmental sustainability; reinforced concrete being a popular material of choice in this type of construction (Henriksson & Hult, 2015). These programmes greatly enhance the scope of Architectural freedom, but such freedom inevitably will also lead to unnecessary energy consumption in construction; thus, it can be argued a return to a more strategic way of designing, one that greatly prioritises sustainability and is enhanced by modern-day principles and technologies like the tensegrity structures mentioned is what the future of Architecture is calling for going forward.

‘Construction of towers, bridges, domes, etc. employing tensegrity principles will make them highly resilient and, at the same time, very economical.’

Robert Burkardt, Principal of Tensegrity Solutions, Cambridge, Massachusets (1994~2004) Via (Gomez~Jauregui, 2004)

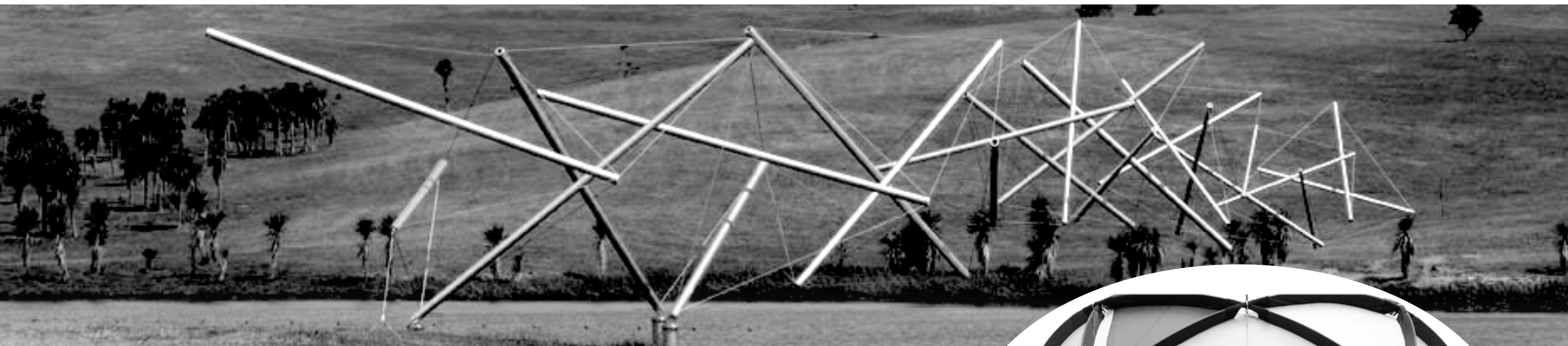

Figure 15: Kenneth Snelson, Easy-K Installation, 1970, Aluminium and Stainless Steel (Snelson, 1970)

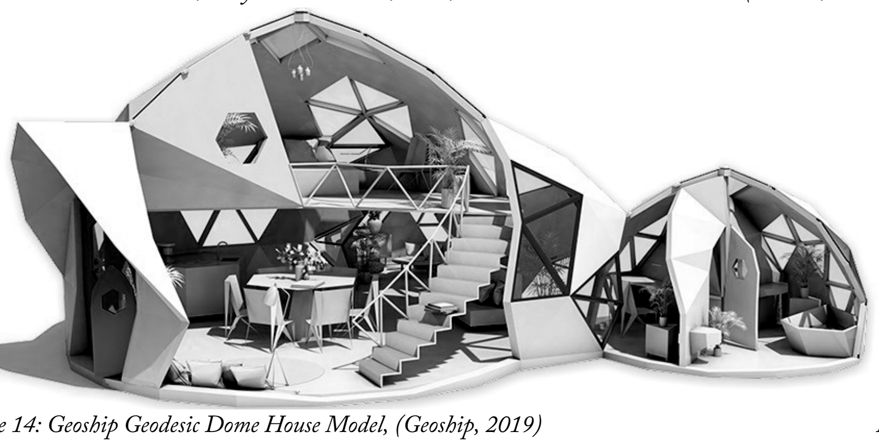

Figure 14: Geoship Geodesic Dome House Model, (Geoship, 2019)

Figure 13: North Face Geodesic Tensile Tent, 2018 (Face, 2018)

Modernism & The Circular Economy.

The next section looks at how embodied carbon created by the construction industry can be addressed through lightness; using Cedric Price's 'Steel House' to suggest a radical restructuring of how Architecture is built and designed to drastically reduce and mitigate the impacts of embodied energy through a 'design for disassembly' approach, an approach connected to a wider system called 'The Circular economy'.

The Circular Economy and its relationship with Nature

Although there are many different ways in which we can use biomimicry to aid architectural form-finding such as in the case of the tensegrity structures mentioned previously, the desperate time we are in is calling for equally desperate measures, and given the severity of our climactic situation this may not be enough. We must look beyond the first two layers of biomimicry of form and process and towards the eco-system as a whole, this brings us to the *circular economy*, 'If we are to meet the needs of a population of nine billion elegantly and effectively, then we need a different operating system for our entire economy.' (Pawlyn, 2016) In nature, there is no such thing as a by-product, this is because all-natural ecosystems follow a circular economy (Schröder, et al., 2021) which are 'closed-loop, feedback-rich systems' (Pawlyn, 2016) which implements the tag lines of 'reduce, reuse, recycle' in a radical way. Ultimately, the circular economy relates back to the 'systems thinking approach' Price was an early adopter of, and 'orientates around principles which irradicate waste and pollution, ensuring products within these economies are re-used and re-circulated for as long as possible.' (Schröder, et al., 2021) It is an economic concept which is relatively novel in the construction industry but is gaining momentum as we look for solutions to mitigate and adapt to the climate crisis with the hopes of 'anticipating new forms of prosperity while decoupling from materials and energy constraints.' (Pawlyn, 2016)

Modernism, Standardisation & Prefabrication

The concept of Standardisation & Modularity was always a prevalent subject amongst the most well-known, pioneering Modernist architectural thinkers such as Le Corbusier and Walter Gropius (founder of Bauhaus) who experienced the rise of industrialisation, living through a 'growing machine-driven culture' (November, 2018). Although enthralled by the novel concept of mass production, one could argue that they were too far ahead of their time as they were often dishonest in the Utopian way they implemented it, achieving the 'machine made' aesthetic through anyways necessary, even if this meant it had to be hand-made, "Throughout the present century architects have made fetishes of technological and scientific concepts out of context and have been disappointed by them when they developed according to the processes of technical development, not according to the hopes of architects." (Banham, 1960) Coming some 40 years later, Cedric Price was born into an exciting, transformational Architectural landscape in which the future of Architecture was spurring 'genuine debate' in public and professional discourse, 'emerging from the self-congratulatory euphoria of the late forties and early fifties' (Price, 2003); Price, who was no-doubt sculpted through the hard times he lived through as a child during the second world war which had him sit 'just outside of the generation that linked the social idea idealism of post-war reconstruction with the passions of the modern movement' (Price, 2003), looked to turn this Idealist narrative on its head with his realist approach to functionalism. In the next section, I will be looking at how Cedric Prices' use of lightness in his 'steel house' project could be crucial in the implementation of an effective circular construction economy.

Designing for Disassembly (DfD), Steel House

Designing for disassembly is a concept which is deeply embedded in the circular economy structure and it aims to address the 'high consumption of resources and low recycling rate within the construction industry'. (Cutieru, 2020) The ultimate goal of DfD is to significantly reduce the embodied energy of the built environment, which as previously mentioned accounted for 11% of annual total global emissions in 2018 (EIA, 2018), making it a vital part in the fight to reduce CO2. As I have talked about in this essay, Price shared similar 'functionalistic utopian' ambitions with that of his mentor Buckminster Fuller, who whole-heartedly believed in the concept of designing for disassembly over 50 years ago, 'Buckminster Fuller suggested that industries should not sell materials, components and buildings, but rather rent them out and retrieve them for recycling. He also proposed that all architects should know how much their buildings weigh, and that they should achieve 'maximum gain of advantage from minimal energy input.' (Crowther, 1999) This notion is well presented in Cedric Prices 'steel house' project; a lightweight, prefabricated, modular housing concept with, 'costs control, environmental impact and mobility' acting as the key design drivers shaping the house. (Lucarelli, 2016) The housing project bears Price's ethos on anticipatory/adaptable architecture heavily with Price believing that, 'a fundamental role in a domestic environment is played by the capacity of architecture to take into account the changeability of the inhabitants.' (Lucarelli, 2016) The Steel house called for, 'rapid assembly/disassembly, flexible unit plans that could be altered by homeowners and appeal to a wide range of owners and their preferences', (CCA, 1965-1969) the rapid assembly and dismantling 'incorporated into the design in order to radically reduce environmental damage.' (Lucarelli, 2016)

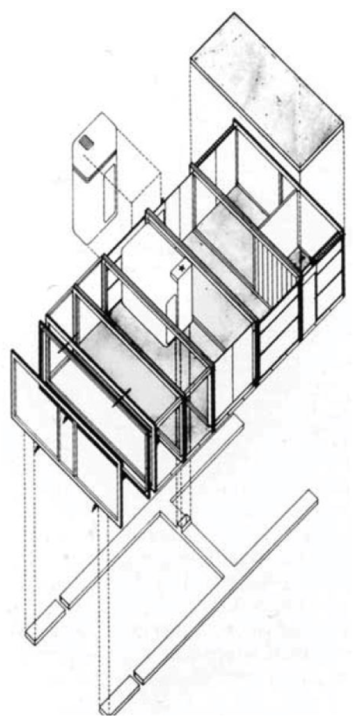

Figure 16: Cedric Price, Steel House Axonometric, 1967, (Price, 1967 - 1971)

Price was not only securing the longevity of the building through his anticipatory approach but was radically increasing the lifespan of the individual material components after the buildings are no longer required; attempting to achieve a state of 'transient permanence' which embraces its demise. Seen often in Prices work, metals such as aluminium and steel are likely the most fundamental materials going forward into a circular economy as not only do they enable the construction of lightweight minimal-use-structures, they 'can be recycled indefinitely without losing quality or properties.' (TransMetal, 2021) Widespread adoption of this design approach would result in the increased implementation of standardisation of components and prefabrication of structural elements to achieve optimum efficiency, ultimately this will result in buildings becoming lighter in weight, 'treading lighter on the earth' (Wilkinson & Eyre, 2001). Not only will this approach reduce CO2 consumption in the construction industry, but will create a more dynamic architecture, one which can adapt more readily to the precarity of changing climatic conditions than the traditional brick and mortar structure. That being said, there is a long way to go, last year the 'circularity gap report' suggested that the world is currently 'only 8.6% circular' and is in a negative trajectory, falling from 9.1%.in 2019.' (The Circularity Gap Report, 2021)

"INSTEAD OF ANCHORING BUILDINGS PONDEROUSLY INTO THE GROUND WITH MASSIVE FOUNDATIONS, THE NEW ARCHITECTURE POISES THEM LIGHTLY, YET FIRMLY, UPON THE FACE OF THE EARTH."
(GROPIUS, 1965)

A key theme attached to the term 'architectural lightness' running through this dissertation and included in the topic of DfD is the notion of transient architecture, in the last section I will be analysing what the cultural impacts of an increased adoption of architectural transiency, implemented though lightness may cause.

Identity Crisis?

The Relationship Between Time & Identity

As covered earlier in the dissertation, we as a species over the thousands of years of us being on this planet have often been transfixed on the notion of permeance and the preservation of the past. The city of London is regarded as one of the leading cultural capitals in the world (Calder, 2007) and is 'unique among Europe's capital cities in still retaining its medieval boundaries', (Hebbert, 2022) its financial district 'still largely defined by the outline of the old Roman town.' (Bishop & Williams, 2012) This suggests the relationship shared between time and identity is a strong one, with deep roots in our human history. Ali Madanipour's cities in time' is a comprehensive clique on the relationship between time and space concerning temporary urbanism, during which he attempts to dissect the philosophical roots embedded in it. Madanipour uses the theories of renowned philosophical figures such as Plato and Einstein; referring to Plato's theory of absolutism, 'time is thought to be 'like an empty container into which things and events may be placed; but it is a container that exists independently of what, if anything, is placed in it', suggesting that the relationship shared between time and space is that of, 'the universe and the observer." (Madanipour, 2017) These views remind us that the notion of time is indeed just a social construct, which has been conceptualised through the use of 'permanent' physical infrastructure, 'a physical infrastructure has been developed to display time, turning an abstract concept into an empirical reality, an infrastructure of social life, which maintains the urban rhythms, showing how the universal and structured notions of time have framed the everyday life of the city.' (Madanipour, 2017) The argument can be made that identity is a by-product, created through the combination of time and physical infrastructure with, 'social institutions and physical infrastructure, all attempting to frame and manage change, engendering a sense of stability and continuity.' (Madanipour, 2017) The question that then starts being put forward is, will rapidly changing cities, fuelled by the wider adoption of lightness in the built environment, lead to a loss of connection with the past, and will this lead its citizens to experience feelings of precarity, disconnection and loss? Or does it just make it more creative?

"Time is not change . . . but it does not exist without change."
~ Aristotle
(Shoemaker, 1969)

Cultural Amnesia? Nomadic Tribe Culture

Nomadic cultures have existed for thousands of years in various forms and are likely the first type of culture ever to have existed. To gain a better insight as to the possible impacts transient architectures may have on society, we should look towards the nomadic cultures which operate through mobile and transient architectures. In Stephanie Carlisle's 'Nomadic Architecture' report, she sought to 'examine the relationship that nomadic people have to their natural and built environments and how that relationship, as expressed through portable, domestic architecture, communicates a different understanding of space and place than that of settled people.' (Carlisle, 2006) Through her 'yearlong study on architecture in the nomadic communities of Mongolia, West Africa, India, and Ireland', Carlisle's observations suggest that the mobile, dynamic infrastructures of the communities she stayed with promoted the constructing of a more sensitive community of that seen in the 'sedentary bias of western architecture' (Carlisle, 2006), one which is more attuned to its current surroundings and social connections which, 'maintains a direct and continual engagement with physical and social construction.' (Carlisle, 2006)

"Material culture is not all that makes a community."
(Carlisle, 2006)

"Nomads call attention to a nascent instability in the world. The structures that they build are based in a natural movement in society. They render visible aspects of all of us that we choose to ignore and are comfortable with a sense of impermanence and change that many people find unsettling. The flexibility and movement (both social and spatial) practiced by nomads are strategies for dealing with this instability." (Carlisle, 2006)

The flexibility of the nomadic culture challenges western architecture's 'tendency to privilege monumental, permanent, static structures' and in doing so places more emphasis on; temporality, community, flexibility and inventiveness to create spaces 'through relationships, ideas and actions.' (Carlisle, 2006) The key take-aways from Carlisle's observations is that nomadic cultures have not been stripped of identity or community by their transient lifestyles, in fact, quite the opposite. The transience of their lifestyle becomes a culture in and of itself, 'Many of the people with whom I lived this year see movement and nomadism as a central element of their identity and survival.' (Carlisle, 2006) Carlisle concludes by suggesting that nomadism should be seen not as 'an attribute of a particular ethnic or cultural group' but as a 'problem-solving tactic and skill that some communities have utilized and perfected over the course of history.' (Carlisle, 2006) Thus, these findings radically oppose the concept that transient architecture caused by wider adoption of lightness would lead to a 'cultural amnesia'.

Lightness and standardisation

Through this dissertation I have covered the fact that wider adoption of architectural lightness could also mean a wider adoption of standardisation, another debate which arises from this is; will this also translate to a loss of identity? 'The loss of identity in the age of globalisation is a major topic of debate, discussing how cities and localities across the world are increasingly variations of the same theme.' (Madanipour, 2017) In this section, I will be briefly addressing the debate which argues the increased standardisation of components, advocated by modernist architects such as Cedric Price, will result in dull, characterless architecture.

Cedric Price was a radical functionalist, and as a result, prioritised function over form. This can be seen evidently in his 'Inter-Action' centre (fig 18) a, 'pioneering urban community project.' (Murphy, 2018) The minimal, industrial, functional aesthetic was heavily criticised by many with Douglas Murphy describing it as a 'banal-looking structure that looks as though a builder had knocked up a timber yard while entertaining fantasies of the Pompidou Centre.' (Murphy, 2018)

Figure 17: Aerial View of Inter-Action Centre, Cedric price (Price, 1979)

This can be seen to back up the claim of standardisation resulting in a dull architecture. However, this is just one example, a radical example at that, and does not mean all architecture evoking lightness has to be dull. The argument can be made that the increased flexibility that architectural lightness enables can evoke a greater sense of creativity. Cedric Price was said to have anticipated the London eye by decades (fig 17), 'Price's inspiration can be seen today in world-famous structures such as the Centre Pompidou in Paris and the London Eye. (St John's College, University of Cambridge, 2014) The master pioneer of modernism sums this argument up concisely and directly, stating;

"The fear that individuality will be crushed out by the growing "tyranny" of standardization is the sort of myth which cannot sustain the briefest examination... There will, of course, always be talented craftsmen who can turn out individual designs and find a market for them. "
(Gropius, 1965)

Figure 18: Cedric Price, 'Why do people have to look up?', Sketch for South Bank, (Price, 1986)

Conclusion.

During this dissertation, I have identified that there not only is a growing need for Architectural lightness as a result of climate change but there is a growing need for the innovation of Architectural lightness. Lightness is seemingly inevitable in the way it is going to play a more prominent role in the design of the future built environment and is becoming increasingly more attainable through the advancements in modern technology. In regards to the cultural impacts lightness may have I have provided evidence suggesting both pros and cons which relate to a more transient built environment. Perhaps the key takeaway is that the number one, fundamental, collective goal of the modern-day Architects should above all else be prioritising the longevity of the earth, doing so by any means necessary; this may mean taking on a more 'Cedric Price' style of efficient, functionalist design, one which heavily incorporates the architectural Lightness.

"Climate change is the fundamental design problem of our time. Not style, not fees, not education, not community, not health, not justice. All other concerns, many of them profoundly important, are nonetheless ancillary. The threat climate change poses is existential, and buildings are hugely complicit. "
(Cramer, 2017)

Further Reading

This dissertation was on a broad subject, and as a result I have touched upon many different topics which leaves a relatively broad scope of opportunity for further investigation. Aspects I would be interested delving deeper into include looking into the logistics of 'design for disassembly', looking at how to improve efficiencies in standardised component design. Another subject from this dissertation I would be interested in pursuing further involves Frei Otto and the work he carried out with tensile, membrane structures; doing an in-depth analysis of what future applications this architecture may be capable of through advancements in material science.

Bibliography

|, M. P., 2018. *Tensegrity Structures: What They Are and What They Can Be.* [Online]
Available at: https://www.archdaily.com/893555/tensegrity-structures-what-they-are-and-what-they-can-be
[Accessed 12 May 2022].

Aburamadan, R., Trillo, C. & Makore, B. C. N., 2020. Designing refugees' camps: temporary emergency solutions, or contemporary paradigms of incomplete urban citizenship? Insights from Al Za'atari. *SpringerOpen,* 7(12).

Admin, I., 2016. Adaptive Architecture & Spatial Management. *Bartlett School Of Architecture*, 13 February .

Adriaan Beukers, E. V. H., 2005. *Lightness : the inevitable renaissance of minimum energy structures.* Fourth Edition ed. Rotterdam: 010.

Alberto Gómez-González, J. N. J. M., 2011. *Pneumatic Skins in Architecture. Sustainable Trends in Low Positive Pressure Inflatable Systems,* Madrid: Elsevier Ltd.

Allen, K., 2013. Beyond the Tent: Why Refugee Camps Need Architects. *ArchDaily*, 14 October.

Architecture 2030, 2022. *Why the Building Sector?.* [Online]
Available at: https://architecture2030.org/why-the-building-sector/
[Accessed 4 May 2022].

Arup, 2009. *The world's first tensegrity bridge.* [Online]
Available at: https://www.arup.com/projects/kurilpa-bridge
[Accessed 12 May 2022].

Autodesk, 2022. *Generative Design.* [Online]
Available at: https://www.autodesk.com/solutions/generative-design
[Accessed 9 May 2022].

Balušíková, K., 2020. Frei Otto. In: *The Book.* s.l.:s.n., pp. 84-89.
Banham, R., 1960. *The Architectural Review*, March.
BBC News, 2022. *Pakistan: Bridge crumbles after heatwave triggers floods.* [Online]
Available at: https://www.bbc.co.uk/news/av/world-asia-61392134
[Accessed 10 May 2022].

Beyman, A., 2018. Geodesic Domes: The Future of Construction since 1954. *Medium*, 24 December.

Bio Domes, 2022. *Geodesic Dome Homes.* [Online]
Available at: https://www.biodomes.eu/
[Accessed 8 May 2022].

Biomimicry Institute, 2022. *Solutions to Global Challenges Are All around Us.* [Online]
Available at: https://biomimicry.org/examples/
[Accessed 21 April 2022].

Bishop, P. & Williams, L., 2012. *The temporary city.* London; New York: Routledge.

Booth, E., 2017. Pop-up Awards 2017. *Architectural Review,* Volume 1438, pp. 73-75.

Boydell, R., 2021. Most buildings were designed for an earlier climate – here's what will happen as global warming accelerates. *The Conversation*, 2 July.

Britannica, 2022. *Albert Speer.* [Online]
Available at: https://www.britannica.com/biography/Albert-Speer
[Accessed 21 April 2022].

Brooks, C., 2009. *Adaptation is key in human evolution,* California: Stanford University.
Buckminster Fuller Institute, 2022. *World Game.* [Online]
Available at: https://www.bfi.org/about-fuller/big-ideas/world-game/#:~:text=The%20World%20Game%20that%20Fuller,or%20the%20disadvantage%20of%20anyone.%E2%80%9D
[Accessed 6 May 2022].

Burroughs, K., 2020. Why garden rooms are at the top of our post-Covid wish list. *The Times*, 31 July.

Calder, B., 2021. *Architecture From Prehistory to Climate Emergency.* s.l.:Pelican.

Calder, B. & Bremner, G. A., 2021. Buildings and energy: architectural history in the climate emergency. *The Journal of Architecture,* 26(2), pp. 79-115.

Calder, S., 2007. London, Capital Of The World. *Independent* , 22 December.

Carlisle, S., 2006. *Nomadic Architecture,* s.l.: Yale University.

CCA, 1965-1969. *Steel House.* [Online]
Available at: https://www.cca.qc.ca/en/archives/380477/cedric-price-fonds/396839/projects/403174/steel-house
[Accessed 13 May 2022].

Cedric Price, e. a., 2002. *Re CP.* Basel: Birkhäuser.

Chattopadhyay, S., 2019. Ephemeral Architecture. In: *The Routledge Companion to Critical Approaches to Contemporary Architecture.* New York: s.n., pp. 23-23.

Clark, N. S., 2014. *Shake Table Test Shows the Dome Shape is Virtually Earthquake-Proof.* [Online]

Available at: https://www.monolithic.org/benefits/benefits-survivability/shake-table-test-shows-the-dome-shape-is-virtually-earthquake-proof
[Accessed 9 May 2022].

Corpuz, J. C. G., 2021. Adapting to the culture of 'new normal': an emerging response to COVID-19. *Journal Of Public Health,* 43(2), pp. 344-345.

Cramer, N., 2017. The Climate Is Changing. So Must Architecture.. *The Journal Of The American Institute Of Architects*, 4 October.

Crowther, P., 1999. Design for Disassembly to Recover Embodied Energy. In: *Sustaining the Future: Energy Ecology Architecture PLEA '99.* Brisbane: PLEA International, pp. 95-100.

Cutieru, A., 2020. A Guide to Design for Disassembly. *ArchDaily*, 10 July.

Cutieru, A., 2021. Framing Indeterminacy: The Incorporation of Uncertainty Into Architecture. *ArchDaily*, 3 December.

Derington, N., 2008. *Ozymandias.* [Art] (Flickr).

DesigningBuildings, 2022. *Geodesic dome.* [Online]
Available at:
https://www.designingbuildings.co.uk/wiki/Geodesic_dome#:~:text=It%20is%20believed%20that%20there,Sports%20stadiums.
[Accessed 8 May 2022].

Drew, P., 1976. *Frei Otto : form and structure.* London: Crosby Lockwood Staples.
EIA, 2018. *2018 Global Status Report,* s.l.: s.n.

F.V, V. J. et al., 2006. Biomimetics: its practice and theory. *J. R. Soc. Interface.,* Volume 3, p. 471–482.

Face, N., 2018. *Geodesic Tensile Tent.* [Art] (https://www.openculture.com/2018/03/buckminster-fullers-collaboration-with-the-north-face-culminates-with-a-new-geodesic-dome-tent.html).
Faegre, T., 1978. *Tents : architecture of the nomads.* New York: Anchor Press.

Falagán, D. H. & Ziaiebigdeli, M., 2022. Parametric Architecture beyond Form—Klein and Price: Pioneers in Computing the Quality of Life in Housing. *Architecture ,* Volume 2, pp. 1-17.

Fankhauser, S., B.Smith, J. & S.J.Tol, R., 1999. Weathering climate change: some simple rules to guide adaptation decisions. *Ecological Economics,* 30(1), pp. 67-78.

Fischer, T. et al., 2012. Rationalisation of Complex Building Envelopes. In: *Beyond Codes and Pixels: Proceedings of the 17th International Conference on Computer-Aided Architectural*

Design Research in Asia. Hong Kong: Association for Computer-Aided Architectural Design Research in Asia , p. 7–16.

Flemons, T., 2018. *Archive.* [Online]
Available at: http://intensiondesigns.ca/about/
[Accessed 11 May 2022].

Foster + Partners, 1998. *New German Parliament, Reichstag.* [Art] (Foster + Partners).
Fox, M., 2016. *Interactive architecture : adaptive world.* New York: Princeton Architectural Press.

Fry, S., 2011. *Smartphones Arms Race.* [Online]
Available at: https://www.stephenfry.com/2011/12/smartphones-arms-race/
[Accessed 16 April 2022].

Fuller, R. B., 1975. *Synergetics : explorations in the geometry of thinking.* s.l.:Collier Macmillan.

Fuller, R. B. & Kuromiya, K., 1992. *Cosmography : a posthumous scenario for the future of humanity.* New York: Macmillan.

Geoship, 2019. *Geodesic Dome House Model.* [Art]
(https://www.gibbsfarm.org.nz/snelson.php).

Giddings, J., 2021. Book review: Architecture From Prehistory to Climate Emergency, by Barnabas Calder. *Architects Journal*, 2 July.

Gomez-Jauregui, V., 2004. Tensegrity structures and their application to architecture. *Thesis for: MSc Architecture*.

Gropius, W., 1965. *The new architecture and the bauhaus.* London: Faber and Faber.
Hebbert, M. J., 2022. *London.* [Online]
Available at: https://www.britannica.com/place/London
[Accessed 13 May 2022].
Helmy, S. E. & Aboulnaga, M. M., 2020. Future Cities: The Role of Biomimicry Architecture in Improving Livability in Megacities and Mitigating Climate Change Risks. In: *Sustainable Ecological Engineering Design.* Cham: Springer International Publishing, pp. 35-49.

Henriksson, V. & Hult, M., 2015. *Rationalising Free Form Architecture,* Sweden: Masters Thesis.

Herdt, T., 2017. *The city and the architecture of change : the work and radical visions of cedric price.* Zurich: Park Books.

Herdt, T., 2017. *The city and the Architecture of change : The Work and radical visions of Cedric Price.* Zurich: Park Books.

Ingber, D., 1998. The Architecture of Life. *Scientific American,* 278(1), p. 30.
Koepnick, L., 2001. Redeeming History? Foster's Dome and the Political Aesthetic of the Berlin Republic. *German Studies Review,* 24(2), pp. 303-323.

Koetsier, J., 2020. *These Carbon-Neutral Bioceramic Geodesic Dome Homes Last 500 Years And Don't Rot, Burn, Or Rust.* [Online]
Available at: https://www.forbes.com/sites/johnkoetsier/2020/04/29/these-carbon-neutral-bioceramic-geodesic-dome-homes-last-500-years-and-dont-burn-or-rust/?sh=58c735bc16cc
[Accessed 12 May 2020].

Langar, S. Z., 2020. Beyond Refugee Housing. *ArchDaily*, 5 May.

Ledwith, A., 2014. *Zaatari: the Instant City.* Boston: Blurb.

Lehne, J. & Preston, F., 2018. *Making Concrete Change,* London: Energy, Environment and Resources Department .

Lucarelli, F., 2016. *Cedric Price 'Housing Research' (1971) and the 'Steel House' (1967).* [Online]
Available at: https://socks-studio.com/2016/04/14/cedric-price-housing-research-1971-and-the-steel-house-1967/
[Accessed 13 May 2022].

Madanipour, A., 2017. *Cities in time : temporary urbanism and the future of the city.* New York: Bloomsbury Academic.

Maganga, M., 2022. Tents: An Architectural Language. *ArchDaily*, 11 April.

Mandanipour, A., 2017. *Cities In Time.* London: Bloomsbury Academic.

Massey, N., 2013. Humans May Be the Most Adaptive Species : Constant climate change may have given Homo sapiens their flexibility. *Scientific American*, 25 September.
Mathews, J. S., 2003. *An architecture for the new Britain : the social vision of Cedric Price's Fun Place and Potteries Thinkbelt.* via 'The city and the architecture of change : The work and radical visions of Cedric Price ed. s.l.:Thesis, Dissertation.

Mathews, J. S., 2007. *From agit-prop to free space : the architecture of Cedric Price.* London: Black Dog Pub.

Mathews, S., 2005. The Fun Palace: Cedric Price's experiment in architecture and technology. *echnoetic Arts: a journal of speculative research,* 3(2), pp. 73-92.
Medina, S., 2017. *Homespun Futurist: The Prescient Projects of Cedric Price.* [Online]
Available at: https://metropolismag.com/viewpoints/homespun-futurist-prescient-projects-cedric-price/
[Accessed 6 May 2022].

Meyer, U., 2015. *Skeletons, Soap Bubbles and Spider Webs.* [Online]
Available at: https://www.world-architects.com/en/architecture-news/insight/skeletons-soap-bubbles-and-spider-webs
[Accessed 11 May 2022].

Milmo, C., 2014. Cedric Price: The most influential architect you've never heard of. *Independent*, 10 November.

Moon, W., 2017. Cedric Price: Radical Pragmatist, in Pursuit of Lightness. *Journal Of Architectural Education,* 71(2), pp. 171-183.

More In Common, 2017. *The New Normal?,* s.l.: s.n.

Murphy, D., 2018. Cedric Price. *Architectural Review.*

myers, l., 2020. *THE NEXT STEP TO AFFORDABLE UTOPIA — GEOSHIP.* [Online]
Available at: https://www.designboom.com/architecture/geoship-worlds-first-ceramic-geodesic-dome-california-01-27-2022/
[Accessed 12 May 2022].

Neufeldt, H. et al., 2018. *The Adaptation Gap Report 2018. United Nations Environment Programme (UNEP), Nairobi, Kenya,* Nairobi: United Nations Environment Programme (UNEP).

Nielsen, P., 2014. Building Bonn : Democracy and the Architecture of Humility. *History of Emotions - Insights into Research*, January.

November, 2018. *Functionalism and Machine Aesthetic of Modern Architecture,* s.l.: https://www.ukessays.com/essays/architecture/functionalism-and-machine-aesthetic-of-modern-architecture-architecture-essay.php?vref=1.

O'Neil, D. D., 2012. *Human Biological Adaptability.* [Online]
Available at: https://www2.palomar.edu/anthro/adapt/Default.htm
[Accessed 20 April 2022].

Otto, F., 1967. *German Pavilion.* [Art] (Photo by Frei Otto).

Pawlyn, M., 2016. *Biomimicry In Architecture.* s.l.:RIBA Publication.

Pereira, M., 2018. Tensegrity Structures: What They Are and What They Can Be. *ArchDaily*, 3 June.

Pires, S., 2021. *My Modern Met.* [Online]
Available at: https://mymodernmet.com/tensegrity-architecture/
[Accessed 17 April 2022].

Potts, R., 1999. Why Are We Human?: Maybe Evolution Favored An All-Terrain Animal.. *The Washington Post,* 14 April.p. 1.

Price, C., 1962. *Fun Palace.* [Art] (Canadian Centre for Architecture).

Price, C., 1962. *Snowdom Aviary Axonometric.* [Art] (Canadian Centre for Architecture).

Price, C., 1963. *Claverton Dome.* [Art] (Canadian Centre for Architecture).

Price, C., 1964. *Snowdon Aviary Under Construction.* [Art] (Canadian Centre for Architecture).

Price, C., 1965. *Pop-up Parliament.* [Art] (Canadian Centre for Architecture).

Price, C., 1967 - 1971. *Housing Research Axonometric.* [Art] (Canadian Centre for Architecture).

Price, C., 1967-1971. *Plans Showing Flexible Floorplan, Housing Research.* [Art] (Canadian Centre for Architecture).

Price, C., 1968. *Archigram 8 - Popular pak.* s.l.:s.n.

Price, C., 1979. *Aerial View of Inter-Action Centre.* [Art] (Canadian Centre for Architecture).

Price, C., 1986. *Why do people have to look up?.* [Art] (Canadian Centre For Architecture).

Price, C., 2003. *The Square Book.* Chichester: Wiley-Academy.

Quin, C. A. C., 2021. *Cybernetic Architectures Informational Thinking and Digital Design.* s.l.:Taylor & Francis.

Ramage, M. & Shipp, K., 2020. *Systems thinkers.* 2nd Edition ed. London: Springer.
Rodgers, L., 2018. *Climate change: The massive CO2 emitter you may not know about.* [Online]
Available at: https://www.bbc.co.uk/news/science-environment-46455844
[Accessed 11 May 2022].

Roorda, R., 2014. Architecture of Weight. In: *New Attitudes.* Amsterdam: Amsterdam Academy of Architecture, pp. 22-36.

Rose, S., 2005. Cedric Price. *The Guardian*, 29 June.

Sant'Elia, A., 1914. *The Futurist Architecture Manifesto.* s.l.:s.n.

Schröder, D. P. et al., 2021. *What is the circular economy?.* [Online]
Available at: https://www.chathamhouse.org/2021/06/what-circular-economy#:~:text=The%20circular%20economy%20is%20an,for%20as%20long%20as%20pos

sible.
[Accessed 22 April 2022].

Scott, M., 2016. Climate and human evolution. *Climate.gov*, 9 November.

Shelley, P. B., 1977. *Ozymandias.* s.l.:Shelley's Poetry and Prose.

Shoemaker, S., 1969. Time Without Change. *The Journal of Philosophy,* 66(12), pp. 363-381.

Simpson, J. A., Weiner, E. S. C. & Press, O. U., 1989. *Oxford English Dictionary.* 2nd Edition ed. Oxford: Clarendon Press.

Smaili, A. & Motro, R., 2005. Folding/unfolding of tensegrity systems by removal of self-stress. *International symposium on shell and spatial structures : theory, technique, valuation, maintenance.,* 6(9), pp. 595-602.

Snelson, K., 1970. *Easy-K.* [Art] (https://www.gibbsfarm.org.nz/snelson.php).
St John's College, University of Cambridge, 2014. *"Anti-building" for the future: the world of Cedric Price.* [Online]
Available at: https://www.joh.cam.ac.uk/anti-building-future-world-cedric-price
[Accessed 16 April 2022].

Stewart, M. G., Wang, X. & Nguyen, M. N., 2011. Climate Change Impact and Risks of Concrete Infrastructure Deterioration. *Engineering Structures,* 33(4), p. 1326–1337.
Synergetic Lattice Field Theory, 2021. *Synergetic Geometry.* [Online]
Available at: https://www.synergeticlatticefieldtheory.org/synergetics.html
[Accessed 9 May 2022].

Tensegritywiki, 2019. *Frei Otto.* [Online]
Available at: https://tensegritywiki.com/wiki/Otto,_Frei
[Accessed 11 May 2022].
The Bartlett, 2021. *Remaking steel for a net zero carbon circular economy.* [Online]
Available at: https://www.ucl.ac.uk/bartlett/news/2021/sep/remaking-steel-net-zero-carbon-circular-economy
[Accessed 6 May 2022].

The Citcularity Gap Report, 2021. *https://www.circularity-gap.world/2021,* s.l.: Circle Economy.

The Hyatt Foundation, 2021. *Anne Lacaston and Jean-Phillippe Vassal Biography.* [Online]
Available at: https://www.pritzkerprize.com/laureates/anne-lacaton-and-jean-philippe-vassal
[Accessed 3 May 2022].

The Hyatt Foundation, 2022. *Biography: Frei Otto.* [Online]
Available at: https://www.pritzkerprize.com/biography-frei-otto
[Accessed 11 May 2022].

The world is poorly designed. But copying nature helps.. 2017. [Film] Directed by 99Percentinvisible. United States of America: Vox.

TransMetal, 2021. *How To Start Recycling Steel.* [Online]
Available at: https://transmetal.co.uk/how-to-start-recycling-steel/#:~:text=Steel%20can%20be%20recycled%20indefinitely,or%20buildings%20it's%20used%20in.
[Accessed 13 May 2022].

UKGBC, 2022. *Climate Change.* [Online]
Available at: https://www.ukgbc.org/climate-change-2/
[Accessed 20 April 2022].

UNHCR, 2021. *UNHCR's Refugee Population Statistics Database,* s.l.: UNHCR.

United Nations Environment Programme, 2021. *Emissions Gap Report 2021 ,* Nairobi: s.n.

United Nations, 2019. *The Climate Crisis - A Race we can Win,* s.l.: UN75.

Veltkamp, M., 2007. *Free form structural design : schemes, systems & prototypes of structures for irregular shaped buildings.* 6 ed. Amsterdam: IOS Press.

Whelan, R., 1981. Kenneth Snelson, Straddling the Abyss Between Art and Science. *Art News*, February .

Wigley, M., 2017. *An Afternoon with Cedric Price #2: Mark Wigley,* s.l.: CCAChannel.

Wilkinson, C. & Eyre, J., 2001. *Bridging Art and Science : Wilkinson Eyre.* 1st Edition ed. s.l.:Booth-Clibborn Editions.
Woetzel, J. et al., 2020. *Will infrastructure bend or break under climate stress?,* s.l.: Mckinsey Global Institute.

World Meteorological Organisation, 2021. *State of Climate in 2021: Extreme events and major impacts,* s.l.: WMO.