RAMBOLL

DESIGN

EXCELLENCE
2023 - 2024

this book is dedicated to all designers who persist in their pursuit of DESIGN.

…to those who adapt their design principles and priorities to aid in addressing environmental challenges.

…to those who carefully blend conventional design elements such as safety, functionality, constructability, scale, harmony, and purpose, with environmental considerations like water, air, biodiversity, soil, and ecology, aiming to shape a world that is not only aesthetically delightful, intentionally purposeful, and harmoniously proportioned, but also environmentally regenerative.

…to all who embody the spirit of innovation and creativity…

…to all rambollians, past and present… everywhere…

Ramboll DESIGN Excellence 2023 - 2024

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The Sponsor's Note

"This book is a contribution to the ecosystem of thought and purposeful design; design that includes yet transcends the theoretical boundaries of thought. One that feels responsible, and has at its core a sense of purpose to address the environmental and other complex problems/ challenges of our time. In Ramboll, we make a conscious effort to view these challenges in a systemic manner in the real world and on every project. This book, and other Ramboll Design Excellence Publications form an integral medium of formulating, applying, and communicating ideas that are relevant now and into the future."

Søren Brøndum, July 2023,
Copenhagen

Søren Brøndum

Managing Director,
Ramboll Buildings

Øresund Bridge
A landmark spanning the major crossing between Denmark and Sweden has transformed the Malmö-Copenhagen area into a thriving region.

Prologue:

"this book is a collection of essays and articles written by various rambollians on contemporary topics relating to design, environment, technology, and leadership throughout 2023 and 2024. it follows in the footsteps of Ramboll Design Excellence 2022 book, which addressed similar topics following the inaugural Ramboll Design Excellence Forum held in October 2022. this and other periodical publications written and shared throughout the year form part of the ecosystem of thought developed in Ramboll, as our contribution to finding meaningful and effective solutions to the complex problems of our time; the challenges of purposeful design to help achieve congruency between the built and the natural environment."

hossein rezai-jorabi

global design director,
ramboll

Cirkelbroen is 40 metres long with a clearance height of 2.25 metres when closed, allowing Canal tour boats and other low vessels to pass under the closed bridge. When it opens, there are no height limitations. An estimated 5,000 cyclists and pedestrians use the bridge every day.

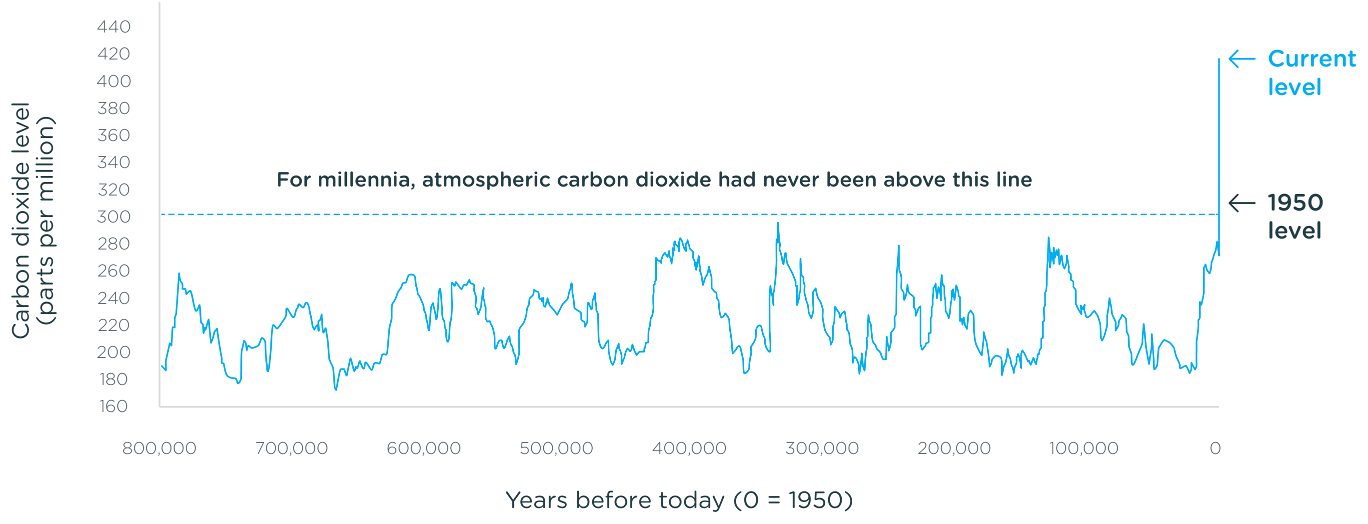
Of Delayers and Delayers...

The widespread debate on environmental indicators and the role of design in directing these toward the desired future is ripe within the industry and beyond. However, every environmental indicator is currently running in the "wrong" direction. Greenhouse gases continue to increase. Currently running at 424ppm (Data source: NOAA Feb 2024) in the atmosphere, it is well beyond anything the planet has ever experienced.

Even accounting for the 100,000-year cyclical variations derived from ice cores. For millennia, atmospheric carbon dioxide had never been above 300ppm.

The key issue is the solar energy received by the Earth's surface, which is 342 W/m² (on average), is not allowed to radiate back and leave the Earth's atmosphere.

Measurements indicate that only 339W/m² radiate out, leaving 3W/m² in the atmosphere, which leads to the continual warming of the planet. (increased GHGs in the atmosphere which increase the heat getting reflected back down).



There are 2 key reasons for this entrapment of heat:

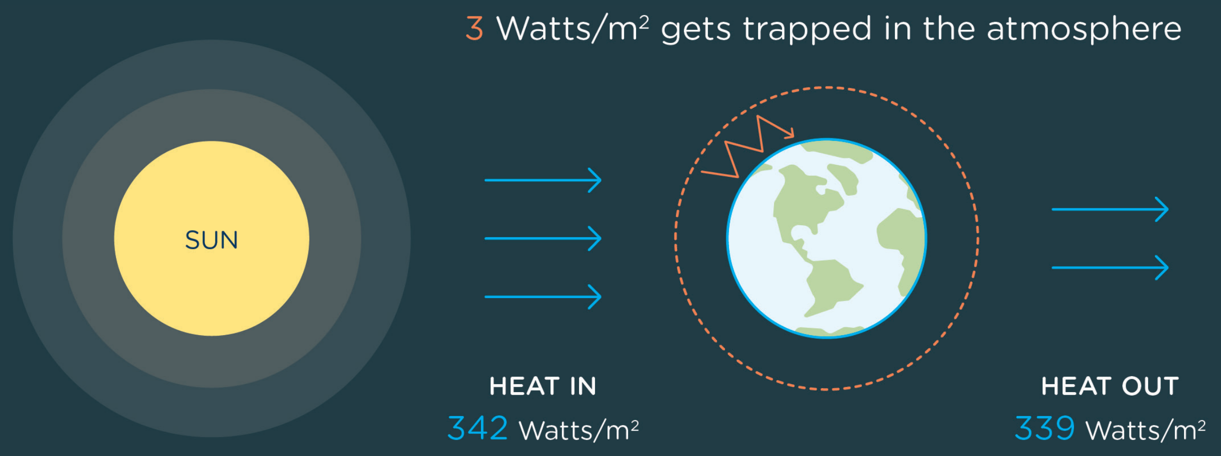
Warming of the surface of the planet, partly due to hard surfaces resulting from the development and expansion of cities and infrastructure, but majorly due to deforestation.

Concentration of greenhouse gases in the atmosphere creates an unintended "blanket" trapping the radiant heat off the surface of the planet.

One good news is that we are aware of the mechanisms termed "Global Warming", and we have known these for at least 100 years since the early 20th century. Another good news is that the 3W/m² is a rather small percentage (<1%) of the total incoming energy, whereas over 99% leaves the planet unimpeded.

Focus on carbon dioxide and the other greenhouse gases in the atmosphere is significant in this entrapment. Water vapor is also a significant GHG responsible for 60-70% of the greenhouse gas effect. It is a condensable gas, making it complex to measure, model, or manage. As the atmospheric temperature rises, it creates positive feedback for the air to hold more water. Thus, the concentration of water vapor increases as a secondary effect causing the atmosphere to warm even more.

Carbon dioxide, however, causes about 20% of the Earth's greenhouse gas effect. There are other GHGs such as methane (CH4), Nitrous oxide (N2O), and Fluorinated gases such as Hydrofluorocarbons (HFC), Perfluorocarbons (PFC), Sulfur Hexafluoride (SF6), and Nitrogen Trifluoride (NF3).



System Thinking

A “systems view of life”, also called living systems thinking, is one that creates an eco-system. It is about seeing the connections that do exist in an eco-system, rather than having a myopic view of the process or parts thereof. Integrated design is acknowledging that design and creative processes are indeed integrated into a “whole”. It is “holistic”.

Contributing writer:
Hossein Rezai-Jorabi
Katri Einola

01

Our world is facing complex and wicked problems (such as climate change, energy, social inequality, biodiversity loss, etc) and tackling these separately no longer work as these systemic problems are all interconnected and interdependent.

Systems thinking can provide a broader, interconnected, and holistic view to solving the challenges and bringing more creative, multidisciplinary, balanced, adaptable, and permanent solutions...

It's about thinking in terms of relationships, connectiveness, patterns and context.

"The world is a complex, interconnected, finite, ecological - social - psychological - economic system. We treat it as if it were not, as if it was divisible, separable, simple, and infinite. Our persistent, intractable global problems arise directly from this mismatch."

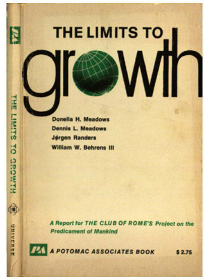
Donella Meadows

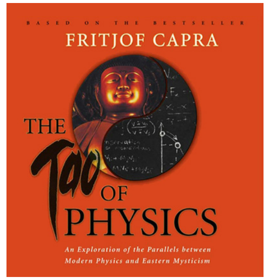
A brief history of System Thinking

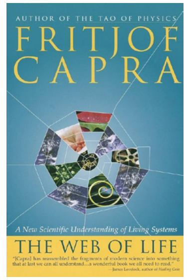
The origins of system thinking can be traced back to the early 20th century with Alexander Bogdanov, a Russian philosopher, who proposed a holistic approach to organically integrate diverse disciplines. Gregory Bateson, an English anthropologist, expanded on these ideas in the mid-20th century by emphasizing the interconnectedness and interdependence of systems in nature and society.

In the 1970s Donella Meadows, a prominent environmental scientist, further popularized system thinking with the book "Limits to Growth," where she and a group of researchers at MIT applied systemic approaches to address global environmental challenges. Fritjof Capra, a quantum physicist and writer of the highly acclaimed book "The Tao of Physics", merged system thinking with deep ecological principles in his book "The Web of Life", highlighting the interconnectedness and complexity of natural systems.

Overall, the evolution of system thinking has been deeply influenced by the works of these visionaries and many others, including Anatol Rapoport, a Soviet physiologist and psychologist, Russell Ackoff, an architect and system educator; and others. Their insights have played a significant role in the development and popularization of system thinking, shaping how we perceive and address complex issues in various fields ranging from ecology and economics to organizational management and social dynamics. By understanding the interconnectedness and interdependence of systems, we can better address the complex challenges facing our world today.







It is noteworthy that most of these pioneering and leading system thinkers tend to come from professions like psychology, physiology, biology, and similar topics talking about life and the way natural phenomena relate to one another. This is a clear indication of how the study of the natural environment instills in one a feeling of connectedness, and how nature is the ultimate system of systems.

A tendency that, to a large extent, still prevails among contemporary system thinkers.

Anthropologists, humanities, life sciences, and scientists, in contrast to management consultants and leadership gurus!

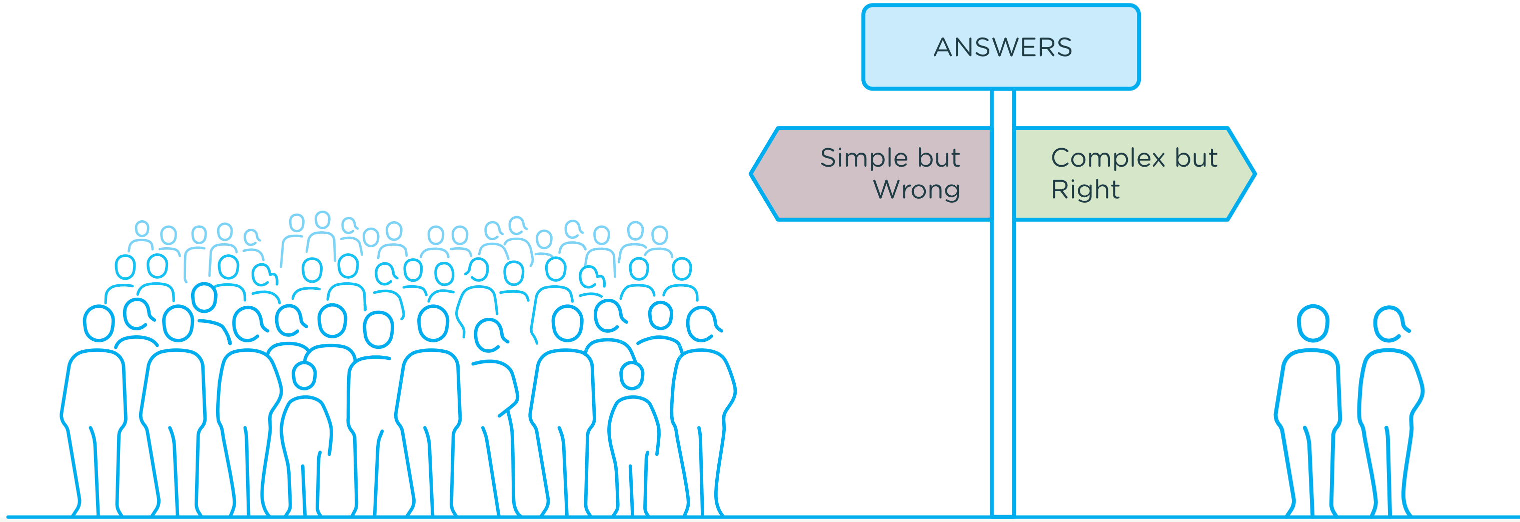
Why do we need System Thinking?

We need System Thinking because life is complicated.
Or is it complex, chaotic, or disorderly?

Simple	**Known Knowns:** simplicity, cause and effect, often an obvious answer exists to be found.
Complicated	**Known Unknowns:** often more than one correct answer, to be found and selected by the leader.
Complex	**Unknown Unknowns:** right answers must be constructed through experience and exploration, the realm of most contemporary business leadership decisions.
Chaotic	**Unknowables:** no answer to be found; leaders must not look for solutions but for stability, then nudge the context towards complexity.
Disorderly	**Mixture of Above 4:** summarily sack the leader who's led the team to this context.

> “ If everything in the universe depends upon everything else in a fundamental way, it might be impossible to get close to a full solution by investigating parts of the problem in isolation.”

Stephen Hawking



“For every complex problem, there is a simple answer that is wrong.”

“We need to embrace complexity.“

Inspired by
wileyink@earthlink.net

The Tyranny of Simplicity

"If we have system of an improvement, that's directed at improving the parts taken separately. You can be absolutely sure that the performance of a whole will not be improved."

Russell L. Ackoff

Our obsession with simplicity, and with looking for simple answers regardless of the context of the problem, must stop. Criticism and debate of the traditional encouragement and incentivisation of simple and simplicity. How do we refer to simple answers as good. How do we incentivise people who come up with simple answers.

We now understand that complex problems do not have simple answers. Our complex problems have therefore grown and transformed into dilemmas and "wicked problems" of our time.

Wicked Problems and Dilemmas

A dilemma is a problem that exists in one system within which there is no solution to it. Solving dilemmas requires a system change; to create a system within which this problem does not exist, or has a solution.

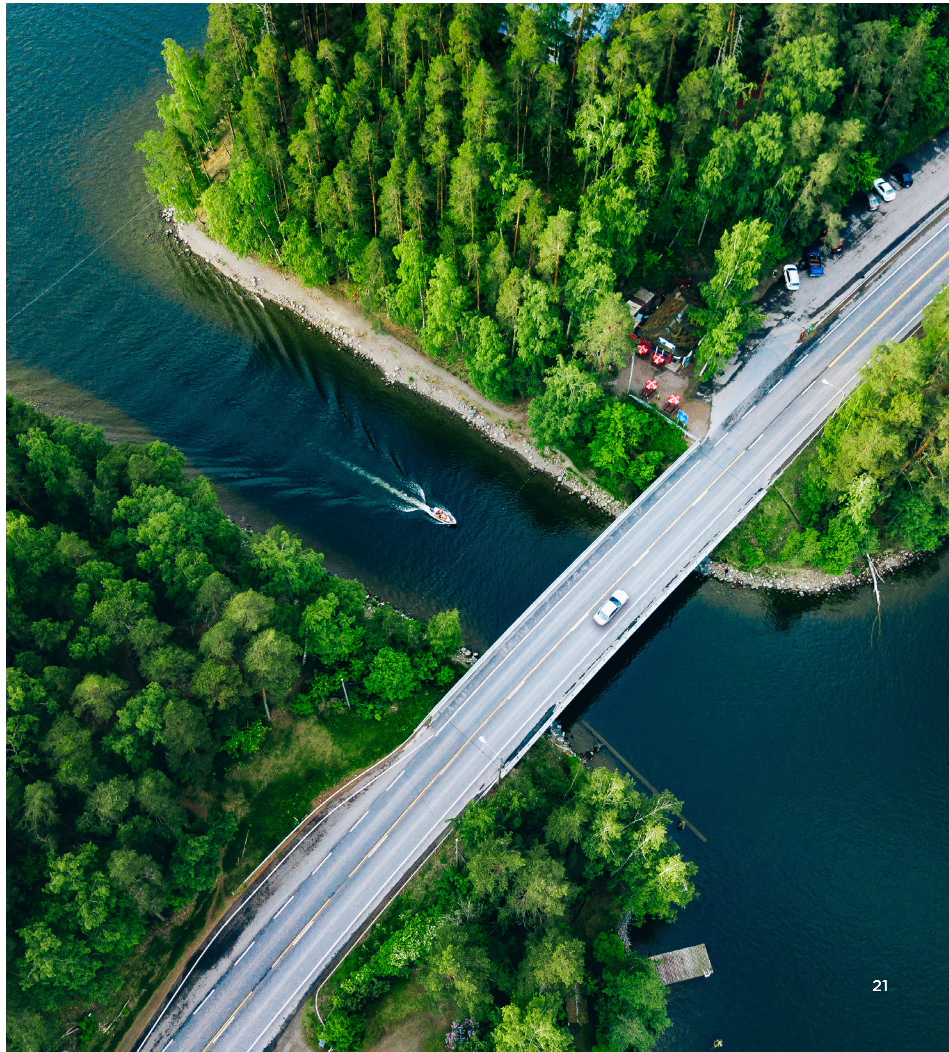
Solutions to wicked problem in one system, only exist inside another system; adjacent or far. So, to solve wicked problem or dilemma, one needs to understand the system within which the problem resides, as well as the system within which the solution may exist.

When Einstein mentioned "problems can not be solved at the same level of consciousness that created them", he was in fact referring to wicked problems.

„You do not rise to the level of your ambition...

...you fall to the level of your system."

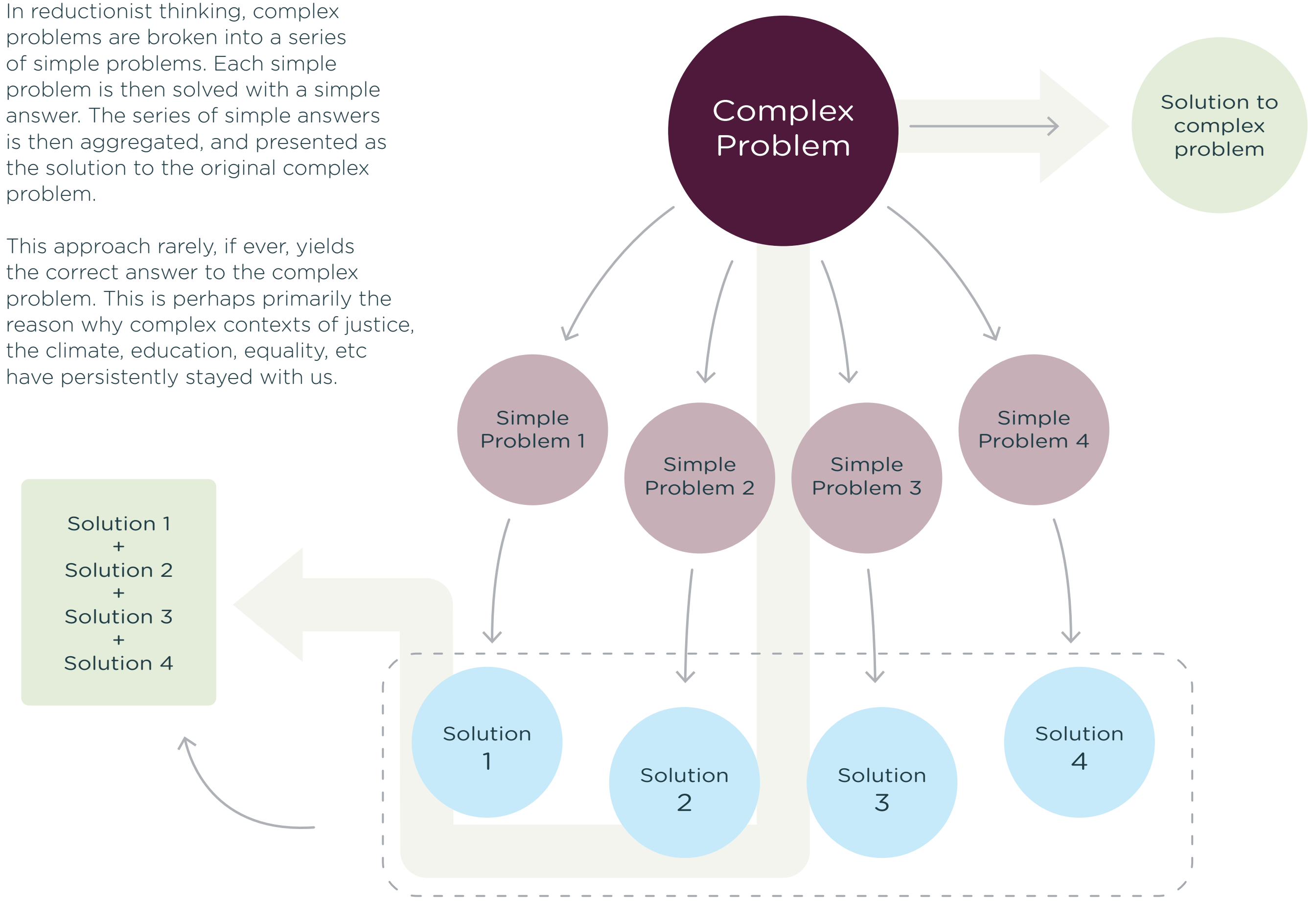
James Clear



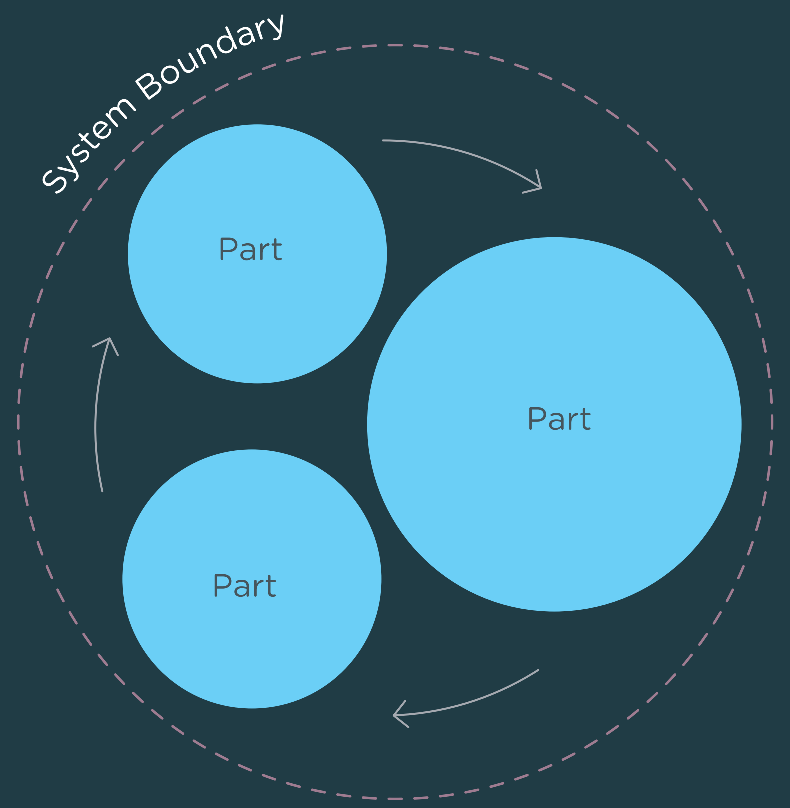
Reductionism VS System Thinking

In reductionist thinking, complex problems are broken into a series of simple problems. Each simple problem is then solved with a simple answer. The series of simple answers is then aggregated, and presented as the solution to the original complex problem.

This approach rarely, if ever, yields the correct answer to the complex problem. This is perhaps primarily the reason why complex contexts of justice, the climate, education, equality, etc have persistently stayed with us.



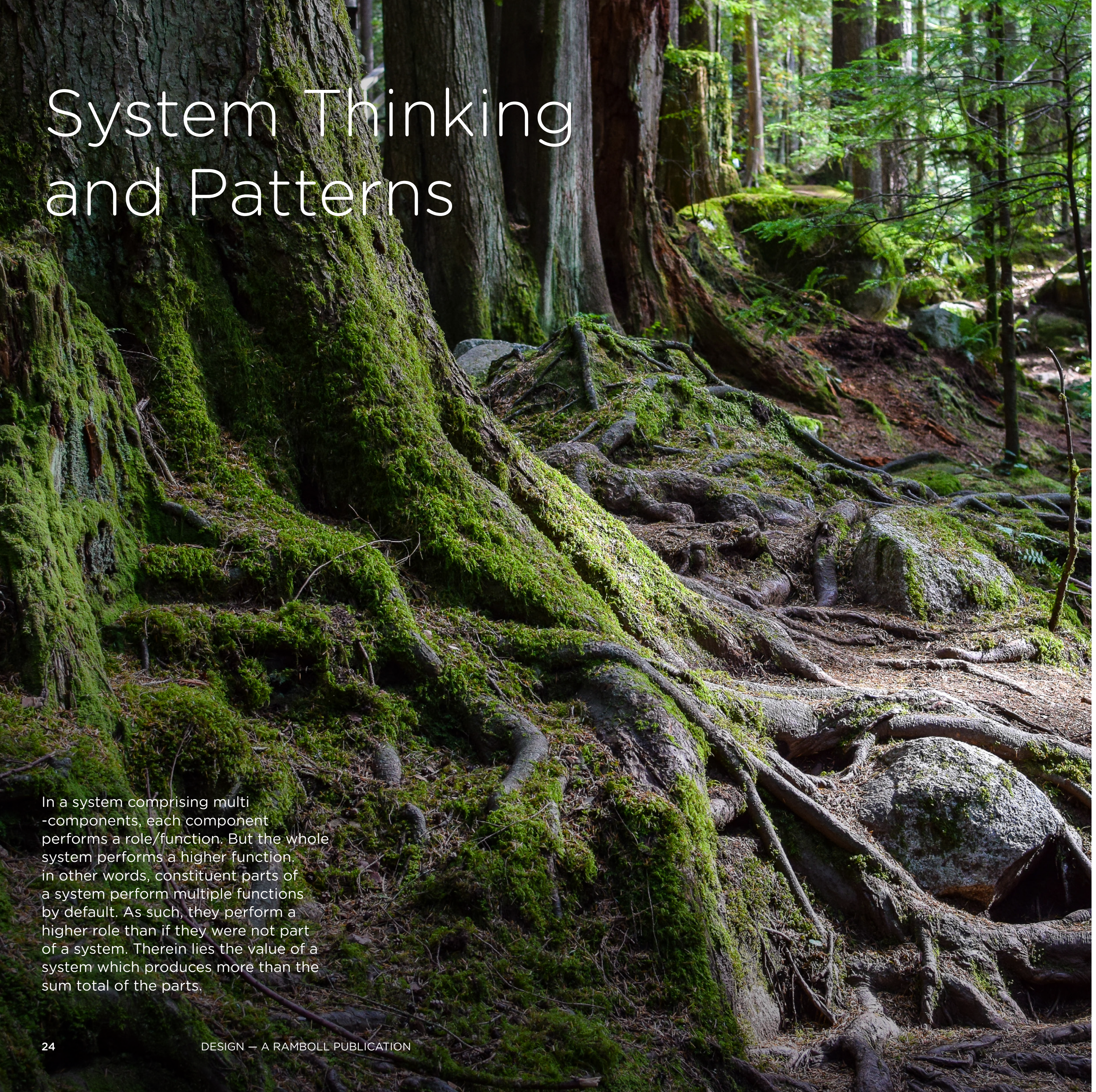
System Boundaries



Systems have no hierarchy, nor do they have a "foundation"! Every component is key in delivering the system outcome. If it were not, then it would not be part of the system but exists outside the boundary of that system. If a system could deliver the same outcome without a component, then that component is not part of that system!

The metaphor of foundations, pillars, support, etc which come from structural engineering, do not apply in system thinking.

System Thinking and Patterns



In a system comprising multi -components, each component performs a role/function. But the whole system performs a higher function. in other words, constituent parts of a system perform multiple functions by default. As such, they perform a higher role than if they were not part of a system. Therein lies the value of a system which produces more than the sum total of the parts.

Resilience and Circularity

Circularity is part of resilience.

Resilience is dynamic.

Dynamic systems are nonlinear.

At one end of any nonlinear system, there is a potential singularity.

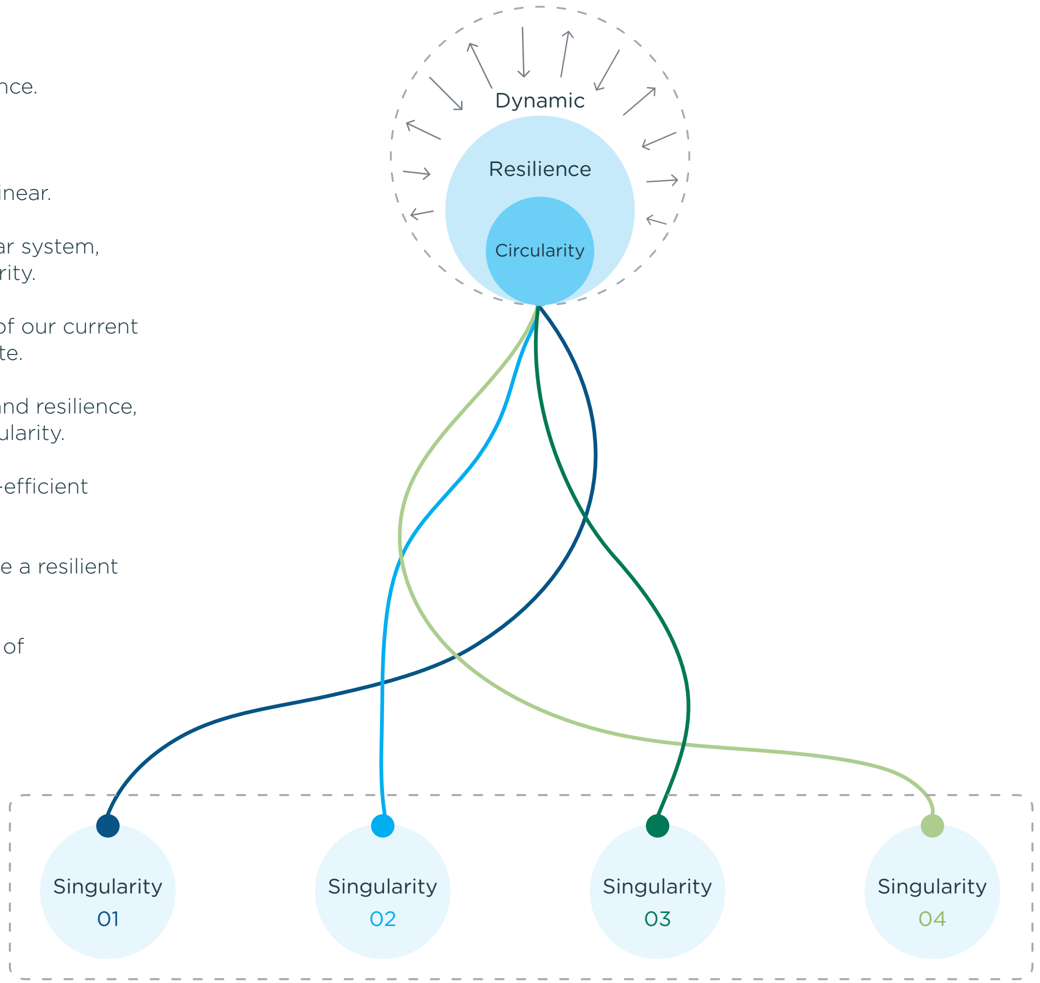
Singularity is where none of our current processes and tools operate.

To understand circularity and resilience, one must understand singularity.

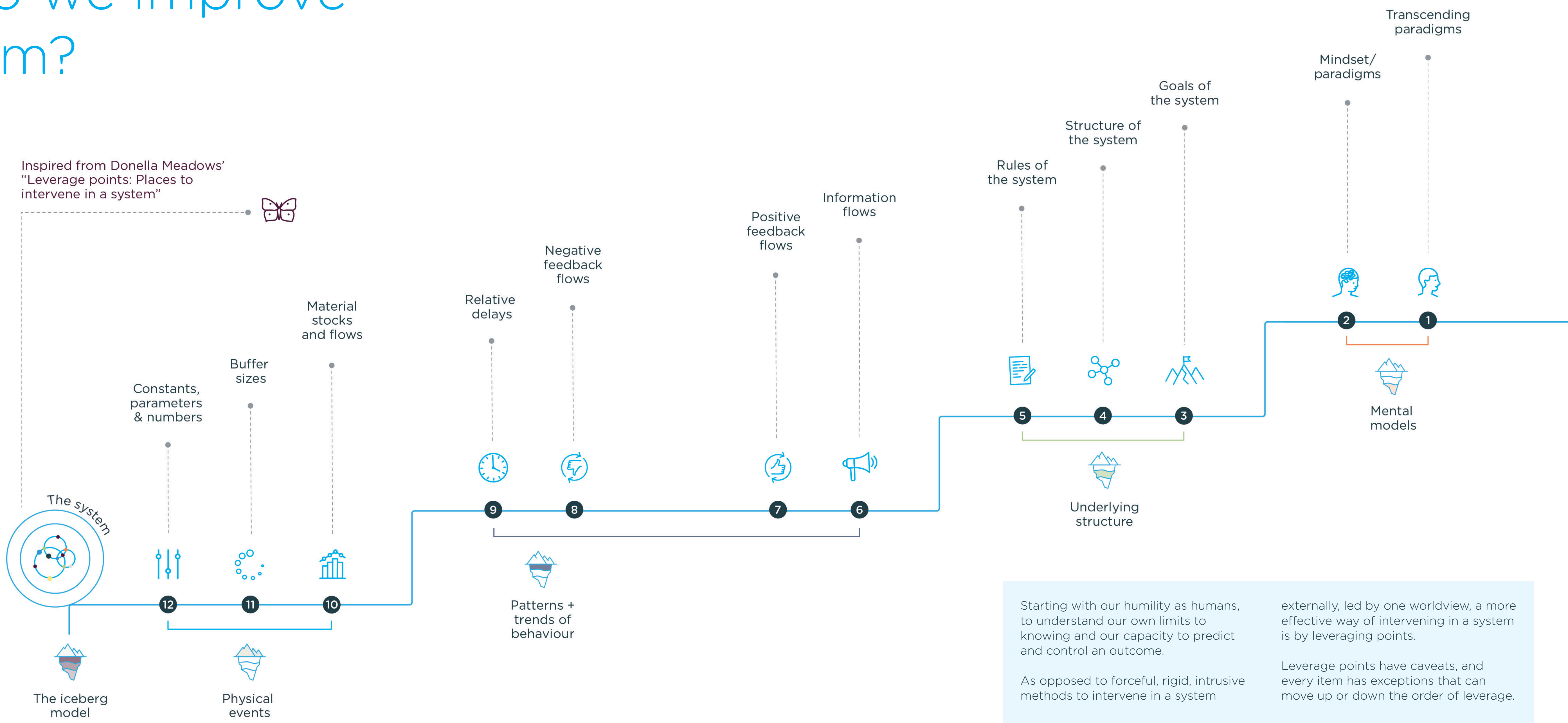
A resilient system is a non-efficient system.

Or "we can always optimise a resilient system".

Resilience is the antithesis of efficiency.



How do we improve a system?



12 leverage points to intervene in a system
Just like acupuncture, we look for high-potential leverage points to create significant shifts in a system.

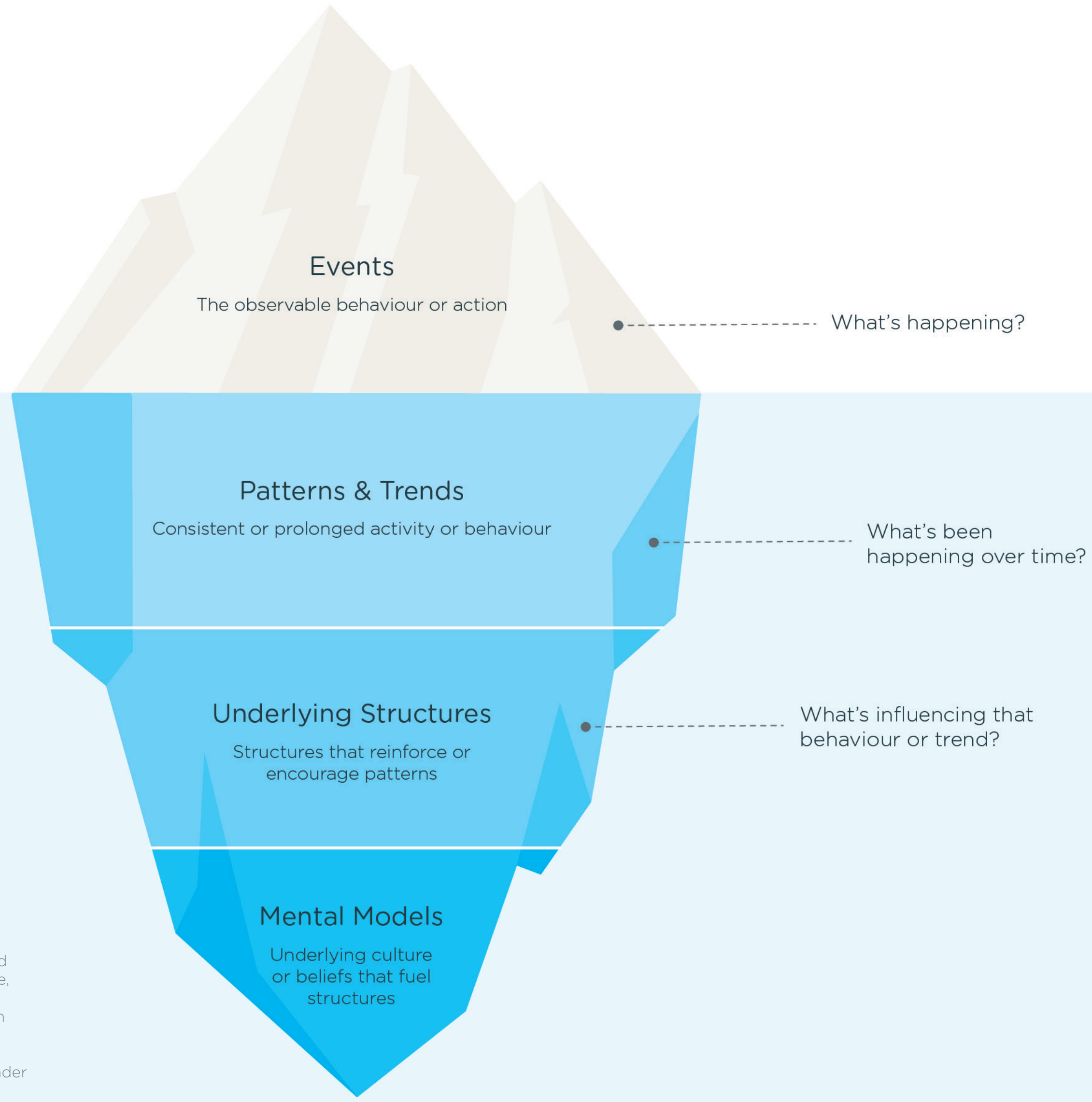
Source: Ramboll, adapted from Meadows, 1999

Starting with our humility as humans, to understand our own limits to knowing and our capacity to predict and control an outcome.

As opposed to forceful, rigid, intrusive methods to intervene in a system externally, led by one worldview, a more effective way of intervening in a system is by leveraging points.

Leverage points have caveats, and every item has exceptions that can move up or down the order of leverage.

The Iceberg Model



An iceberg model
The layers of system thinking: visible events and patterns above the surface, and underlying structures and mental models hidden beneath.

(Inspired from The pathfinder coach)

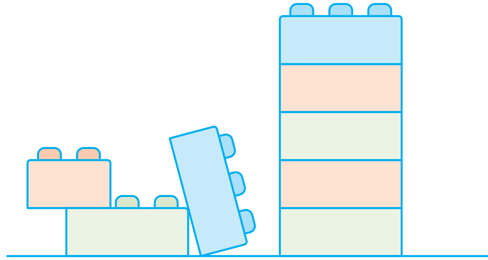
The Duality of System Change

Inherent in most systems is a resistance to change. If a new component is added to a system, the rest of the system wants to reject it. Interventions in existing systems that are dancing in balance tend to trigger a natural resistance to that which is new and alien.

Organ transplant in humans or other biological systems, is a clear example of such resistance to interventions. The rest of the body tends to reject the new organ. We now know that further interventions, in the form of additional medication, are required in order to rebalance and attenuate such system resistance. Design decisions that we make and implement within the built environment are by default interventions in the existing natural systems. A dilemma, therefore, arises when we design, as any design is in fact an intervention. This questions the concepts of co-creation with nature, unless we fully align with nature. Partial integration and co-creation will have elements of intervention which will be rejected.

Co-creation, therefore, may need to occur at a much higher level of a new system creation, rather than tweaking the existing, which is oxymoronically impossible!

System restoration is different, in that it identifies the previous interventions, and sets out to eliminate them. You solve a complex problem by changing the context or the framework within which they exist and thrive. You don't solve them by first order tackling them.



Cities as Systems of Systems

Cities – developed by people – are dynamic adaptive systems that consist of different layers from mobility sub-system to social systems that each form a part of the bigger system that is the city. Within and through these are other sub-systems that are interconnected to each other, which makes cities 'systems of systems'

Recognizing these interlinkages and the points of leverage can help to build resilient and regenerative living environments for the future. This requires holistic living systems thinking.

In many indigenous cultures, holistic, systemic, and symbiotic view of life by default understood as the basis for daily life and its processes. In contrast, especially in the Western world, we are trained differently. Many times, we have a reductionist view where we try to simplify complexity into parts and fix only the parts, not thinking of the whole system. This applies well to engineering...

Ramboll Design System

The Ramboll Design System (RDS) is composed of three pillars: Purposeful design, Regenerative designand Augmented design. The three pillars are inseparable and integral parts of one whole with symbiotic relationships between them.

Contributing Writer:
Hossein Rezai-Jorabi

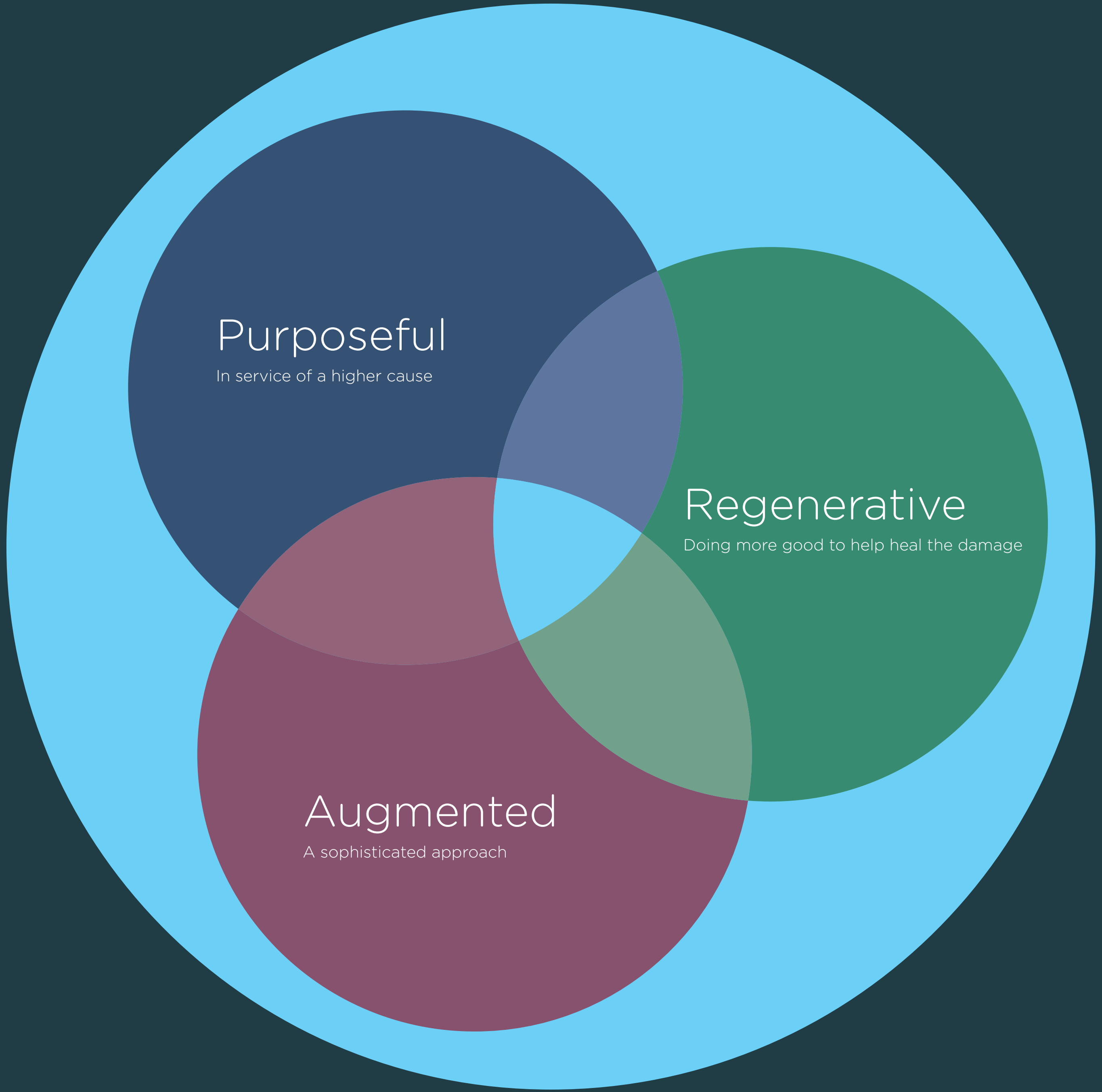
02

Paramit - Factory in the Forest
A competition winning entry for an electronics manufacturing plant. This site is conceived as a forest that penetrates, surrounds & steps over the building creating maximum contact with nature - green, breeze, scent, sound, touch. A canopy supported by a 'forest' of columns creates unity to office & courtyard while giving protection from the tropical sun. Office levels give access to roof gardens and staff are encouraged out for breaks, meetings or just contemplation.

Sustainability
is a goal. An ambition.

Innovation
is a tool.

Design
is the enabler that harnesses the power of innovation to help achieve the sustainability goals and ambitions.



The Ramboll Design System

The Ramboll Design System (RDS) is composed of three pillars: Purposeful design, Regenerative design and Augmented design.

The three pillars are inseparable and integral parts of one whole with symbiotic relationships between. It does not see design for design purposes, nor technology in islolation, or aims to achieve sustainability goals through sustainability (which won't be possible, nor achievable).

Design Excellence is the PURPOSE. This is about the quality of what we deliver to our clients — What we must do better than the competition.

Digitalization is The ENABLER to deliver design excellence and meet sustainability targets by increasing efficiency in the design process and quality in the product.

Sustainability is a set of design CRITERIA that defines the ambition of the design and its environmental, social, and financial impact

Our design is **purposeful**

Our design is Purposeful Design. It does not celebrate itself. It is not vain. It is not about aesthetics, nor iconic or beautiful, though our buildings can have all three attributes.

But our design is purposeful at the core. It sets "solving the challenges facing humanity and the planet" as its ultimate purpose. These challenges are numerous, but five of these can be listed as follows, as depicted in the Ramboll Design Rosette.

1 – Design as an integrator: to bind our efforts and resources within Ramboll together, and to ensure that the best of Ramboll comes out of every Ramboll project, no matter where we operate. as depicted in the Ramboll Design Rosette.

2 – Design as an enabler: to help achieve our sustainability and environmental goals.

3 – Design as an optimizer: to help ensure that all our designs are fully optimized vis-à-vis efficient use of materials and the ultimate cost of the projects we deliver.

4 – Design as a profit maximiser: to help increase our productivity, efficiency and profit (see McKinsey design index, MDI).

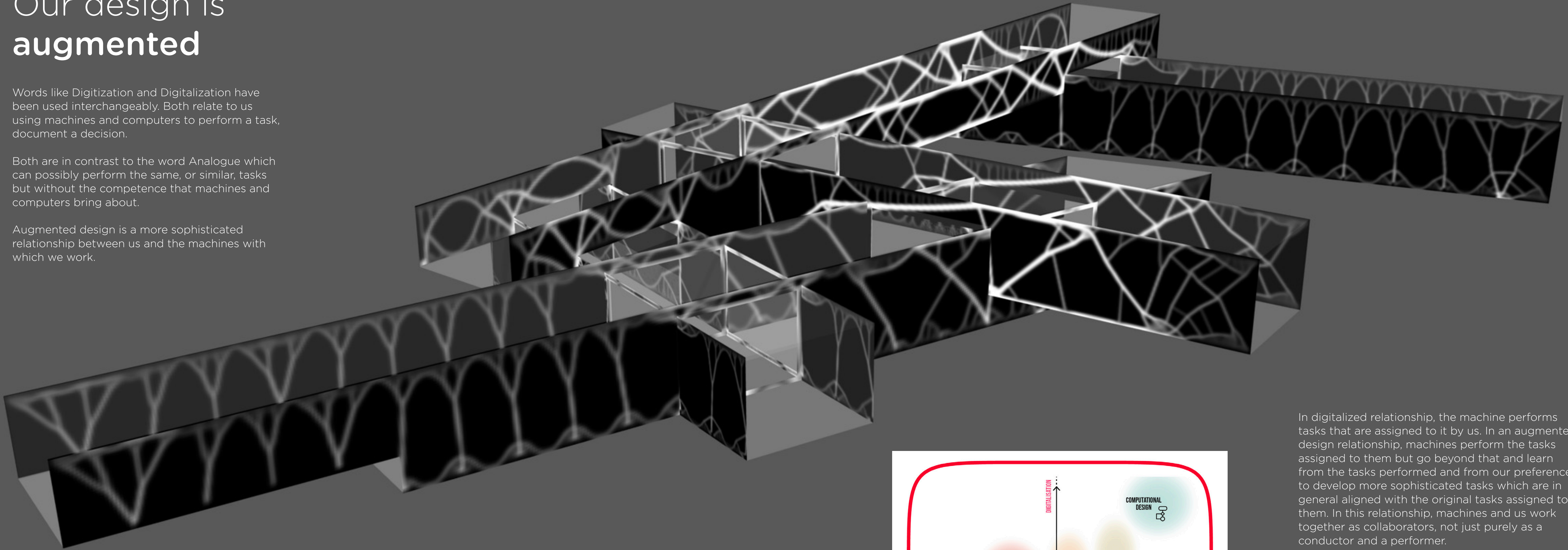
5 – Design as an Influencer: to help enhance our influence across the industry. To elevate the valour and position of the engineer in the society at large to help attract bright minds to our industry and to make it more attractive to the younger engineers and those planning for their tertiary education.

Our design is **augmented**

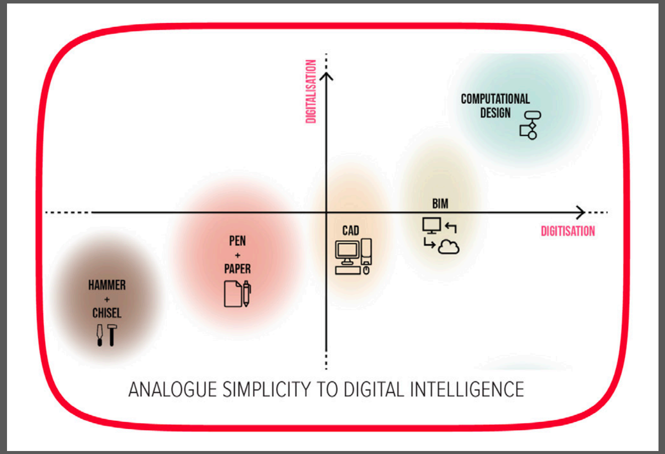
Words like Digitization and Digitalization have been used interchangeably. Both relate to us using machines and computers to perform a task, document a decision.

Both are in contrast to the word Analogue which can possibly perform the same, or similar, tasks but without the competence that machines and computers bring about.

Augmented design is a more sophisticated relationship between us and the machines with which we work.

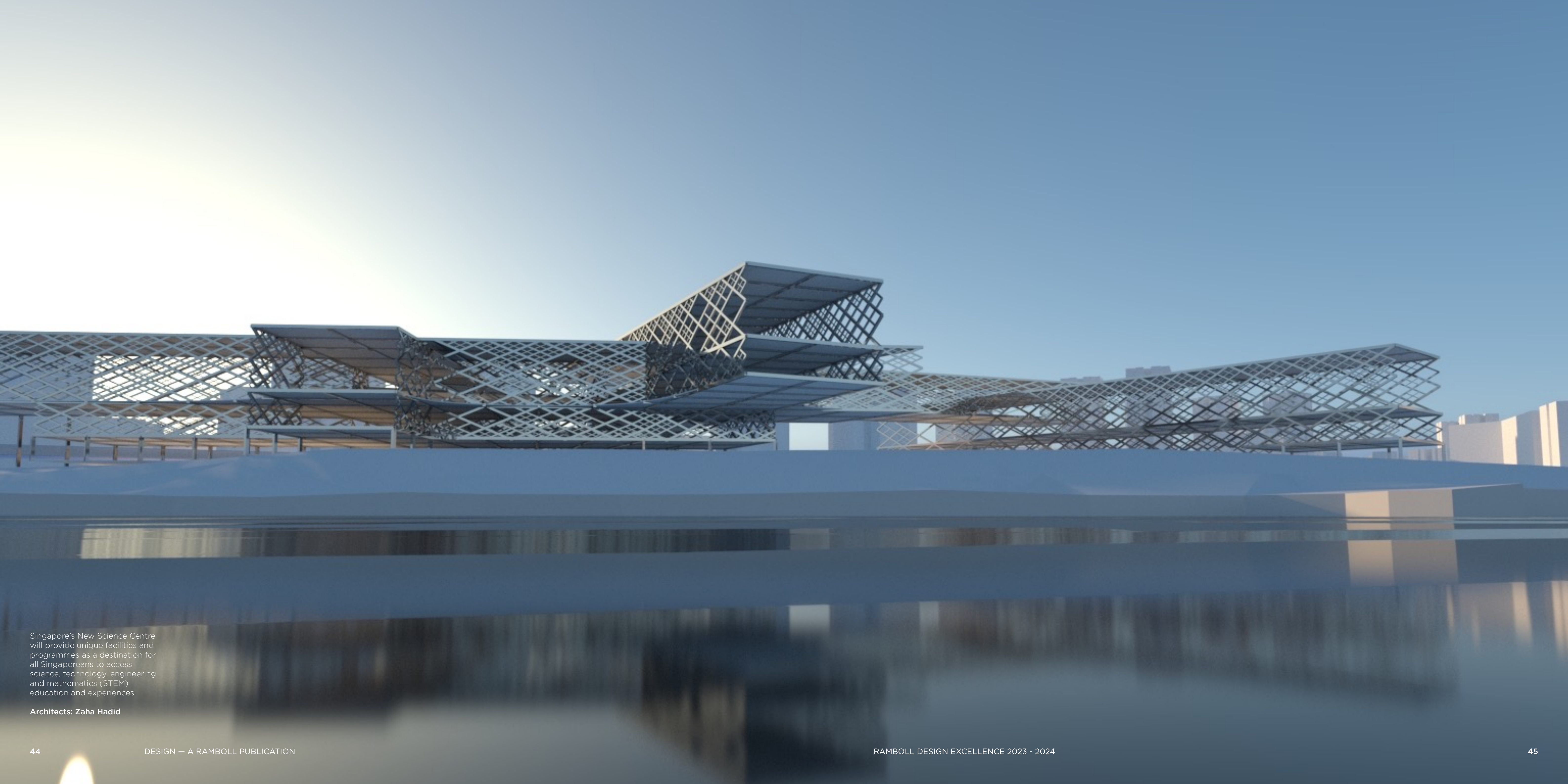


New Science Centre – Singapore: A topological optimisation algorithm was used to calculate the most efficient load paths for each façade of the building, taking into account differing programme loads and support conditions. This image shows the final result of this process, with white indicating the most optimal location for structural members and black indicating the least. This method minimises material usage and waste.



In digitalized relationship, the machine performs tasks that are assigned to it by us. In an augmented design relationship, machines perform the tasks assigned to them but go beyond that and learn from the tasks performed and from our preferences to develop more sophisticated tasks which are in general aligned with the original tasks assigned to them. In this relationship, machines and us work together as collaborators, not just purely as a conductor and a performer.

In the design arena, a higher form of augmented design is a "Digimetric" workflow where the entire design process from conceptualization through to detailed development and documentation happen in a seamless workflow where we are more in control at the earlier stages of thinking, conceptualizing and decision making, while the machine is more in control at the later stages of detailed design, documentation and visualization.



Singapore's New Science Centre will provide unique facilities and programmes as a destination for all Singaporeans to access science, technology, engineering and mathematics (STEM) education and experiences.

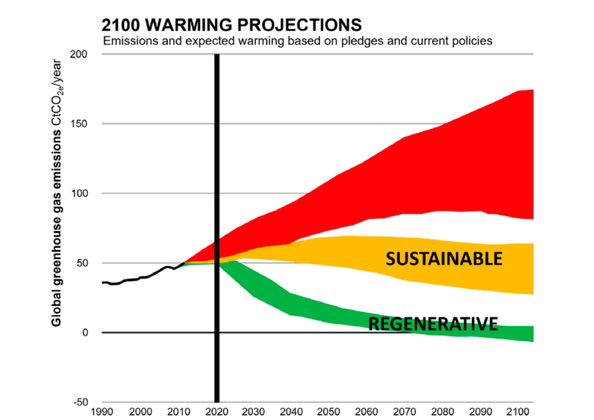
Architects: Zaha Hadid

Our design is **regenerative**

Regenerative Design and thinking are predicated on the fact that a “Degeneration” has taken place. This is particularly in relation to environmental degradation, and especially since the advent of the industrial revolution over the past 200 years.

The contrast with sustainable design is that sustainability is founded on two flawed premises: one is that the natural environment is a “resource” that we have unfettered access to. The other that we ought to use these natural resources in a measured and controlled manner such that we leave enough for the future generations to continue to use same.

In effect our sustainability efforts have been limited to “being less bad, and doing less harm” to the natural environment. In contrast, regenerative design is based on “doing more good to help heal the damage” hitherto inflicted on the natural environment.



CO2 EMISSIONS TRENDS AND HOW TO CHANGE THEM

Regenerative Worldview

Regenerative Design is a system-based approach to our relationship with the environment. The approach sets to improve the environmental indicators while responding to the need for development. In a regenerative environment, every building/project sets to roll back the environmental degeneration that has happened over the years.

Contributing Writers:
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Lars Ostenfeld Riemann

03

Future of sustainability is in Regenerative Design, in systems thinking and in creating ecological civilizations

The story of our journey in the past 300 years has been one of separation from the natural environment and from the natural workings of the food chain.

Our built environment has been developed at a rapid pace and in contrast to the natural environment. The resulting impact has been one that has caused tremendous amount of damage to the planet, its ecology and biodiversity, as well as to the definition of justice; both inter-homo-sapien and inter-species.

We are probably the first generation of humans who live at the intersection of a viable past and a collapsing future. In this context issues of justice, design and resilience hold key and determining positions in the way they help us change this course towards a future that flourishes and supports us and the environment which we influence; the change is from a "quasi-sustainable" past to a "regenerative" future.

Environmental resilience, social resilience and intellectual resilience are issues that we rightly apply a lot of our attention and energy to.

Architects, engineers and other design professionals in our industry are no longer busying themselves with the outdated mantras of "client centricity" and "decarbonization", per se, but are continuously innovating on the curve of "climate centricity" and "regenerative design".

The Regenerative High-rise (Haptic Architects and Ramboll)
Modular timber-composite tower designed for future adaptability and flexibility, removing the need for demolition and increasing the building's longevity

Regenerative Worldview

Regenerative Design is a sub-section to Regenerative Thinking, which in turn is part of Regenerative Worldview. In this new paradigm, new language, culture, and value system evolve.

Ecosystem of a Regenerative Worldview

The First Nordic Swan Ecolabel Primary School in Denmark
In collaboration with SKALA Architects, BO-HUS, ETN Arkitekter, Autens and MOE, Henning Larsen and Ramboll have won the competition for a new school in Sundby on Lolland-Falster. With the awarding of the Nordic Swan Ecolabel, the school ensures both a healthy and productive learning environment for all its students.

The New School has been awarded the Nordic Swan Ecolabel, making it the first Primary School in Denmark to achieve this status. The label is awarded based on a variety of environmental considerations that include both sustainability factors such a low-emissions, energy consumption, and waste as well as other health factors such as ventilation, daylight, noise, and chemical exposure.

Regenerative Design

Regenerative design and thinking are predicated on the fact that a “degeneration” has taken place. This is particularly in relation to environmental degradation, and especially since the advent of the industrial revolution over the past 200 years.

The regeneration process is one that goes back to a state prior to degeneration, and attempts to bring about that state into the future. The contrast with sustainable design is that sustainability is founded on 2 flawed premises: one is that the natural environment is a “resource” that we have unfettered access to. The other that we ought to use these natural resources in a measured and controlled manner such that we leave enough for the future generations to continue to use same.

In effect our sustainability efforts have been limited to “being less bad, and doing less harm” to the natural environment.

In contrast, Regenerative Design is based on “doing more good to help heal the damage” hitherto inflicted on the natural environment.

It’s about fusion of the positive attributes of the past with those of the future. It’s about developing now and in the future in total congruency with the ecological civilization of any site. It is about developing without destroying.

Regenerative Design is not about destroying but leaving enough for the future generations to also destroy, but is an attitude which puts an end to sustainability’s vicious circle of destruction.

Regenerative Worldview, from which regenerative thinking and design stem, is a system of thinking with a varied and wide ecosystem of ideas and thoughts which fuse the interrogative and skepticism of science and knowledge, with the wisdom and insight of nature.

Ecology

Regenerative Design is about ecology, and ecology is about a multitude of key environmental and other drivers.

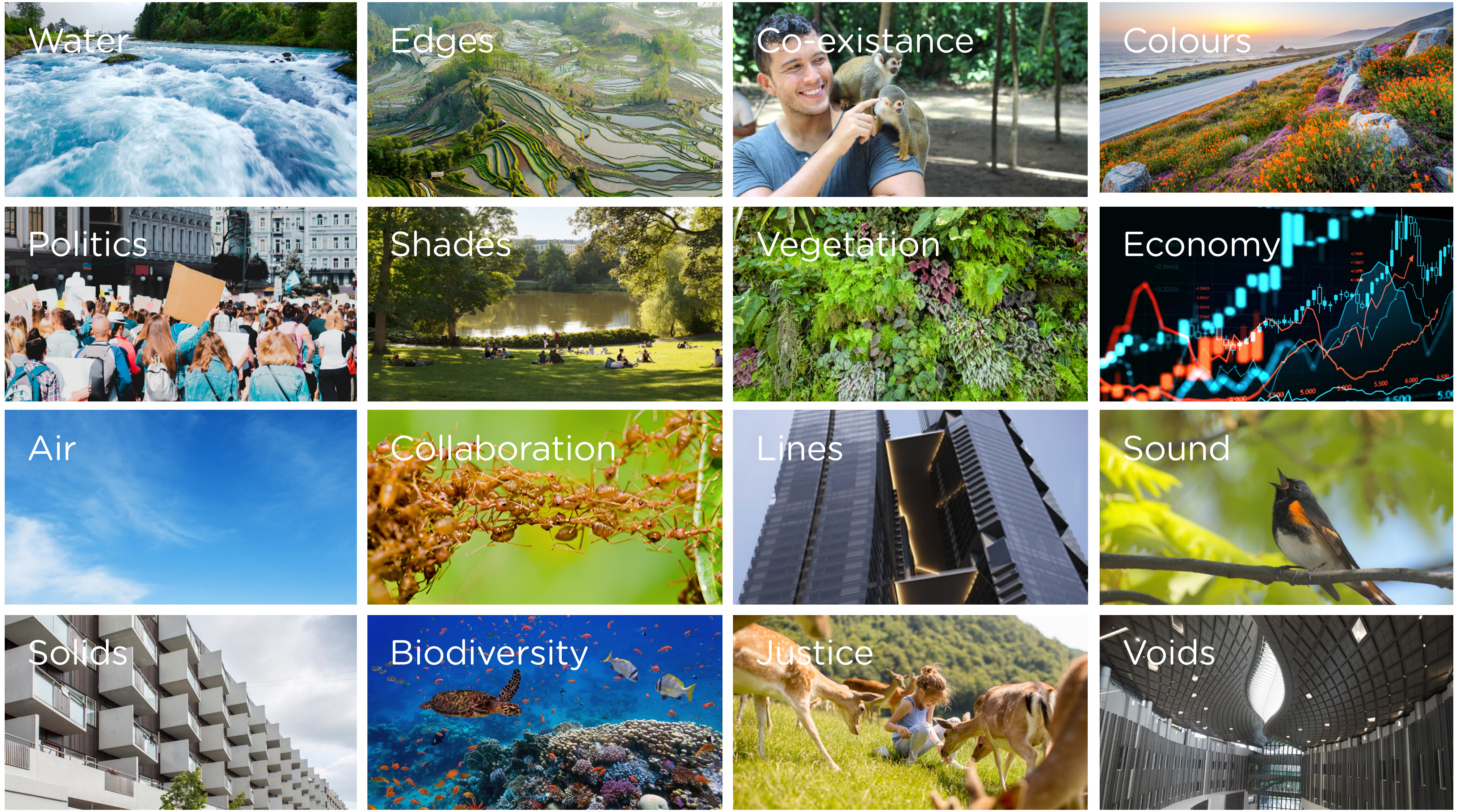
Key amongst these are:

- **Water:** the critical shortage of fresh water.
- **Vegetation:** not so much the manicured landscape design, but the re-wilding agenda.
- **Biodiversity:** the near annihilation of biodiversity down to 30% of what existed as recently as the 1970-s.
- **Air:** green house gases in the atmosphere which have gone up by 7 times since the 1940-s.

While these are key ecological and design drivers, they are not all.

Ecology is also about **sound**; sound of a forest is very different from that of a tree orchard. It's about **colours** of nature versus those of a mono-culture plantation. It's about **shades** and massing of our buildings, **lines** in our buildings, **edges** and adjacencies, **solids** and **voids** that allow natural ventilation through.

The list continues, and extends into **coexistence**, **collaboration**, **justice**: both environmental and social justice, and **economy**: the value system we have, and finally, it is about **politics**: the way we run ourselves and the governance we have created.



The 16 drivers of Regenerative Design

Decarbon isation

Decarbonisation of our built environment processes is good, but is not enough to get us anywhere near the 1.5 degree target we have set for ourselves since the Paris Agreement.

The evidence for this has been compelling for sometime now. Latest reports by the UN's Intergovernmental Panel for Climate Change (IPCC) unequivocally puts to bed the "soft" ideas that decarbonization and tree planting will get us there. They won't.

Much more radical systems thinking is needed to roll back the damage and to heal the planet.

The question is whether we are really up for it? Or are we merely setting the chairs on the deck of the titanic?

Decarbonisation per se will not solve issues with water scarcity, floods due to hard surfaces we have built, heat island effects in our cities, plastic issues in our oceans, food waste issue, loss of life, species and biodiversity, and many other challenges our current lifestyle has created.

Carbon is but one of many challenges we face. We need to overcome the "carbon vision" some of us suffer from! We need Regenerative Thinking to address the ecological challenges that we have in a holistic and systematic manner.

Of the 16 dimensions of ecology listed, carbon is but one.

Regenerative THINKING

Regenerative Design is a system-based approach to our relationship with the environment. The approach sets to improve the environmental indicators while responding to the need for development. In a regenerative environment, every building/project sets to roll back the environmental degeneration that has happened over the years.

Regenerative Design is a sub-section to regenerative thinking, which in turn is a sub-section to Regenerative Worldview. Worldview is the collection of data, information, knowledge, insight and opinions, as well as intuition and beliefs in a subject. It is imperative that we start with Regenerative Worldview which is system-based and is a complete paradigm shift from all that we have done and developed in the sustainability era.

As such, Regenerative Thinking sets out to deal with a degeneration through a system-based approach which relies highly on knowledge acquisition from adjacent scientific disciplines likes biology to get us closer to the mind and wisdom of nature.

Regenerative Design transforms multi-disciplinary design from a quest for a "compromise" to one that strives for "co-creation".

It is not about architecture compromising to accommodate structure, (or vice versa), but about structure informing architectural design so that it is more than just a beautiful stroke of a brush.

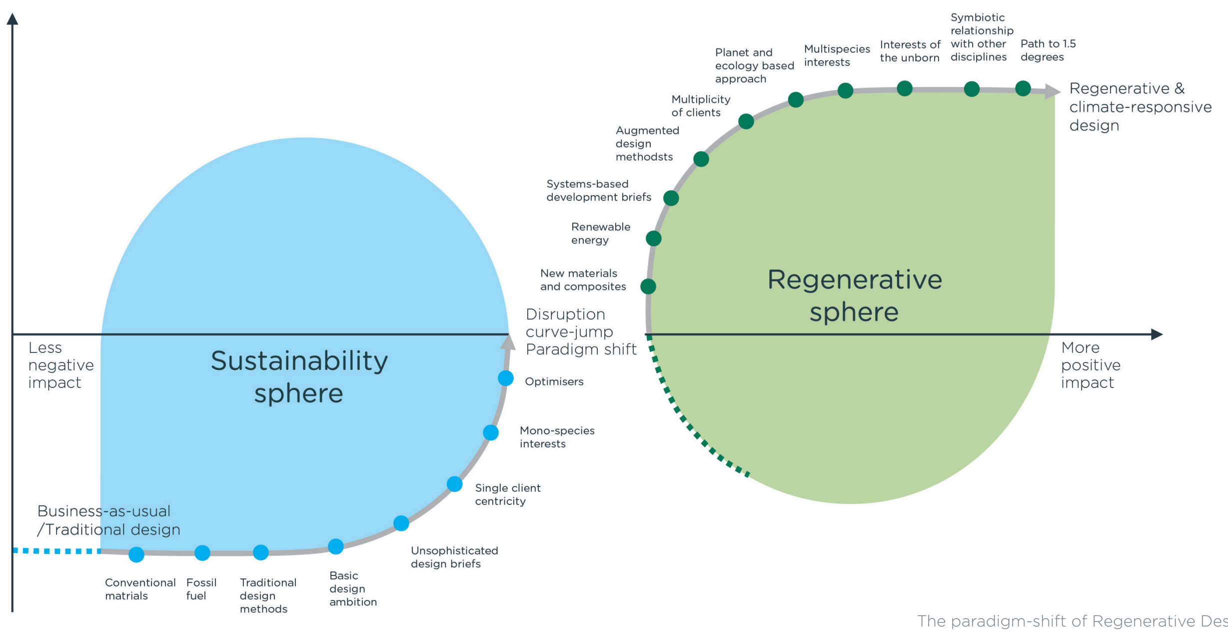
It is about the space guiding the usage, acoustic informing the shape of the interior.

It is about a symbiotic connectivity in a functioning system where each node (discipline) sends ripples of goodness and knowledge to others in a continuous and generous manner.

Downsview, Toronto Canada
People, place, and nature come together in this vision for the future of Downsview in Toronto. Jointly led by Northcrest Developments and Canada Lands Company and with design partners SLA, KPMB Architects and Henning Larsen, we have reimagined the future of the expansive, 520-acre former airfield as a green-minded, human-scale and people-first community.

Regenerative Lexicon

Sustainable vs Regenerative



The paradigm-shift of Regenerative Design. (Background image inspired by Reed, 2007 and Craft et al, 2017)

Formation of new paradigms start with new thoughts, which in turn start with new lexicon.

Whereas in the sustainable design era we pre-occupied ourselves with terms like conventional materials, fossil fuel, traditional design methods, basic design ambitions, unsophisticated design briefs, single-client centricity, mono-species interests and optimization of existing processes, the Regenerative Worldview is full of terms and ideas like new materials and composites, renewable energy, augmented design methods, systems-based development briefs, multiplicity of clients, planet- and ecology-based approach, interests of the unborn, symbiotic relationship with other disciplines, and path to 1.5 degrees.

Each and every one of these terms open up the vision and ethos of design and designers to a completely new world of possibilities and potentials.

Biomimicry: Emulation, ethos, reconnection

Biomimicry as a means of achieving Regenerative Design, is about emulating nature. This emulation or mimicry can be in terms of shapes, forms or systems that prevail in nature.

But biomimicry is more than just mimicking nature. It requires an ethos of respect and care for nature. It requires a feeling of oneness with nature. Our earlier reference to mother earth was reference to as though we all came from the same mother or ancestors. It made reference to a perception that we and nature were relatives with rights to enjoyment of all that mother earth or gaia had to offer. This attitude towards all that exists on the planet is still prevalent in many indigenous communities that exist across the globe. They have kept that attitude and tradition going. A tradition that we held dear for more than 290,000 years of our specie's existence on the planet, and which some of us gradually lost over the more recent 10,000 to 13,000 years. And more so in more recent past.

Biomimicry is also about getting "re-connected" with nature as an integral system. It is about rekindling our long lasting relationship with nature. This reconnection will empower us to understand better the inherent wisdom that exists in nature, to synergize with its powerful forces and to understand the processes that underpins it. It is these processes that we need to fuse with our own scientific knowledge to achieve true mimicry and congruence with nature.

Regeneration can be achieved with biomimicry. However, throughout the entire process, we must maintain a sense of humility and remorse towards the rest of nature. Our attitude in this respect must not be that of a valiant saviour of nature, having appeared at the last minute to slay the dragon and to save the whole world.

On the contrary, our attitude must be that of a reformed criminal who has become aware of the bad deeds, and who now wants to change course.

Establishing Complete Connected Communities
Designing for the human scale is a central tenet of the design vision, and mid-rise buildings will make up the bulk of the development. Transit nodes and major intersections will serve as densification points, supporting ease of movement both within the Downsview site and across the Greater Toronto area. In all, the plan calls for 50,000 units of housing for 80,000 residents that meet or exceed affordable housing requirements.

Regenerative Steps

Cultivating City Nature
Downsview will introduce a new form of development – City Nature – that blends the built and natural world, integrating green infrastructure, biodiverse habitat, gathering spaces, and play into the public realm. Inspired by Toronto's ravine network, and celebrating the example set by Downsview Park, City Nature invites nature's generosity into the bustle of the every day, delivering public health, ecosystem, sustainability, and resilience benefits.

The process of Regenerative Design starts by a comprehensive and detailed study of the past environmental credentials of a site. A review of how a specific site may have contributed to the 16 parameters set above in a distant past.

The past journey to environmental degeneration of the site is then documented and quantified, where possible. A roadmap of ambitions and targets are then set on how to roll back the tide of degeneration, and on how to regenerate back the site. The study is that of the past, but the movement is into the future. In this quest, technology plays a key role, so does our understanding of nature and the wisdom in it.
It is through fusion of the hard technology and soft biomimicry that regeneration can happen.

Regenerative Chart & Opportunity Matrix:
Regenerative opportunities chart is a tool that can be used to chart a road map to regeneration on any specific site, brief and development.

The chart lists out the 16 ecological design parameters, and identifies where there are opportunities to enhance these drivers on the site while at the same time developing on the very site.

The chart helps identify qualitative potentials and opportunities that exists in a multi-objective viewing of the drivers of brief, site, community and ecological drivers.

These ecological drivers can be selected from a wider range of drivers, depending on the specifics of each project

A scale of 1 to 5; 5 representing the highest opportunity; whereas 1 representing the lowest opportunity. The chart can be revisited and filled during different stages of the project.

Regenerative Design Chart

The evolving story of Regeneration

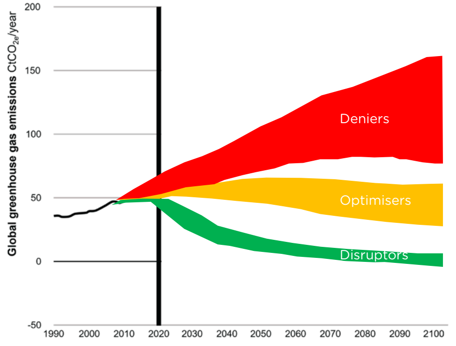
Regenerative Worldview is a true paradigm shift from all that we have been doing on the sustainability curve. This change in paradigm changes our attitude towards development from being defensive and reactive to being proactive.

Regenerative Thinking sees the two distinctly different natural and built environments as entities that can be fused into one regenerative environment in which the built environment, with all its limitations , is underpinned with the systems which prevail in nature.

As “doing less harm” is still doing harm, then the sustainability attitude of “doing less harm” discourages development; whereas the “doing more good” mantra of Regenerative Design encourages more development. Because the more development we do, the more good we can do. The attitude towards the site will also change from an inward looking view of how best we can do within the site boundaries, to an outward looking attitude of how we can regenerate the street, the neighbourhood and the city with our developments, one building at a time.

In our quest to address the environmental challenges we face, we all have our roles and responsibilities. While the road ahead is harsh and arduous, the good news is that for every environmental challenge we have, we have technically viable solutions.

We need all the energy, brain power and positive attitude we can muster.



CO2 EMISSIONS TRENDS AND HOW TO CHANGE THEM

Future scenario planning based on greenhouse gas emissions: The path of climate deniers and optimizers will lead to temperature rises of as high as 4.2 degrees and as low as 2.9 degrees; both are highly perilous to future of life on earth. Only the disrupter’s path to 1.5 degree will lead to a healthy future

Singapore Pavilion in the world expo in dubai; a true oasis in the desert. it attracted millions of visitors; of all species

In Praise of Retrofit

The ideas of retrofit, refurbishment and alterations to existing stock of our built environment assets ought to receive more attention from us. We ought to develop skills, knowledge, and teams to be able to meaningfully contribute to these efforts.

Contributing Writers:
Hossein Rezai-Jorabi
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Martin Burden

04

“Every existing building has the right to be heard.”

Capella Resort, Singapore (Foster + Partners | DP Architects)
Existing pre-war buildings were retained and underwent extensive repairs for cracked floors, corroded reinforcement, rising damp, termite-infested timber. All remedial work was performed with utmost care to reinstate the past glory of the building fabric, including repointing the brickwork with soft mortar and replacing damaged timber elements. Underpinning was also performed on certain sections of the shallow foundation. The project won a conservation award, which was well deserved.

Schwanthalerstrasse 55-57 Munich (UNStudio)
The refurbishment and extension of these 1913-1915 buildings in Franz Marc Quartier in the inner city of Munich is an example of successful transformation from old industrial and logistic spaces to commercial and office use, giving the neighbourhood 12000 m² of real estate with a modern and lively twist.

In praise of retrofit

Over 95% of the buildings we will have by 2030 are already built!

This percentage will probably hover around 80% or more in a time horizon up to 2050.

In any reasonable time projection into the future, the vast majority of our buildings and neighbourhoods and infrastructure and cities are already built.

These are built to standards which fall well below what would now be environmentally acceptable. It is therefore imperative that we focus on greening the existing and working with what is already built in order to make these sustainable and environmentally in tune with our 1.5 degrees and other aspirations.

The ideas of retrofit, refurbishment and alterations to existing stock of our built environment assets ought to receive more attention from us. We ought to develop skills, knowledge and teams to be able to meaningfully contribute to these efforts.

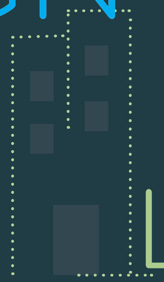
Greening the existing may take the literal form of enhancing the conditions of an existing building, or be in the form of adding new buildings and nodes to our neighbourhoods and cities which are not inward looking but are generously giving back to the neighbourhood. We need to be regenerative.

Of engineers and trees

Statistics on the contribution of the construction industry to Green House gas emissions are aplenty. The industry is "burdened" with contributing around 39% of the total GHG emissions. While the origin of this figure is debatable, in that the vast majority of this has been "imported" from the energy sector, it is nonetheless imperative to appreciate the embodied carbon figures in construction. The structural frame of a typical 40-storey highrise building in reinforced concrete can have an embodied carbon footprint of around 300 kg/m^2 of the built area. The actual number varies widely, depending on the external factors (location, seismicity, prevailing wind, usage and Live Load allowance, etc), and on the various stages within the overall life cycle of a building, but the figure remains high when compared with other GHG-generating activities we engage with. Demolishing an existing building and replacing this with a new building tantamount to emitting such additional GHG-es for the new build. The environmental impact of the demolish-rebuild development model, therefore, is similar to cutting trees which absorb greenhouse gases. Demolishing a large building, can have similarly adverse environmental impact to setting vast swathes of forest in fire. Forest fires conjure up justifiably negative images in one's mind; whereas demolishing existing buildings seem to have been somewhat "normalized" in our minds and our built environment and construction industry.

This erroneous mindframe must change.

DE SIGN Life



In assessing viability and implications of retaining an existing structure, it is imperative to have accurate visibility on the residual life of the existing structure.

Residual life is the balance of the overall design life of a structure. Buildings are designed and built to specified levels of performance. Such performance levels are implicit or explicit in the codes of practice to which the buildings are designed.

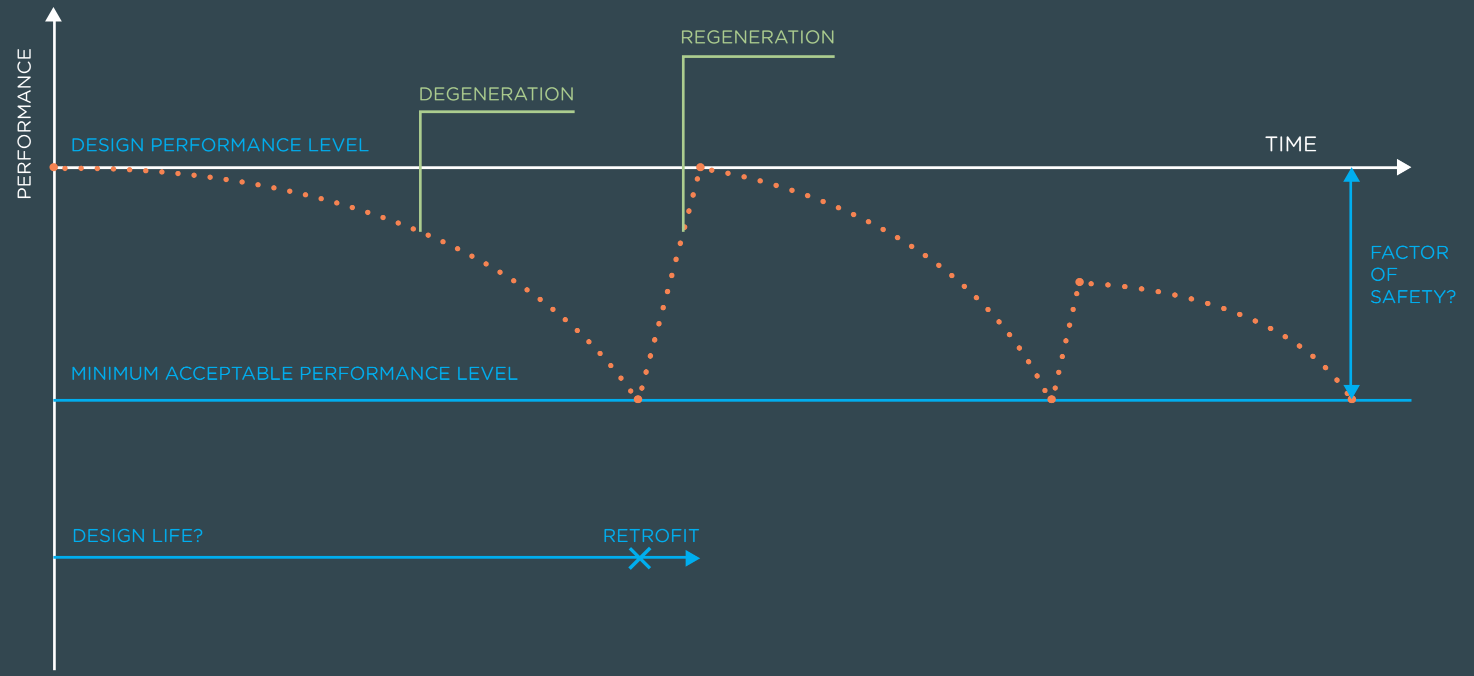
Such Design levels of performance continue to deteriorate as the building ages. Such deterioration continues until such time as the level of performance reaches the minimum acceptable level of performance.

The time that it takes for the design level of performance to reach the minimum acceptable level of performance is called the "design life" of a building.

The roadmap through the design life of a building is also traceable. This will enable us to determine how much residual life is left in each building at anytime within the design life. This information will be a key driver in determining the viability and relevance of retaining an existing building and incorporating same in a new development.

A variety of engineering techniques, methods and tools are available to determine the health of an existing building, design life of same, and the residual life.

The irony is that for every environmental and development problems we face, there is a viable and workable solution. We have the knowledge, the skill and the techniques of dealing with existing buildings. What we lack, at times, is the courage and the policies that are needed to save our buildings and, with it, life on this planet.



Left to Right
55 Market Street (AR+D Architects)
137 Market Street (Teh Joo Heng Architects)
Bank of East Asia (Teh Joo Heng Architects)

Major refurbishment, retrofit, additions and alterations to non-conservation reinforced and prestressed concrete framed buildings in downtown Singapore.
Load replacement technique was used in most of these projects to enhance height and floor area without major strengthening to the foundation and to existing walls and columns.

> "For every environmental and development problems we face, there is a viable and workable solution. We have the knowledge, the skills and the techniques of dealing with existing buildings. What we lack, at times, is the courage and the policies that are needed to save our buildings and, with it, the life on this planet."

Hossein Rezai-Jorabi
Global Design Director, Ramboll

Utilisation of existing buildings

Of all the roadmaps towards environmental congruency, the **“build nothing”** route is evidently analogous with zero-harm scenario.

If we must build, then we must do so Regeneratively.

(see Regenerative Worldview in Chapter 3, Page 52)

Of all the roadmaps towards environmental congruency, the "build nothing" route is evidently analogous with zero-harm scenario. While this is practically impossible to achieve in a situation where we are in need of more buildings to respond to development needs of our growing societies, this may well be possible in the arena of existing buildings where embodied carbons have already been expended to build them. It should be possible to stay close to a “build nothing” scenario by keeping existing buildings which have a reasonable residual design lives. Furthermore, the ideal of “build nothing” may also be achievable by higher utilization of existing buildings.

Current anecdotal evidence points to most genre of our existing buildings being used under 30% of the times! Office buildings, for example, tend to be used around 8 hours in 24 hours. Adding the weekends and other holidays when our office buildings remain idle and unused, reduces the utilization ratio of this genre of our buildings to way below 30%. It is imperative that, through clever future planning, and by utilizing technology in our “Smart Buildings”, we make better and more use of what we have in order to reduce pressure on the demand for building more, with all the deleterious effects that come with more and more buildings.

Kirstine Seligmanns
Skole, Denmark (Ramboll)
This project has a school, kindergarten and a neighbouring housing development. The housing developement was partly demolished to build a brand new two-storey building with teaching spaces. This includes a roof terrace and a large `learning staircase’. The structure is strengthened, the facade renovated, the roof replaced, and all internal walls and floors have been rebuilt.

IPCC, Sufficiency and Efficiency

IPCC's latest report in 2022 rightly identifies **retention of existing buildings as the most Preferred model** in the developed world.

Efficiency,

is the most suitable and least destructive model. This relies on design and scientific techniques of optimization, minimization of material usage, efficient design processes, and all that will ensure the best material usage for various components of each development. Efficiency, therefore, is highly dependent on design and analysis tools, as well as on technology to ensure that best forms, shapes and material usage is found through complex multi-objective optimization methods. The approach applies to architecture, massing, built area, natural ventilation, form, shape, structure, servicing, interiors, etc; all to ensure that the sum of embodied and operational "carbon" (read "greenhouse gas") is targeted towards zero or better over a reasonable period.

Sufficiency,

in simple terms, refers to "building what is sufficient". This is in contrast to the wasteful extravagance which has crept into our built environment under the guise of comfort and delight! At a most basic level, ceiling heights which have been continuously going up, primarily in response to demand for "perceived luxury", ought to be controlled. On structural frames, design live load allowances have been going up over the past 50 years, not in response to a deficiency in previously lower live load allowances, but in response to marketing campaigns which presents higher load allowances as a positive attribute rather than the waste that they actually result in having structures which are stronger than ever need to be! The upshot of such wasteful demands on much higher floor-to-floor heights and live load allowances in our buildings is that most existing buildings which have been performing satisfactorily for many years, fall short of the newly normalized and "deemed acceptable" limits.

We are demolishing buildings that are now seen as not "marketable" due to their lower, yet perfectly functioning, floor-to-floor heights!

This needs to change

Concepts like "delight" and luxury, ought to be complimented with "understanding" and "thriving".

The Lighthouse, United Kingdom, (Ramboll)
Located in the heart of King's Cross and dating back to 1875-1895, the Lighthouse building is a local landmark. It was left derelict for many years until developers; UK Real Estate, took the bold decision to redevelop the Grade II listed building that was on Historic England's Buildings at Risk Register.

The building now features an additional storey-and-a-half, conserved and repaired masonry façade and the restored timber lighthouse, ensuring its great character was retained and its long term viability secured.

Hard Limits on Embodied Carbon

It is imperative that we now limit the embodied carbon of all our buildings, and to continue to reduce this limit over the next decade or so, such that we can reach a limit which can be readily offset with operationally "Carbon Negative" systems in our buildings within a short period leading to 2030 or 2035. It is suggested that a basic embodied carbon per square meter of built floor area of about 300 kg is a reasonable and achievable limit for residential buildings of up to 10-storey in places with mild wind speeds and no seismic activities. This is proposed to be taken as an upper bound number for the assessed embodied carbon (excluding operational carbon emissions) per square meter of the built area. In the Nordics, for example, many low-rise buildings record emission levels of much lower than this limit. The recommendations provided here are intended for the global construction industry, and for buildings at the upper limit of 1 to 10-storeys. For a building with a floor area of about 10,000m², this will add up to an overall embodied carbon of 3,000,000 kg of CO2e. In the way of a simple comparison, this is the amount of carbon sequestered by over 135,000 referenced trees in one year.

The limit of 300kg/m² ought to be reduced by 10% on a year-on-year basis till 2025, then further reduced by 8% year-on-year till 2030. This will reduce the overall embodied carbon to less than 150kg/m² of the built floor area. Upward adjustments to the 300kg/m² limit can be made for taller buildings, and for buildings with higher live load demand, or those in highly seismic zones, etc, but adherence to the hard limit and the reduction journey imposed would reduce the embodied carbon down to 150kg/m². By 2030, it should be possible to defray such numbers with negative operational carbon to achieve net-zero carbon status within as short as 3 to 5 years.

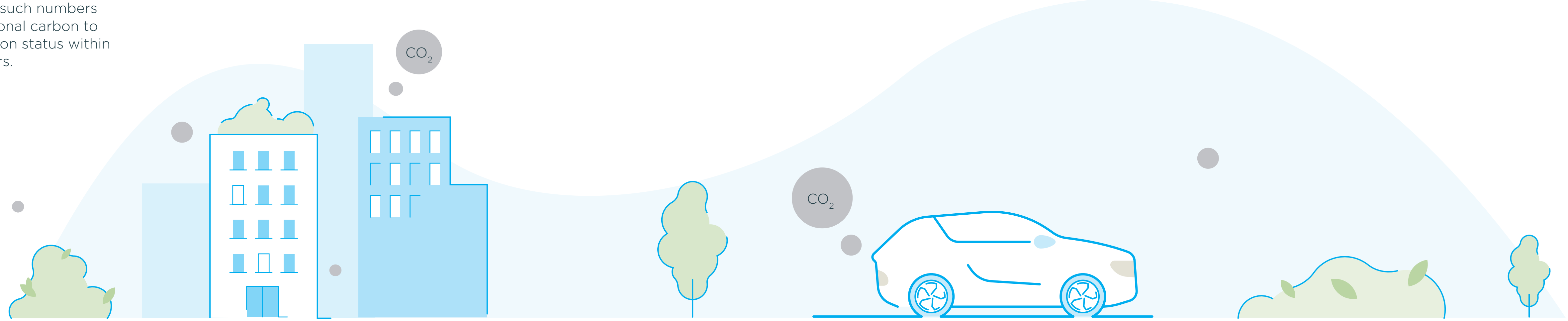
By then, as the energy sector continues to decarbonise, the embodied carbon numbers will progressively reduce too. The combined effect of reduced embodied carbon and net positive operational carbon will help accelerate the journey towards full decarbonisation in the built environment industry.

A future edition of Ramboll DESIGN publication will be dedicated to the important topic of decarbonization to net zero, which is one of our four strategic unifying themes.

Quantifying Embodied CO_2e

1 ton CO_2 ≈ 5,000 km driven in a car

Grand Hyatt = 20,520 tons reduced embodied CO_{2e} ≈ 102,600,000 km driven in a car ≈ 3640 cars taken off the road for a year



National Design Centre, Singapore, (SCDA Architects)
Existing heritage conservation building was restored, and additions and alterations were made to transform them into the new National Design Centre (NDC).

At the heart of the existing building composition was a central courtyard which in the proposed design was roofed over. The space was internalized and is now the main atrium space in the NDC.

Physical, environmental, historic and cultural aspects of retention

In addition to the physical and environmental aspects of retention hitherto described, the built environment offers historic, cultural and social values too. These can be adversely affected with demolition of a building.

Buildings, the communities and the streets they form, are depositories of collective memories of their past and present inhabitants. Historic events which have taken place in a particular building have been archived in that building. Memories of such historic events live on through fond, or otherwise, memories that continue to exist in people's consciousness. Historic events do not necessarily have to be of general public and general interest, but can be personal experiences of our citizens. Removal of buildings tends to lead to a gradual fading away of such experiences and memories.

A relevant question to raise, therefore, is "Whom do our buildings ultimately belong to?". Parallels to this paradigm are drawn on the agenda of the natural environment. While the Amazon Rainforests happen to be mostly located within the geographic boundaries of Brasil, "Whom do they ultimately belong to?".

Demolition of buildings has been likened to deforestation, "Architectural and Heritage deforestation", that can damage the collective memories and paradigms of a neighbourhood and a city at large. We must protect such historic and social capitals in our cities through preservation of the fabric of our buildings.

Tate Modern

A success story of retention

London's Tate Modern gallery, a Grade II listed structure occupies a former oil-fired power station on the south bank of the River Thames. The gallery opened in 2000 expecting 1.8 million visitors a year. Now, it receives an average of 4.5 million visitors, often topping the charts as the UK's most visited attraction.

Between 2008 and 2016, Tate Modern's existing building underwent three stages of renovation and addition.

Chapter 1

Floor Strengthening

Tate Modern's floors required strengthening for an exhibition which featured heavy art pieces at 23.5kN/m² that were beyond the capacity of the existing structure. The floors were strengthened to achieve a higher load-bearing capacity.

To strengthen the floor, new steel beams were introduced in the plenum space between the upper and lower slabs. By strategically positioning these beams to reduce the span of the upper deck, the floor's localised capacity was increased.

Chapter 2

Redevelopment of the existing Switch House

This phase encompasses the redevelopment of the neighbouring Switch House, aiming for a seamless integration with the main building in both visual and physical aspects.

In the Switch House, the existing steel frame was removed and a new steel frame added to bridge the resulting void between the reinforced concrete tower structure and the new steel columns. This created 18m clear spans to the galleries below.

Both structures are supported on piled foundations to ensure continuity through the two buildings.

Chapter 3

The New Extension

The new building increased Tate Modern's display space by 60% over 11 levels, and provided additional performance and educational spaces, retail areas, cafés and offices. Its form is complex, with an irregular ground plan dictated by the constraints of the site.

Engineering the building was a geometrically complex feat. For the inclined perforated brick façade, an innovative design was developed from first principles.

The Tate Modern, UK

A truly ground-breaking retention, renovation, and addition to an existing building that pushes the boundaries of modern design engineering and building technology.

Engineered by Ramboll UK
Contributing writers: Martin Burden and Eleanor Fox

AI for Augmented Intelligence

AI, for the first time in our history, enables the true meaning of the name “computer” for some modern and powerful machines to be reflected in what they actually can now do; that is “to think together” with us.

Contributing Writers:
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Robert Bamford
Lars Ostenfeld Riemann
Bruno Ainsworth
Emily Scoones
Andy Brahney

05

A friend or a foe?

“Technology is our friend”

The story of our separation from the natural environment is closely entangled with our journey of technology development and adoption. Biological life on planet earth is as old as 3 billion years.

As recently as 1 billion years ago, the highest form of intelligence on the planet were the forerunners to our beautiful and hardworking earth worms. In such timescales stretching billions of years, the 250 thousand or so years that we, the homo-sapiens, have been on this planet is minuscule. It is literally 0.00008333 times the duration of biological life on earth.

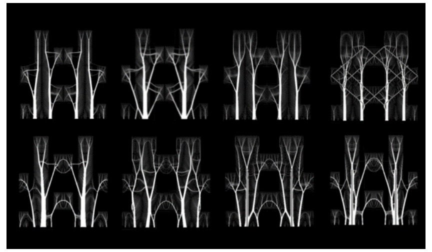
This has been likened to the measuring scale “yard”; which has its origins in the distance between the tip of the stretched arm of the emperor and his nose. If life on earth is as long as a yard, the entire time the sapiens have been on the planet will be wiped off with a single file on the nail of the emperor’s index finger!

While we were fully integrated into the natural environment up until as recently as 10 to 15 thousand years ago, we now are totally and sadly isolated from it, with the devastating outcomes of climate change, loss of biodiversity and other huge environmental challenges we are grappling with.

It is widely believed that the origin of such separation and disenfranchisement is firmly embedded in that first piece of stone our ancestors sharpened, and used as a tool.

The sharpened stone, which was the tip of our technological advancement at the time, has put a gap between us and other species, and empowered us to pull ourselves outside of the food chain, and instead, to command, colonise and exploit the natural environment as a resource.

While the cutting-edge technology of the time, and since, empowered us to separate from the natural environment, it is ironic that this very technology is now a major catalyst to help us integrate back into the natural environment and become an active member of the community of life, in the best interest of all living and non-living forms.



Topological Optimization
Unlocking natural efficiency for an unwrapped elevation of a high-rise building façade structure

Innovating:

For which future?

Embracing a World of Possibilities
Amidst the challenges we face, we recognize that technology holds immense potential. It is up to us, as stewards of innovation, to harness its power for positive transformation. With responsible actions, we can shape a thriving future—renewing our planet and venturing into uncharted cosmic realms—ensuring our survival and advancement.

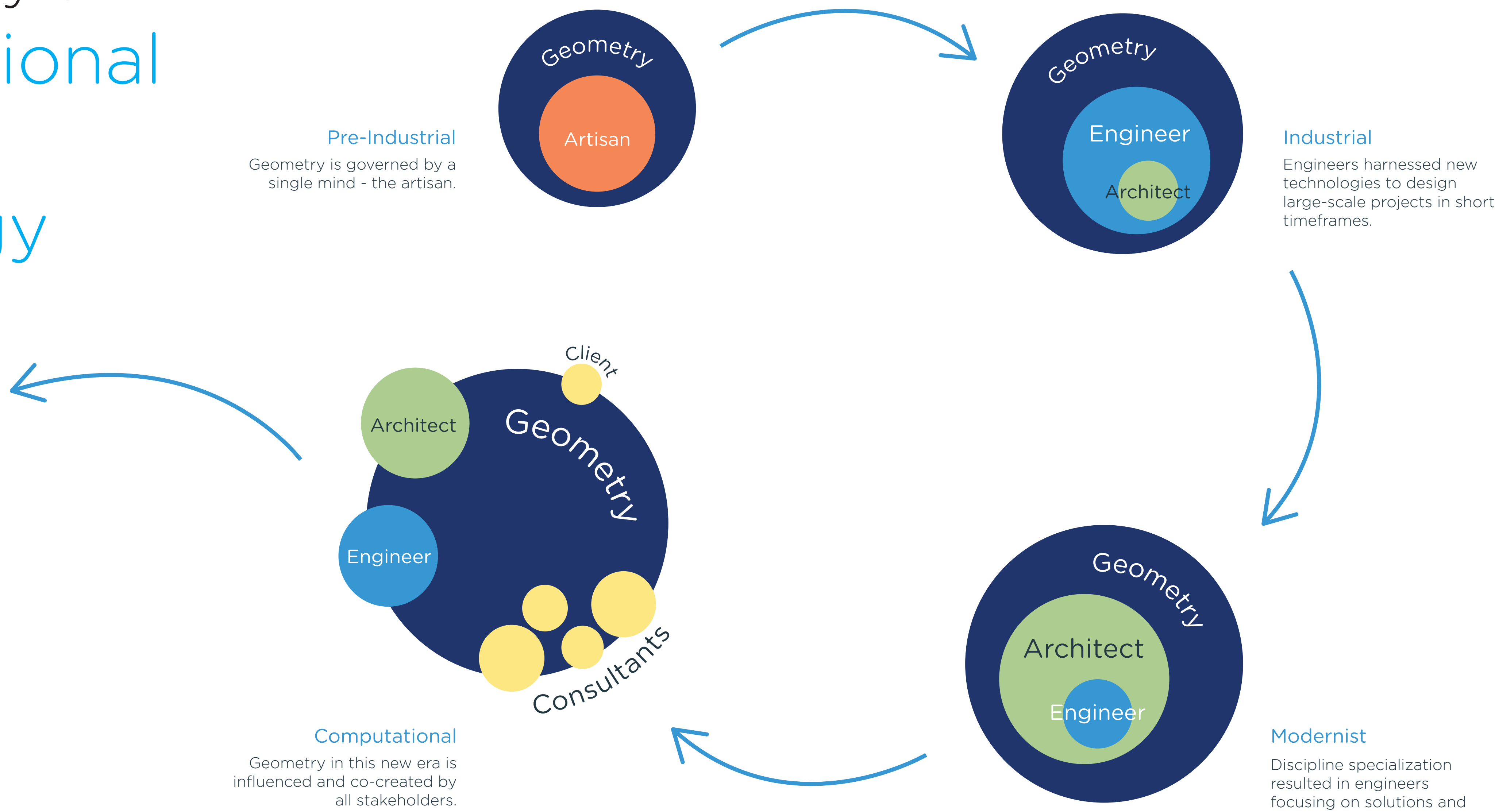
The construction industry stands at a crossroads, grappling with its carbon footprint while striving to meet the growing demands of a burgeoning global population. As aspirations for improved living conditions surge, sustainability becomes an imperative. In this race against time, innovation is paramount to secure a prosperous future for humanity.

Within the Architecture, Engineering, and Construction (AEC) industry, Computational Design Technology (CDT) serves as an essential key to keeping pace with the rapidly changing crises – climate, environment, waste, water, security, and food (to name a few).

Penang South Islands, Malaysia (Bjarke Ingels Group (BIG), Hijjas Architects and Planners)
In a masterplan entitled BiodiverCity, its focus is not just on liveability, economy and quality of life but critically on creating an environmentally-rich, biodiverse and regenerative developments that would be a first in the region.

A brief history of
Computational Design Technology

Design Through the Ages.
Over time, geometry has been controlled by practitioners who are best-placed to influence design language. In the new Computational Design Age, geometry is co-created by design 'influencers' who develop intelligent design DNA using augmented parametric processes to enable wide-ranging objectives.



Geometric Influence across design ages

The origins of computational design can be traced back to the early days of Computer-Aided Design (CAD) in the 1960s. Initially, computers were used to automate drafting and documentation processes, providing architects and engineers with greater precision and speed. However, as technology progressed, so did the capabilities of Computational Design Technology (CDT).

In the 1990s, parametric modeling and Building Information Modeling (BIM) emerged, allowing designers to create complex digital models with intelligent relationships between elements. This breakthrough marked the first step towards integrating computation into the design process. As computational power increased and algorithms became more sophisticated, designers could explore multiple design options and simulate real-world scenarios with ease.

In recent years, the capabilities of computational design technology have skyrocketed, thanks to advancements in machine learning, artificial intelligence, and data-driven algorithms. Designers can now generate design solutions that were once inconceivable, harnessing the power of algorithms to optimize building performance, analyze energy consumption, and enhance sustainability.

CDT's integration with generative design has been particularly transformative. By setting parameters and constraints, designers can let algorithms explore vast design spaces, generating countless alternatives and identifying optimal solutions based on predefined objectives. This iterative process allows for design exploration on an unprecedented scale, facilitating faster and more informed decision-making.

The Computational Design Age

With the widespread adoption of computational design technology, we are witnessing the dawn of the Computational Design Age. This era represents a fundamental shift in how we approach design challenges and unlock the full potential of our built environment. It emphasizes the symbiotic relationship between human ingenuity and computational power, enabling us to tackle complex problems with greater precision, efficiency, and sustainability.

Within the AEC industry, the rapid evolution of CDT has brought about a paradigm shift. What was once considered an emerging tool has now become an intrinsic part of leading practitioners' processes, revolutionizing the way we approach design. The rise of CDT has given birth to a new era, aptly named the Computational Design Age, where the fusion of human creativity and machine intelligence propels us into uncharted territories of innovation and efficiency.

As we enter the Computational Design Age, we must embrace this transformative wave of technology and harness its potential to create innovative and resilient spaces. Designers, architects, engineers, and construction professionals must continue to push the boundaries of computational design, exploring new frontiers and constantly challenging the status quo.

Ignite a world of possibilities by harnessing Computational Design Technology for positive transformation

Parametric Design:

Disruptive? Evolutionary? or both?

Parametric design is not new. One of the co-authors of this edition of Ramboll DESIGN wrote a paper on a parametric research project back in 1988. As designers, we have been parametrizing, both consciously and subconsciously, to seek innovative concepts and creative solutions to stretch the envelope of possibilities.

Indeed, parametric design may simply be the applied science of human curiosity – i.e. testing and tweaking parameters to develop more optimal systems. However, the evolutionary model of parametrics we have observed in the past 30 years has leapt forward by the revolutionary modern tools with which we now collaborate.

Previously unthinkable horizons have been crossed and dream-like possibilities have been realised, all in the 'evolutionary' blink of an eye.

Kistefos Museum, Norway (Bjarke Ingels Group)
An iconic museum building that functions as a bridge and an elegant sculpture. Parametric modelling techniques were used to assess, inform and optimise various architectural design options.

Future Parametric :

Researchers, academia and other professionals are constantly developing new parametric tools and improving existing ones to enable the exploration of ideas at the edge of our cognitive ambitions.

We are now empowered to test the most extreme ideas which, until recently, our psyches might have subconsciously suppressed considering them impossible to realize.

Furthermore, these new parametric collaborators are daring us to think beyond our current cognitive horizons. The open-platform nature of these tools further enables established design disciplines such as architecture, engineering and sustainability to further collaborate and co-create together.

We are now empowered to carry out super-early-stage combined parametric studies with holistically conceived geometries.

In a short article we wrote as recently as February 2019, we wrote:

"At some point in the future, we envisage that buildings will be "generated" from optimisation algorithms by using a comprehensive set of weighted design parameters.

Some (and clearly not all) of these design parameters could be aesthetics, size, efficiency, cost, speed of construction, aerodynamics, structural performance, heat gain, daylighting, code and authority requirements. This range of new possibilities together with the rapid advancement of additive manufacturing, will eventually generate its own design typology whereby material can be minimised through the freedom of form.

The "economy" in material usage and the "generosity" in form can be borrowed straight from the playbook of the oldest and most masterful of all builders – i.e. nature itself."

This future scenario imagination is already upon us, beyond proof of concept!

With currently ongoing and further development of such ideas, a bespoke and exciting design environment awaits us all and in particular, those of us who wish to shape it. Such design ideas further extend into manufacturing and construction fields with speed and at scale.

The future is now

Most of these futuristic-feeling tools and ideas are already developed, and are being further explored. So far, we have found that the solutions they present have already challenged our preconceived notions of effective structures.

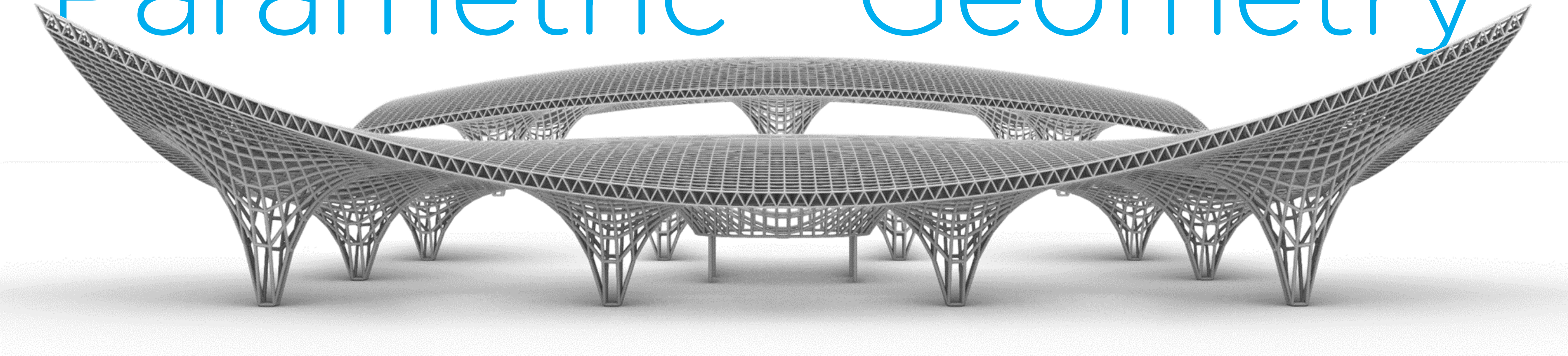
Counterintuitively, we now know that inclined columns are more efficient than their vertical cousins and that geometric optimisation is independent of scale. Curves are more efficient than straight lines and bespoke is more cost-effective than modular and standardized.

Paradigms will continue to shift, and progress will further accelerate. We can only wonder and imagine with a sense of excitement, respect and awe what will be achieved in the next 30 years, but there can be no doubt that the developing field of computational design will be intrinsic to the way in which the built environment is shaped to deliver innovative and efficient forms by solving the challenges of their day.

The future is now.

Founders Memorial, Singapore (Kengo Kuma & Associates + K2LD Architects)
A visionary landscape that highlights Singapore as a 'City in a Garden'. This bold and sustainable design blends organically with Gardens by the Bay. The Memorial aims to commemorate Singapore's independence and inspire Singaporeans to unite in shaping the nation's future.

Parametric Geometry



Parametric geometry stands as a cornerstone of computational design, empowering architects and designers to unlock new realms of creativity and redefine the possibilities of architectural expression. At its core, parametric geometry harnesses the power of algorithms and data-driven processes to generate intricate, adaptable, and dynamic design solutions.

By embracing parametric geometry, architects can transcend traditional design limitations, breaking free from the constraints of standardization and embracing a world of limitless possibilities. The flexibility inherent in parametric geometry allows for the creation of complex, non-linear forms that were once thought to be unattainable. It enables the exploration of organic and biomimetic structures, inspired by the beauty and efficiency of nature itself.

The true power of parametric geometry lies in its ability to respond and adapt to varying design criteria. Through the manipulation of parameters and inputs, designers can generate a multitude of design iterations, each with its own unique set of qualities. This iterative process not only facilitates exploration and experimentation but also enables designers to optimize their designs based on specific performance goals, such as structural efficiency, energy consumption, and occupant comfort.

Moreover, parametric geometry empowers designers to create highly customized and site-specific solutions. By integrating site data and environmental factors into the design process, architects can shape structures that harmonize with their surroundings, optimizing solar exposure, ventilation, and views. The result is architecture that seamlessly integrates with the environment, creating a sense of harmony and enhancing the overall user experience.

In the realm of computational design, parametric geometry serves as a catalyst for innovation, pushing the boundaries of what is possible in architecture. It offers a transformative approach that combines mathematical precision, design intuition, and technological advancements to reshape our built environment. By embracing parametric geometry, architects can navigate uncharted territories of design, creating awe-inspiring structures that captivate the imagination and shape the future of architecture.

Parametric Long-span
Newtonian gravitational laws were applied to architectural surfaces to generate an efficient long-span airport terminal geometry. The full geometry is defined via 2 # surfaces and 1 # formula.

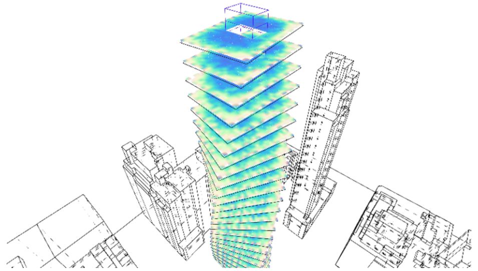
Informative Design

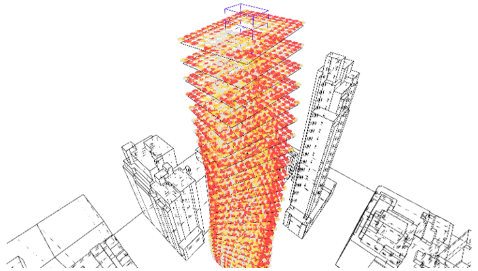
In this captivating image, we witness the marvel of Building Environment Analysis (BEA) employed for a parametric tower, unlocking a new era of architectural intelligence. Through a revolutionary one-click simultaneous analysis, this cutting-edge approach enables multiple assessment attributes to be seamlessly evaluated.

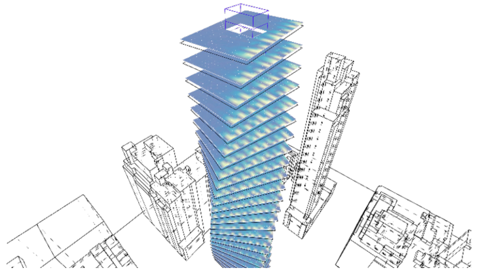
At the super-early design stage, stakeholders are empowered with profound design intelligence. This transformative process allows for passive benefits to be seamlessly integrated into the very fabric of the tower's geometry. By harnessing the power of Computational Design, the true DNA of good design is unveiled, paving the way for maximum performative gains in terms of both environment and cost.

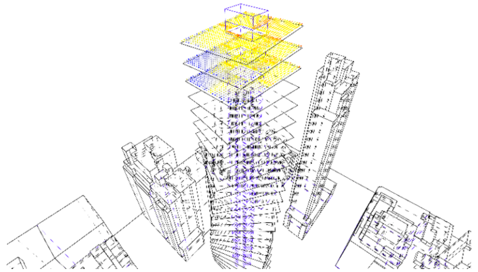
The BEA methodology embraces the essence of efficiency, streamlining the design process while magnifying its potential impact. Gone are the days of isolated and time-consuming analysis; now, a comprehensive understanding of the tower's environmental performance can be obtained effortlessly, thanks to the synergistic convergence of computational power and design finesse.

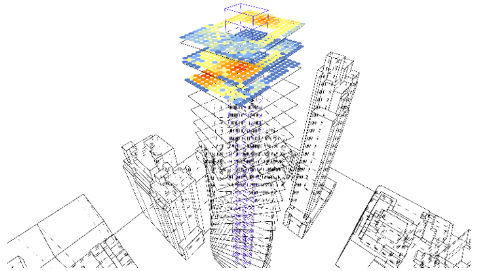
This image serves as a testament to the profound impact of computational design techniques. As the tower's intricate geometry unfolds, a symphony of insights emerges, illuminating the path towards a sustainable and optimized future. It exemplifies how the integration of advanced analysis tools at the earliest stages of design empowers architects, engineers, and stakeholders to make informed decisions that harmonize form, function, and environmental stewardship.

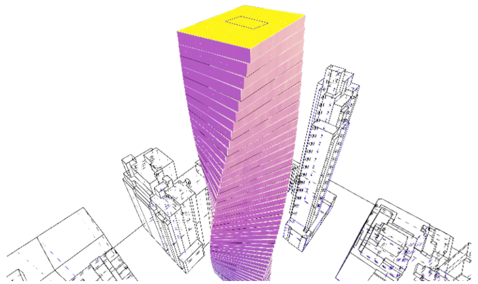

DAYLIGHTING

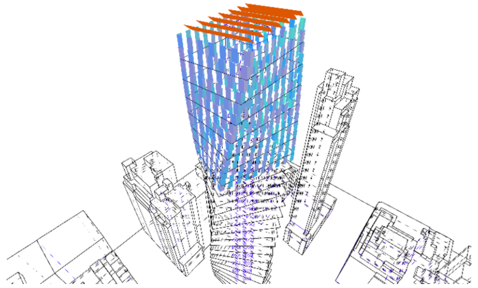

GLARE

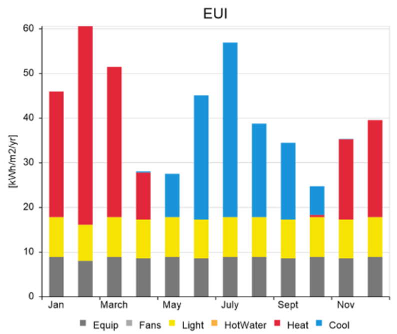

QUALITY VIEWS


SPATIAL COMFORT

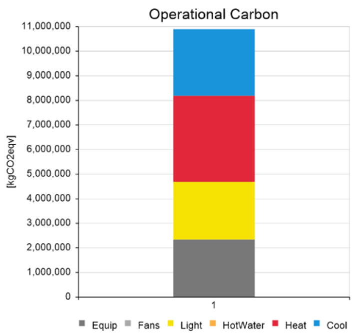

ACOUSTICS


SOLAR RADIATION


PV ENERGY



ENERGY USE



CARBON

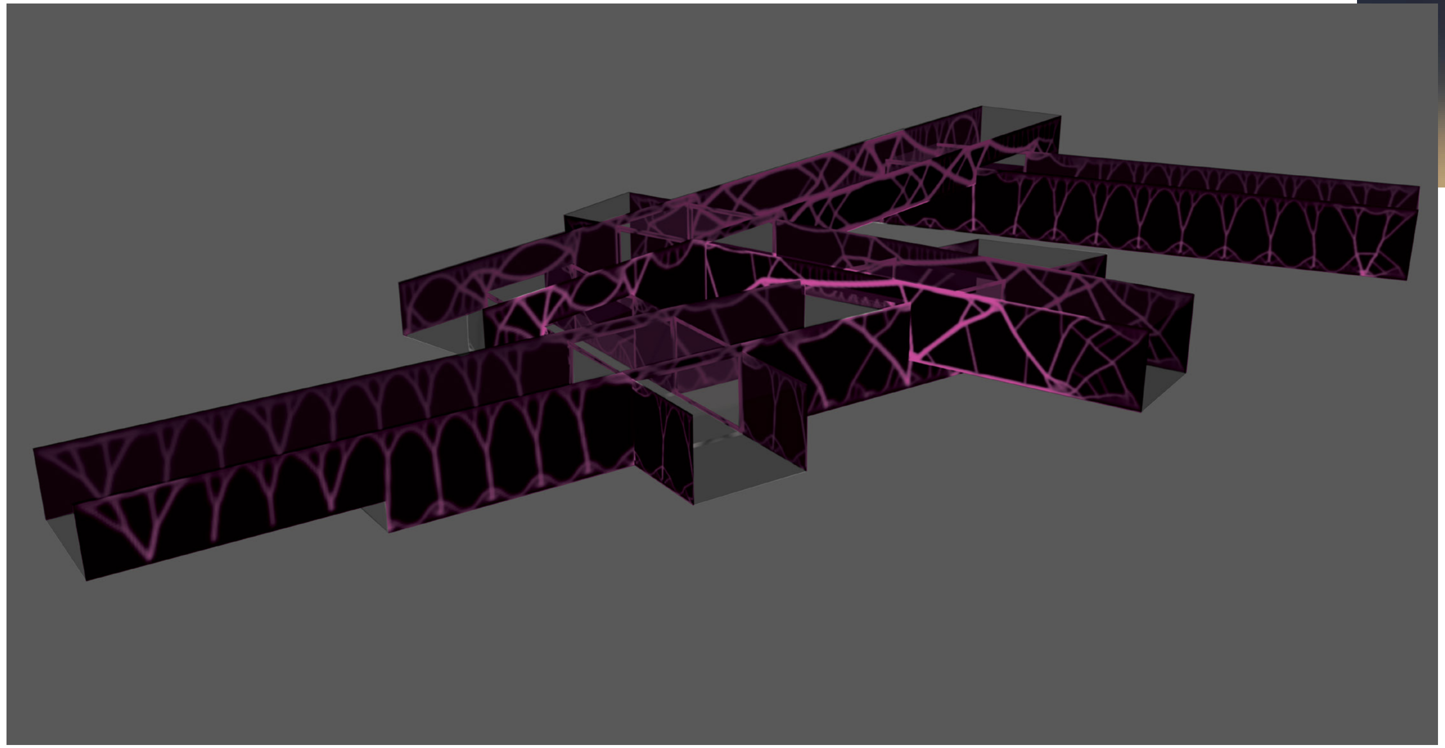
Early-stage insight with one-click simultaneous Building Environment Analysis (BEA)

Finding Form:

Learning from Nature's Playbook

Computational design has elevated structural form-finding to new heights, both at the building and elemental scale. No longer bound by rectilinear boxes, vertical columns, and horizontal beams, the freedom to explore geometric possibilities leads to greater efficiency. This borrowing from nature's playbook, embracing the freedom of form and frugality of material, allows for innovative structural solutions that optimize resource usage and minimize waste.

Computational design unlocks a realm where buildings take cues from the natural world, resulting in regenerative and aesthetically captivating architecture. These new techniques will inform a new design typology for the Computational Design Age.



Emulating Nature
Stress patterns in a cantilevered structure and in a cantilever wings of a dragonfly

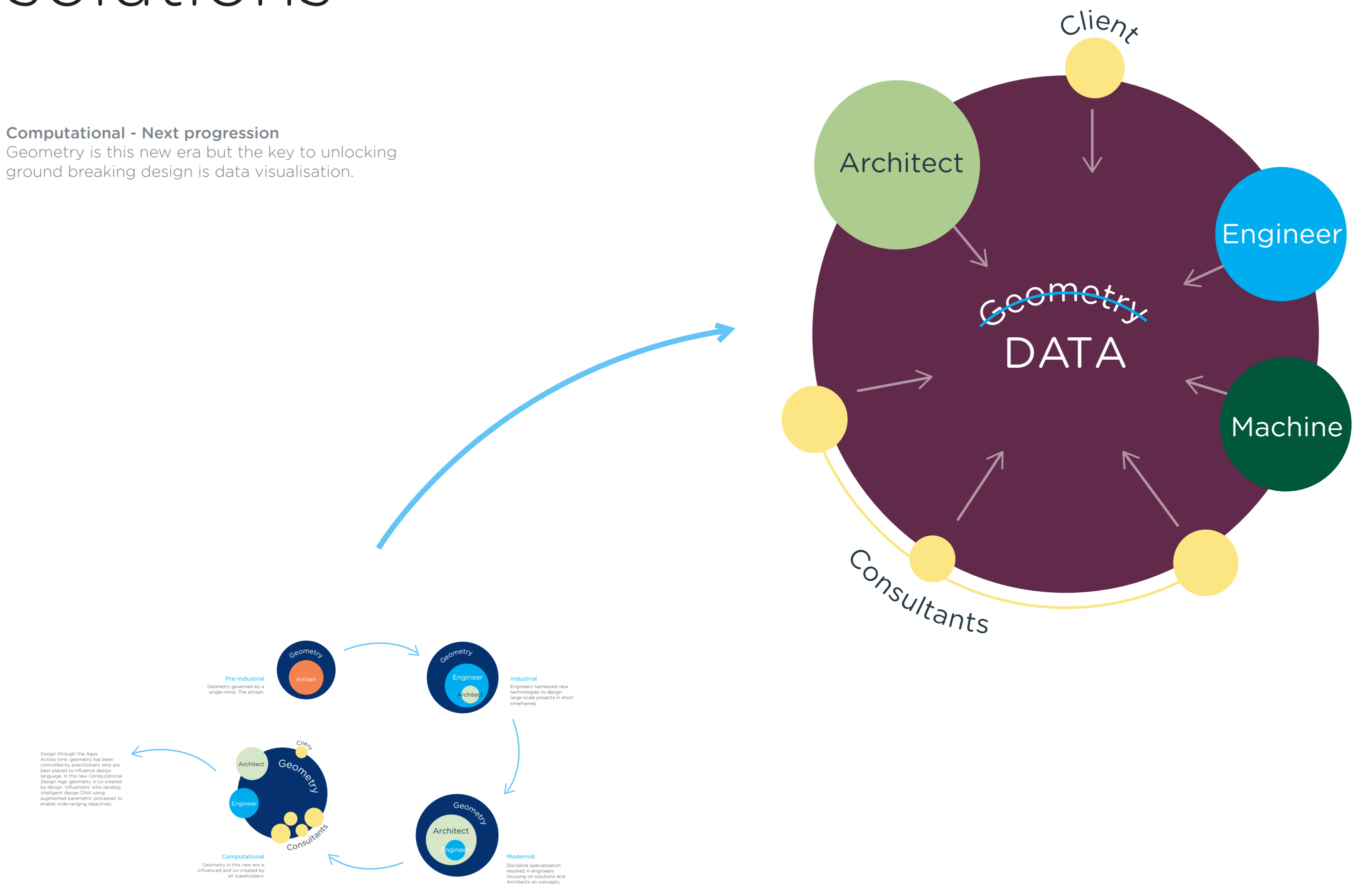
Dragonfly

"The 'economy' in material usage and the 'generosity' in form can be borrowed straight from the playbook of the oldest and most masterful of builders.... Nature itself."

Cloud Simulation

Detaching processing power from design solutions

Computational - Next progression
Geometry is this new era but the key to unlocking ground breaking design is data visualisation.



External microclimates are critical for the comfortable use of outside space in large parts of the world. This is particularly important when targeting passive or low-energy strategies in more extreme environments for masterplans, projects of large scale or areas where the public realm is particularly sensitive.

Conventional assessments utilise intensive CFD, physical models and defined performance criteria (Pedestrian Wind Comfort–Lawson Criteria, etc.) These manifest in computationally heavy, detailed assessments carried out post-optioneering and architectural form finding. Wouldn't it be better if we understood and visualised these dynamic effects whilst developing the building massing? - this is where most negative impact is committed.

How do we make wind assessment as parametric as solar radiation analysis?

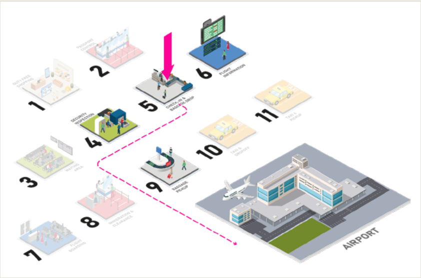
We can use a cloud-base CFD which is linked to parametric models that drive Universal Thermal Climate Index (UTCI) grids. This removes the inertia of local computation.

User Experience

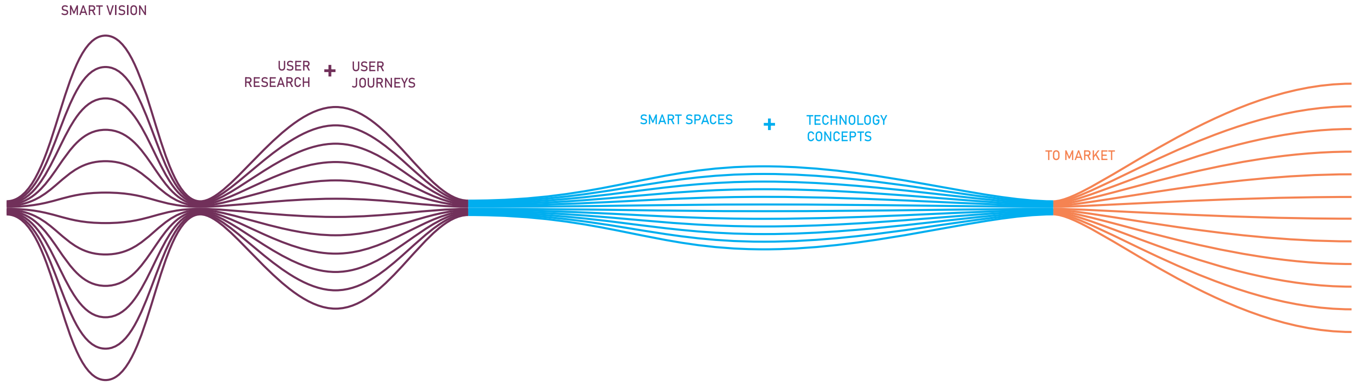
Technology underpins the way we live, work and interact. Demand for infrastructure that facilitates a seamless user experience and energy monitoring is accelerating - this must anticipate the needs of future generations. The growth of associated applications is almost exponential. The built environment and construction sectors, whilst historically slower in adoption of emerging technologies, are not immune. We see increasing complexity, requiring vast quantities of integrated systems.

Systems that manage the built environment are becoming truly sophisticated in the way they manage space, resources, and enhance user experience. Developments which combine a considered technology suite with an integrated design approach create new opportunities for innovation, interaction, and investment. SMART technology can be a tool to improve the health and well-being of users and reach new levels of liveability, sustainability and wellness.

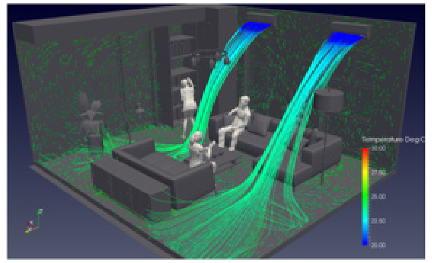
The future of SMART, does not only design a space. It designs a time, a series of moments that exist at the convergence of the physical, digital and psychological. The times where people find meaning and have purpose, all within a platform we call the SMART Future.



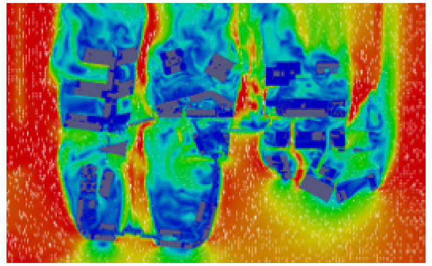
Key user journeys to inform the design and technology interventions for the project



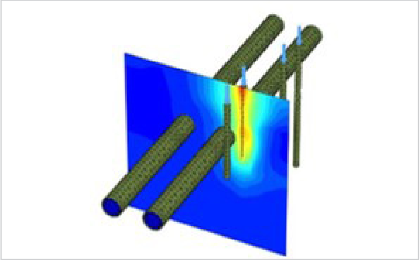
Everything Advanced Simulations



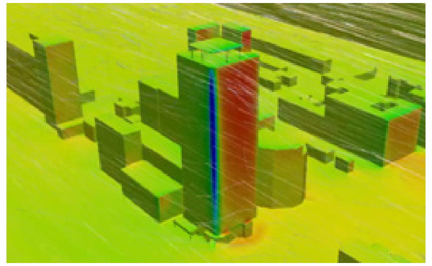
Thermal comfort study: CFD Simulation for ACMV flow



Natural ventilation CFD analysis

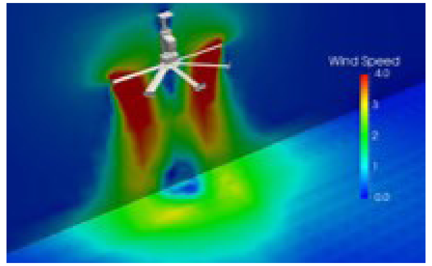


Tunnel settlement from consolidation of soils around loaded piles

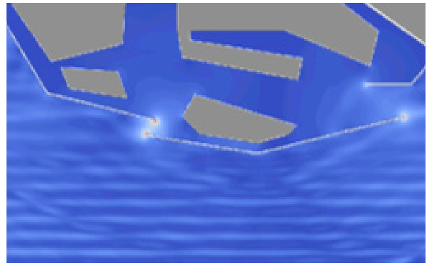


Wind pressure on building facade using CFD analysis

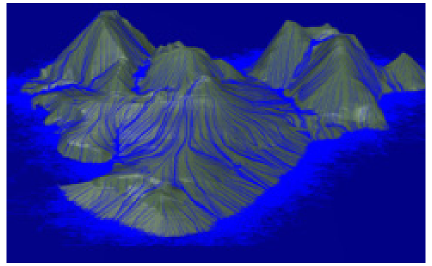
Wind-driven rain analysis



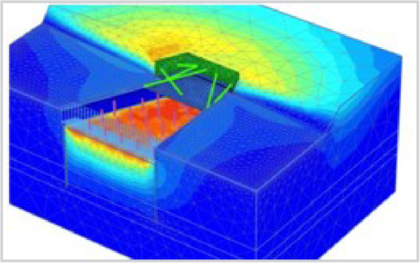
Thermal comfort study: CFD Simulation for fan air flow



Hydraulic CFD simulation on wave propagation

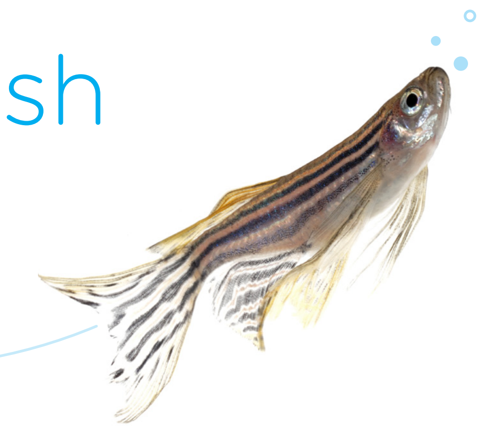


Hydrological analysis of rainwater on a hillside site or slope



Deep basement excavation soil deformation in top-down construction

Of Genes, Zebrafish & Net Zero



At Ramboll, we have developed a digital tool called Zebrafish.

It uses a mix of parametric and comparative modelling, cloud technology, bespoke analysis, and data visualisation to analyse hundreds of thousands of options for each building.

SETTING UP THE SIMULATION

Step 1 : Gather Information
In this initial phase, we gather a range of data, including weather data, geometrical measurements, fabric properties, room usage and occupancy information.

Step 2 : Set up a Baseline Model
A baseline model can be established depending on the project type: either for an existing building or a new construction. In the case of existing buildings, metered data can be gathered and correlated to the energy modeling results. This correlation ensures that the digital representation remains closely tied to real-world conditions.

Step 3 : Propose Interventions
A combination of numerous passive and/or system interventions can be proposed to create an exhaustive analysis that can be swiftly conducted during the early stages of the project.

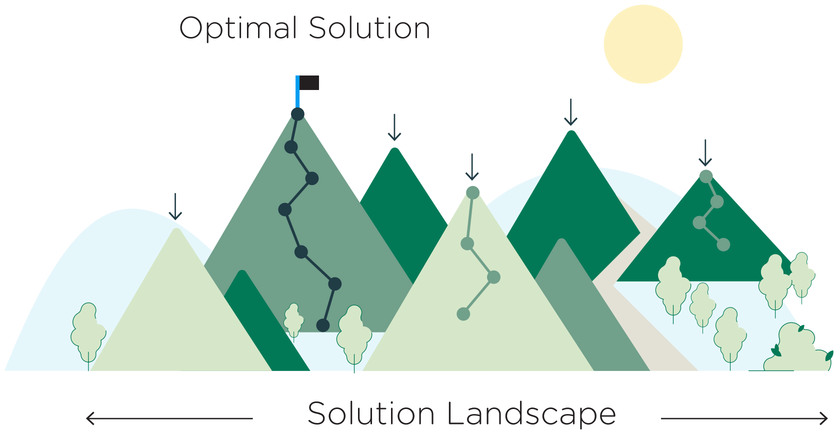
Results and Post-Processing

Step 4
Rapid Exploration

By considering many interventions, we can find the “sweet spot” where the maximum benefit can be achieved for the minimum cost and/or carbon investment.

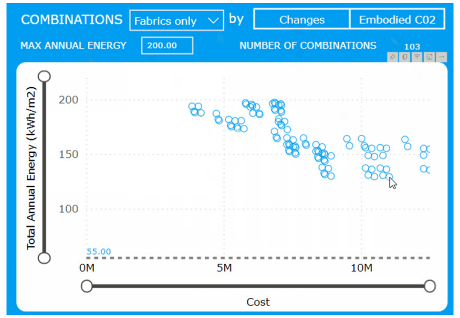
This approach enables us to efficiently explore a multitude of potential options.

Zebrafish helps scale decarbonisation of existing buildings



Step 5
Visualise and Interrogate the data

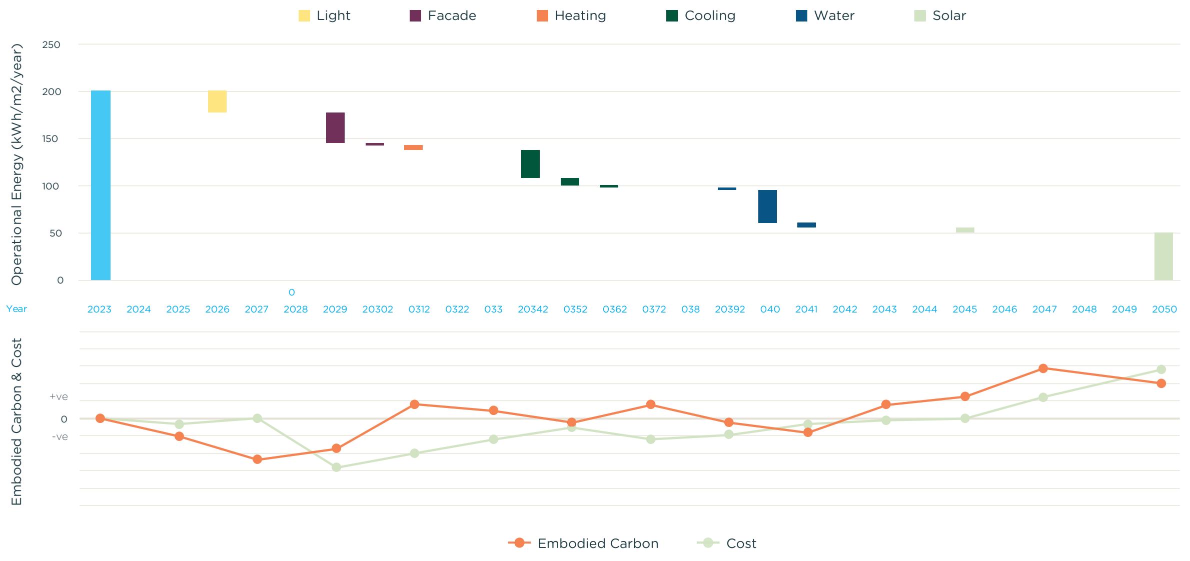
Interactive dashboards are used to outline and develop insights from the hundreds of thousands of data points which helps to inform decisions to be made.

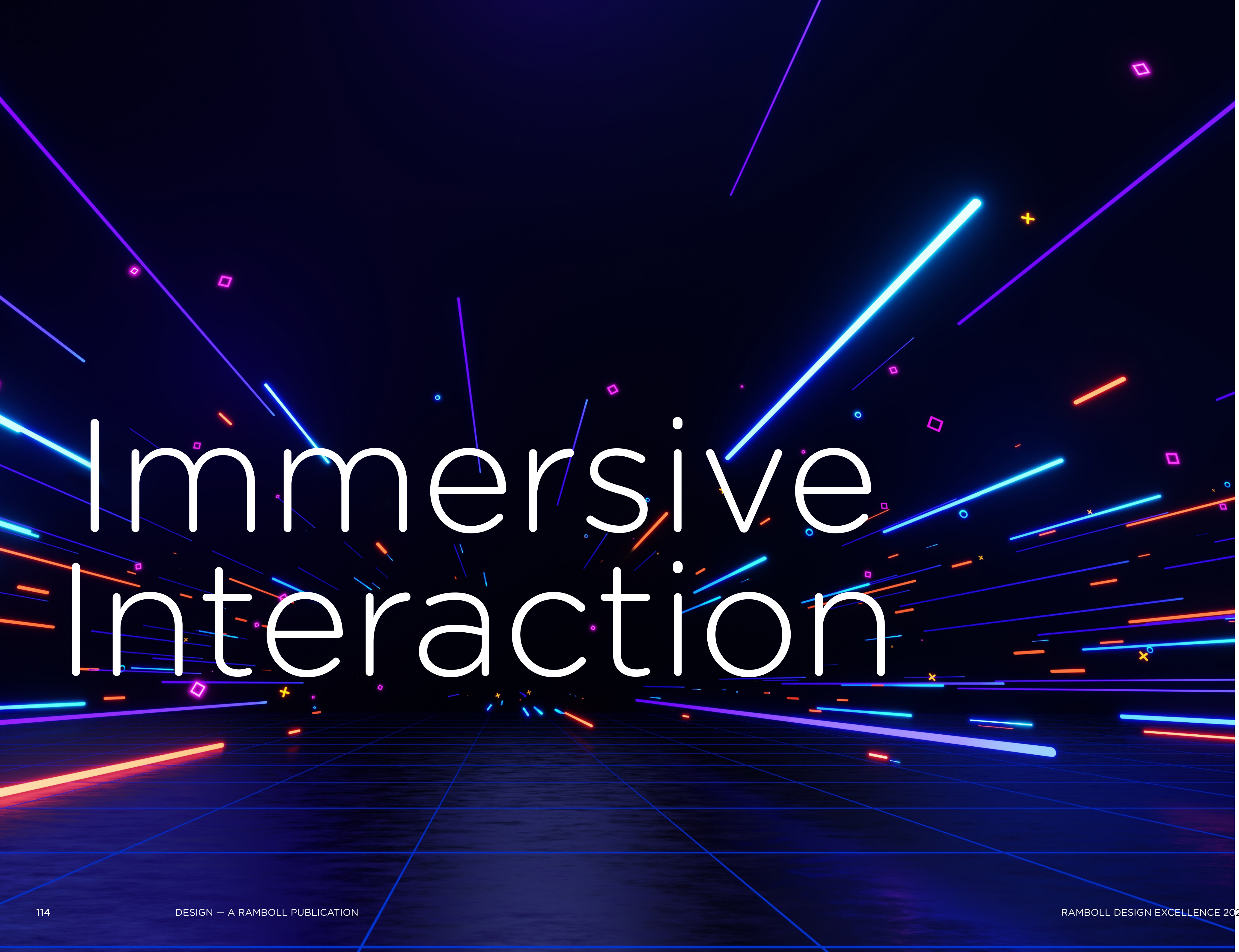


Step 6
Create a carbon reduction roadmap

The ultimate result is a visual roadmap for asset owners on how clients can reduce the energy usage for their buildings and improve their energy ratings.

This sets out the pathway to decarbonisation and any interrelationships between interventions.





Immersive Interaction

In the realm of computational design, immersive interaction has emerged as a powerful tool, revolutionizing the way architects and designers engage with clients and stakeholders. By harnessing the capabilities of the latest film studio animation and video game rendering software, computational design teams are bringing projects to life with rich media interactivity, enabling unprecedented levels of co-creation.

The integration of advanced rendering software from the film and gaming industries allow computational design teams to create immersive experiences that transport clients into virtual environments. From interactive walkthroughs to real-time visualizations, these technologies provide a glimpse into the future of the built environment, offering clients a chance to experience spaces before they even break ground.

Through immersive interaction, clients can explore designs, interact with elements, and gain a deep understanding of the spatial qualities, materials, and ambience envisioned by the design team. This level of experiential engagement fosters collaboration and empowers clients to provide valuable insights and feedback early in the design process, enabling a truly co-creative partnership.

One of the key advantages of computational design is its ability to accelerate workflows, bringing high-end visualizations to clients and stakeholders from the project's inception. By leveraging computational power and advanced algorithms, design teams can rapidly generate and iterate on design concepts, integrating feedback seamlessly. This accelerated workflow not only saves time and resources but also enhances the decision-making process by allowing stakeholders to make informed choices based on realistic and immersive visualizations.

The convergence of computational design and immersive interaction heralds a new era of co-creation and client engagement. By immersing clients in virtual environments and providing them with the tools to interact and co-create, computational design empowers stakeholders to shape the trajectory of projects with a level of detail and realism never before possible.

In this dynamic landscape, computational design enables a transformative design process where collaboration and creativity thrive. Embrace the power of immersive interaction and computational design to redefine the boundaries of co-creation, shaping a future where client visions are seamlessly brought to life.

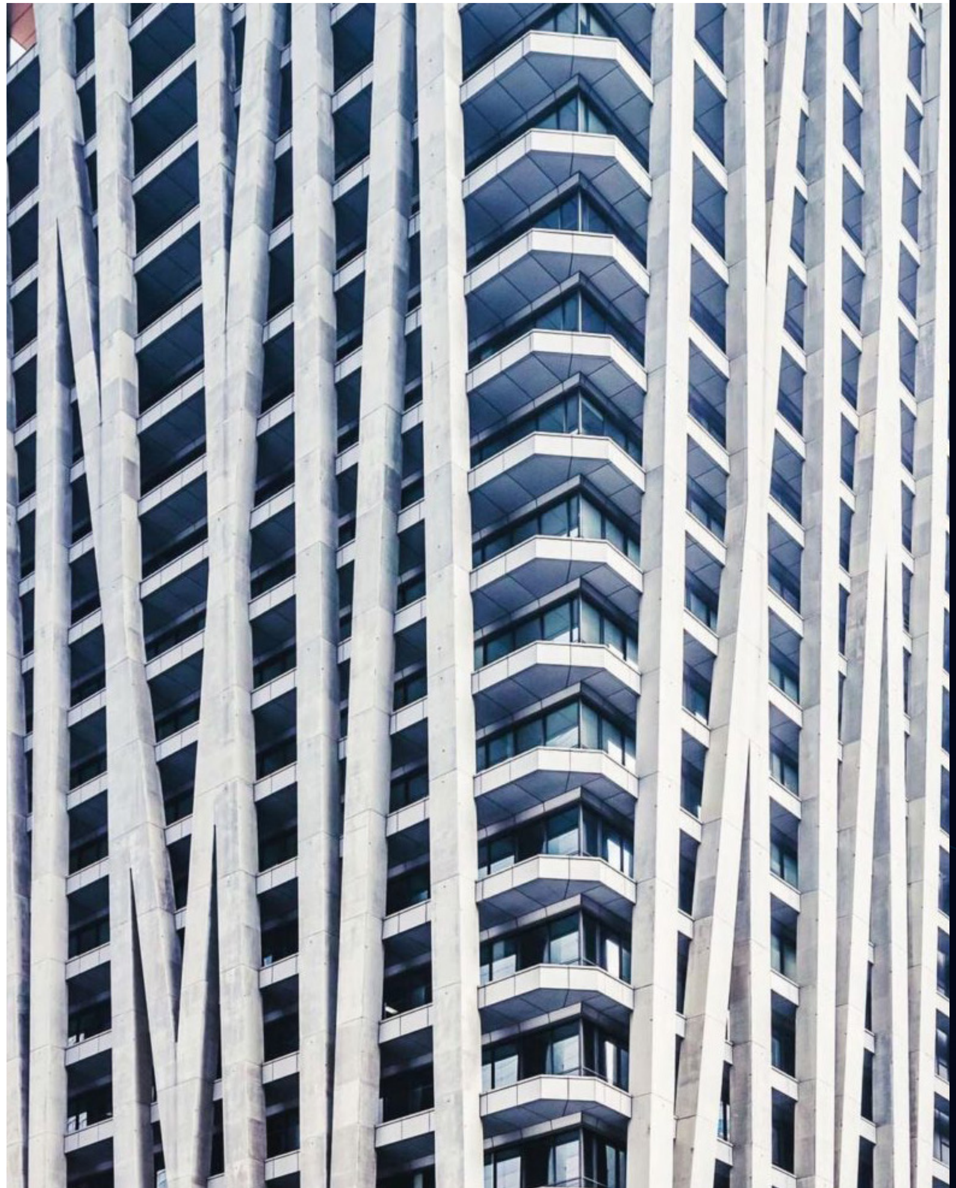
Reshaping the Future
and reducing carbon emissions

Computational design and technology hold immense promise in the battle against carbon emissions, offering a pathway to a regenerative future.

Through adaptable buildings, we can create structures that endure for centuries, reducing the need for frequent re-construction. By embracing organic materials, we tap into nature's toolbox, substituting environmentally harmful substances with sustainable and abundantly available alternatives.

Finally, the augmentation of human intelligence with AI empowers us to unlock new levels of innovation and efficiency.

As we embrace these transformative forces, we can pave the way for a regenerative future that harmonizes technological progress with environmental stewardship. It is through these synergistic efforts that we can reduce carbon emissions and shape a regenerative world for generations to come, and to become "**Good Ancestors**"...



Tokio Marine Centre, Singapore (CSYA)
A parametrically tuned structure

Augmenting Human Potential

The rapid advancements in AI tools and capabilities have sparked both fascination and fear. However, it is increasingly evident that the augmentation of human intelligence with AI can lead to ground-breaking new horizons.

By combining human creativity and intuition with computational power, we unlock the potential for innovative solutions to complex design challenges.

AI-powered algorithms and simulations enable designers to explore countless design possibilities, optimize energy efficiency, and reduce material waste.

This symbiotic relationship between humans and AI may become our saviour, guiding us towards a regenerative future by leveraging the strengths of both human ingenuity and computational power.

Unleashing Synergy
Where the intricacies of human insight and AI computational might converge, weaving a tapestry of innovation for complex design endeavours

Ecology of Intelligence

"My more optimistic prediction is that we're moving towards an ecology of intelligence where artificial intelligence is becoming a new creature within this ecology, which is forcing us to adapt. In the end, we move to a higher level of complexity and value through the introduction of this new intelligence into the universe."

Richard Hassell
Founding Director,
WOHA Architects

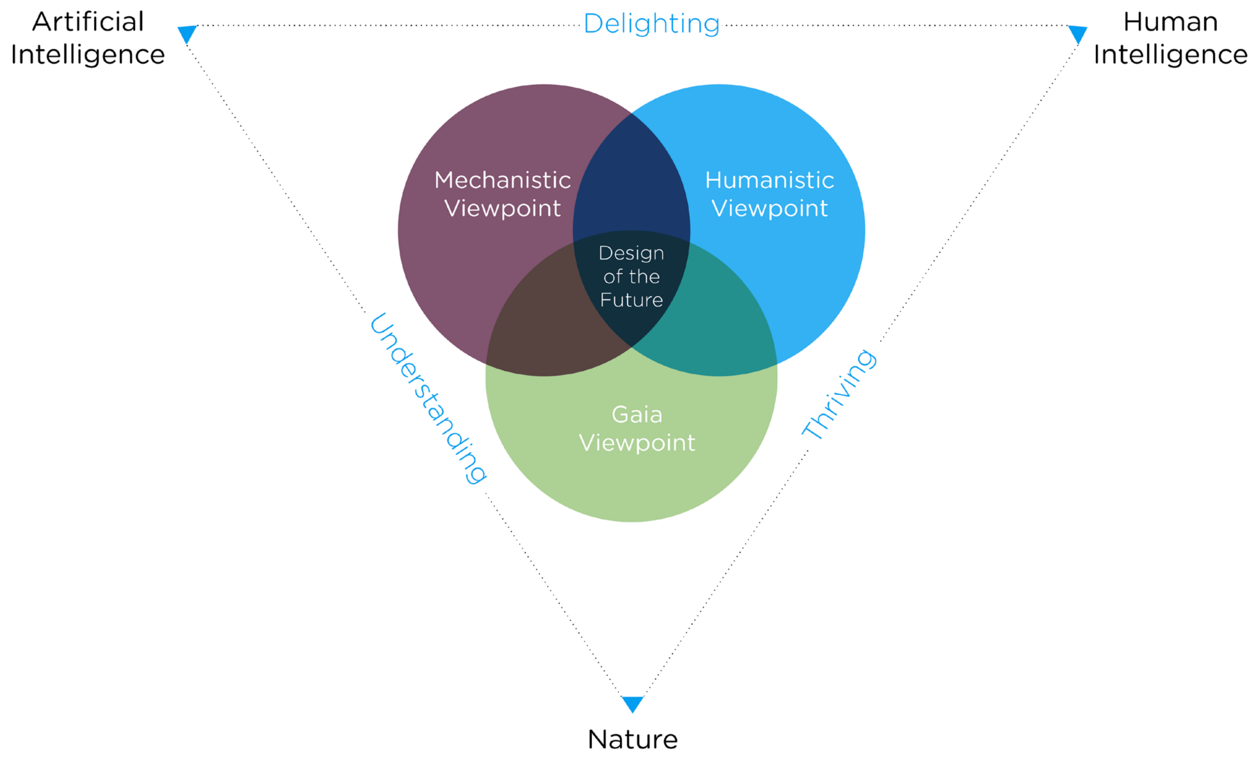


Image and idea: courtesy of Richard Hassell of WOHA Architects, Ramboll Design Excellence Forum 2022 (RDEF22)

Artificial Intelligence an etymology

Artificial Intelligence is not yet another software to buy, nor an extension to current digitalization initiatives. AI is a completely new paradigm in which we have radically different attitude and relationship with technology compared to what we have hitherto had.

In an AI environment, machines are no longer mere tools that follow our instructions. Instead, they are real collaborators who not only bring to the table high levels of algorithmic and other computational power and prowess, but also contribute to the thinking and brainstorming process. The term Artificial Intelligence was coined 67 years ago back in 1956, when any level of autonomy by machines was seen by many in the context of Mary Shelley's "Frankenstein's monster"!

This perception, as old, flawed, and erroneous as it obviously is, still prevails in the minds of many. This needs to change. A change the lexicon is needed to reflect the positive impact that machines have brought to our lives, and how they can help co-create with us a better future for all.

The word computer is way older than the term AI. Surprisingly to many, it is over 400 years old! It was used, as far back as the 1600s, to describe the position of an assistant to accountants! One who would perform most of the detailed number crunching associated with keeping the books and accounts up to date.

The origin of the word comes from the 2 Latin words of "com" meaning "together", and "putare" meaning "to think". The literal meaning of the combined word "computer" is, therefore, to "think together".

AI, for the first time in our history, enables the true meaning of the name "computer" for some modern and powerful machines to be reflected in what they actually can now do; that is "to think together" with us.

"Artificial Intelligence is not yet another software to buy, nor an extension to current digitalization initiatives."

Punggol Digital District, Singapore (WOHA Architects)
The 50-hectare Punggol Digital District (PDD) is envisioned as the driver of Singapore's Smart Nation push through technology and ideas innovation.

PDD is the first district in Singapore to adopt an integrated masterplan of a business park, Singapore Institute of Technology's (SIT) new campus, an underground MRT station and other community facilities to create synergy and close integration between industry and academia and build strong creative communities.

Jiangxi River Park, China
(Henning Larsen, SADI and Ramboll)
This development is a linear riparian park acting as a vital regional ecological corridor for flora and fauna, playing a vital role in providing flood control & water storage for the new district. Our involvement in the project allowed layers of risks and vulnerabilities to be identified through iterative mapping, laying the foundation for the overall design and policy of the park.

AI for Augmented Intelligence:

AI is about a complete paradigm shift in our relationship with the machine

"Hitherto, or until very recently at least, our imagination has been limited by our "natural" intelligence. With AI, this intelligence is augmented and multiplied many folds. This augmented intelligence empowers us to imagine things we would otherwise not allow ourselves to imagine; and to create things we would otherwise not imagine creating."

Hossein Rezai-Jorabi
Global Design Director, Ramboll

Decarbonisation

IN DEPTH

Decarbonisation in the built environment is about using design as a lever of innovation. Operational energy and carbon associated with existing buildings and infrastructure must be addressed, but the materials used to achieve this, as well as those required to meet ongoing development, must not excessively draw down our carbon budget.

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Andy Brahney
Lai Wan Sing

06

“Our relationship with carbon, greenhouse gases, and the whole agenda of decarbonisation, is a true story of 2 halves!”

On the one hand,

there have been many well-intended initiatives by committed individuals and organizations, not least the UN over the past 50 years or so, to reduce or cap such harmful and deleterious emissions into the atmosphere.

The following key milestones are noteworthy:

- 1979: First World Climate Conference
- 1987: Brundtland Report “Our Common Future” was published,
- 1990: First IPCC Assessment report,
- 1995: First UN Climate Change Conference,
- 2005: Kyoto Protocol entered into force,
- 2009: Copenhagen Accord,
- 2015: Paris Agreement adopted,

These, and a multitude of COPs (Conference of Parties), including: COP26 in Glasgow (2021), COP27 in Sharm Al Shaikh (2022), COP28 in the UAE (2023), and the recently published 6th IPCC Report (AR6 Synthesis Report: Climate Change 2023).

These provide valuable resources produced by highly committed and competent climate scientists and other committed individuals, corporations and governments from across the globe, on the dangers of inaction on the climate front, and on ways to control, minimize, and eradicate deleterious gases into the atmosphere, and to adopt practices which are more in tune with planetary boundaries and a congruent co-existence and co-creation with nature.

On the other hand,

the concentration of such gases in the atmosphere has relentlessly continued to go up, and exponentially too! Carbon dioxide (CO_2) concentration, measured in parts per million, in the atmosphere stands at 422 ppm in December 2023.

This has gone up by more than 70 since 1984; the same level of increase seen in the previous 200 years since the late 1700s!

Similar degenerative tendencies are observed in all environmental indicators, from loss of biodiversity and forests, to the acidification of our oceans. It is as if the good intentions and deeds of the very competent and capable scientists, activists and agencies have happened on a different planet to the one we live on, and in which these harmful gases are pumped into and piled up in its atmosphere.

The harmful mechanisms of the effects of fossil fuels in all our industries, and the resulting harm they do have now been known for over a century.

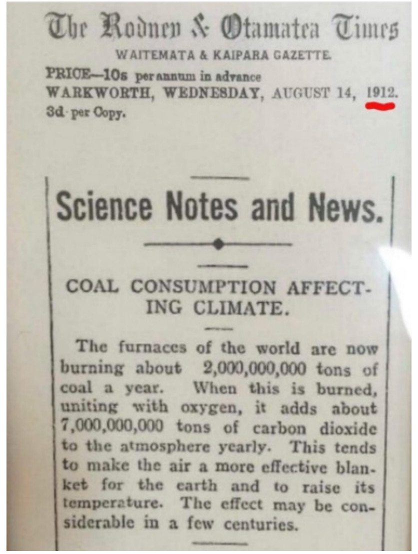
However, vested interests and cheap oil and coal, have persisted and until recently prevailed. This must change, and must do so in the very short window still available to keep the rise in average atmospheric temperatures above those prevailing in the late 18th century, to below 1.5 degrees, as committed in the Paris Agreement: COP21.

The paramount environmental indicator is the heating of the biosphere. Terms like global warming, climate change, global heating, and more recently, global boiling, have been coined to describe this phenomenon.

The rise in average temperatures compared to those prevailing at the onset of the industrial revolution, back in the 1780s, currently sits at around 1.1 degrees centigrade. There is near consensus amongst climate scientists that 1.5 degrees is the trigger point for unforeseen (unimaginable) consequences.

Key amongst all environmental drivers, like greenhouse gases, biodiversity, forest areas, etc, ought to be about controlling these temperature rises with a view to keeping them within the 1.5 degrees. Emission of excessive amount of Greenhouse Gases (GHGs) into the atmosphere is not the only contributor, but a key contributor, to rise in atmospheric temperatures.

This edition of Ramboll DESIGN addresses decarbonisation of the built environment, and makes hard and verifiable commitments to reducing them in Ramboll buildings. It also invites all industry partners to join us, and make similar or better commitments.

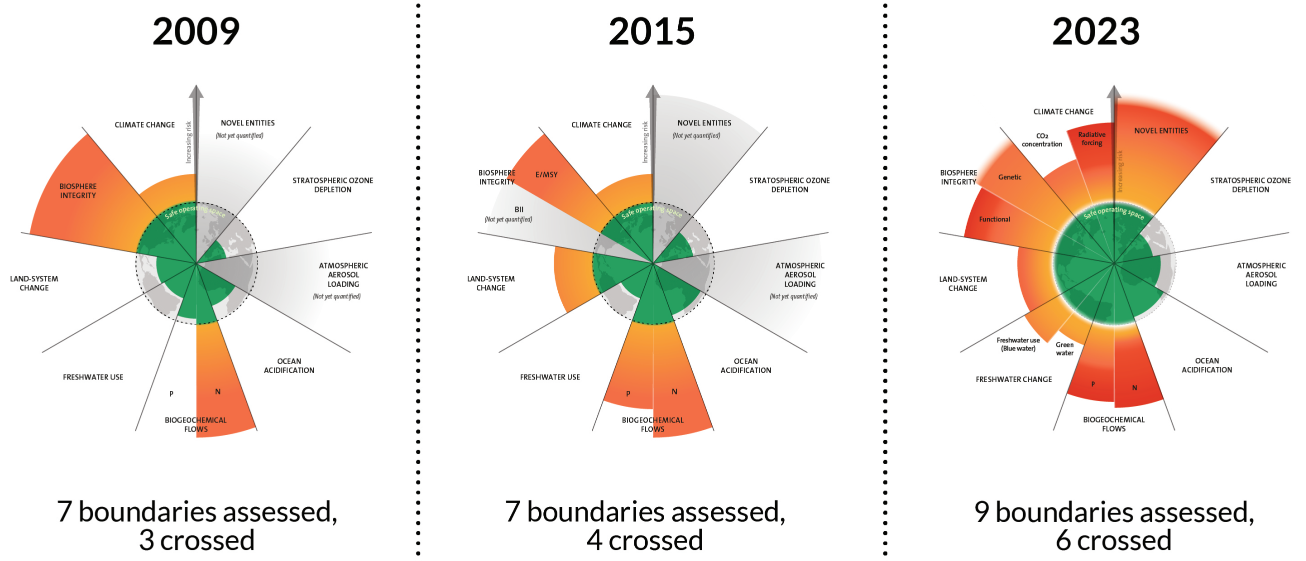

The Rodney & Otamatea Times
WAITEMATA & KAIPARA GAZETTE.
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

Newspaper cutting from 1912 New Zealand
Over a century ago, coal furnaces were recognized for emitting Carbon Dioxide (CO2), and there was an early understanding that this greenhouse gas contributed to global warming.



Planetary boundaries:
A regression in progress ...

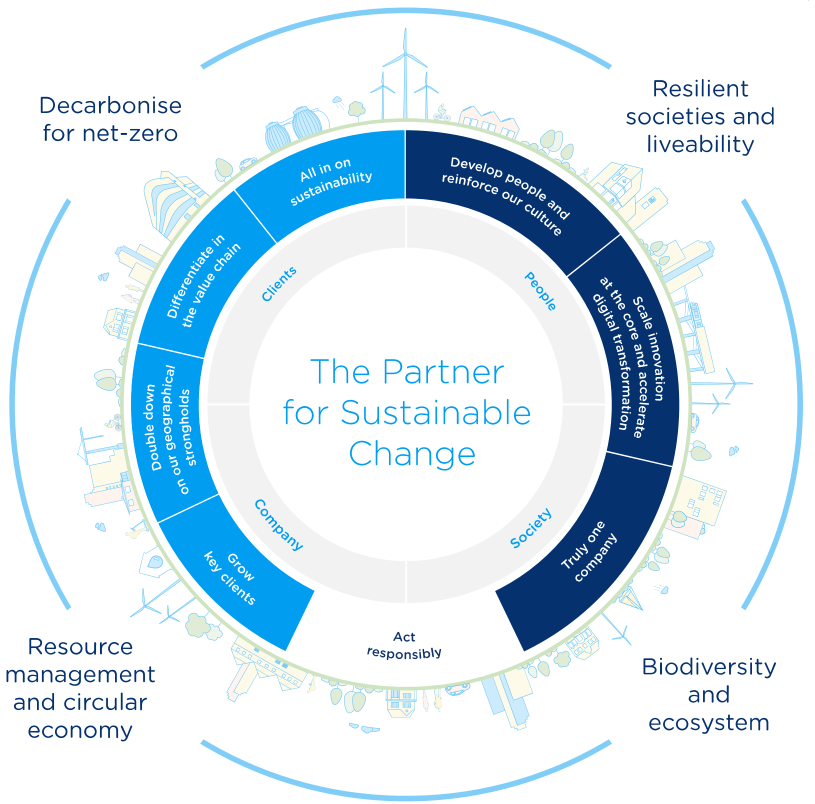
Ramboll’s Global Strategy 2022 - 2025

Ramboll’s global strategy for the strategy period 2022 to 2025, “The Partner for Sustainable Change”, is built around four key themes, one of which is, ‘Decarbonise for net-zero’.

The other three are aimed at, “Resilient societies and liveability”, care for “Biodiversity and ecosystem”, and on “Resource management and circular economy”.

Key commitments in Ramboll’s Decarbonisation strategy are:

- That decarbonisation must be pursued until a net-zero state is achieved. (Our commitment is not about “doing less harm”, but about “halting the harm”)
- That hard limits are to be set now on the limits on Embodied Carbon we allow in each and every one of our projects, (We are committing to a hard limit on embodied carbon of 150kg.m² for the superstructure of the buildings we design. More on this later in this edition of DESIGN.)
- That a roadmap to zero carbon is set, so that it is achieved in a finite and definable timeframe. (We commit to reducing the embodied carbon in the building structures we design by 30% by 2025, and by 50% by 2030.)



4 strategic unifying themes in Ramboll
In our strategy for 2022 – 2025, we go all in on sustainability and deepen our commitment to a sustainable future.

“With our strategy, we commit our expertise and effort towards solving the world’s toughest challenges within decarbonisation, resilience, circularity, and biodiversity.”

Jens-Peter Saul
Ramboll CEO

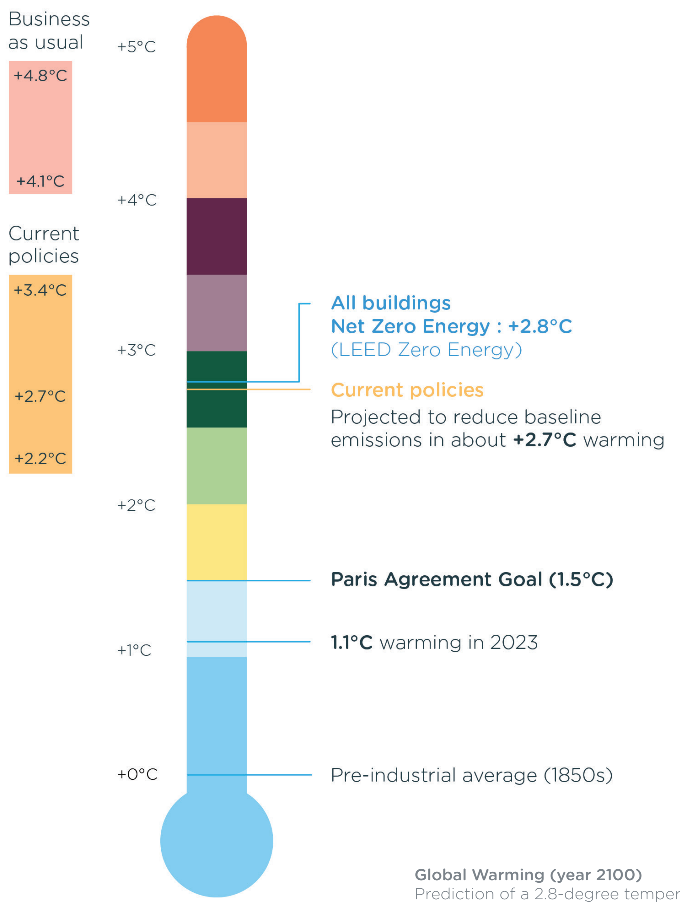
Decarbonisation in the Built Environment

The built environment is both the largest consumer of energy and the largest consumer of materials. Whilst this poses a huge challenge, arguably it is also our greatest opportunity to tackle Greenhouse Gas (GHG) emissions. The vast majority of the emissions associated with the built environment is associated with the energy required to produce the materials used in the industry, the energy required to power the processes of construction, as well as the operational energy demand, whether it be for heating, lighting or increasingly, cooling – by 2050, it is anticipated that we will use more energy for cooling than for heating.

Energy generation is still dominated by fossil fuels though some countries are rapidly decarbonising their grid. As such, one may assume that electrical gird decarbonisation will automatically lead to the decarbonisation of operational energy in buildings.

However, many buildings still use fossil fuels directly, and as more of our energy becomes electrical, there will be a huge spike in electrical demand that may be impossible to meet through renewables alone. Demand reduction in existing buildings and infrastructure is therefore critical.

Demand reduction, through improved building performance is also key to addressing fuel poverty, health and well being, especially as we must adapt to more uncertain weather patterns in the future.

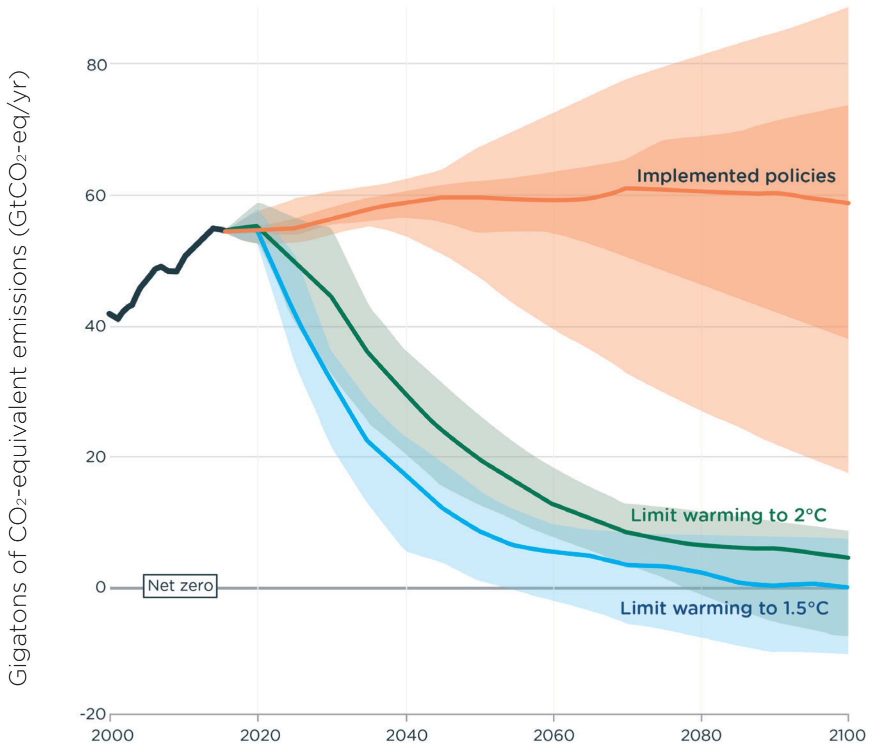


Global Warming (year 2100)
Prediction of a 2.8-degree temperature increase even if all buildings are rated LEED Zero Energy. Relying solely on decarbonisation initiatives within the built environment industry is insufficient to effectively mitigate global warming.

Adapted from Climate Action Tracker. The CAT Thermometer
Credit: Climate Analytics and NewClimate Institute

Pathway to 1.5°

Net global greenhouse gas (GHG) emissions



Global emissions pathways consistent with implemented policies and mitigation strategies

Source: AR6 Synthesis Report - Climate Change 2023, IPCC, Figure SPM.5

Key decarbonisation "shifts" required in the Built Environment industry:

Shift 1:
Retaining and Retrofitting existing buildings

Shift 2:
Decarbonisation of energy and all

Shift 3:
Design excellence, disruptive innovation, technology and regenerative design.

Shift 4:
Alternative materials, carbon-capture and carbon-sequestration

Shift 5:
Decarbonisation through Behavioural Change

Furthermore, we must also be cognisant of the significant inequality that faces the population, much of this must be addressed through improved infrastructure and buildings. This, coupled with population growth and urbanization, reinforces the fact that our remaining carbon budget must be targeted at where it can provide most value.

Decarbonisation
valuing Existing Buildings

Chapter 4 emphasizes the importance of addressing the environmental impact of existing buildings, as 95% of the structures projected for 2030 are already built and often fall below modern environmental standards. The focus on greening existing structures through retrofits, refurbishments, and alterations, and developing the skills, teams, and knowledge in this area is necessary.

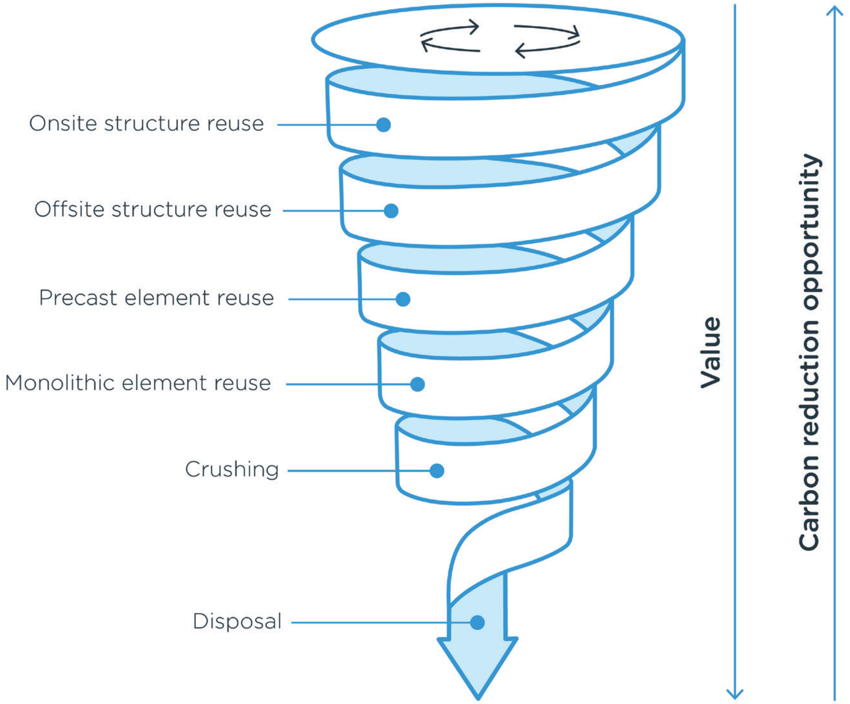
The edition argues that the demolish-and-rebuild development model has a similar environmental impact to deforestation, making it vital to explore alternatives. To make informed decisions about retaining existing structures, assessing the residual life of these buildings is crucial. While a "build nothing" scenario is impractical given societal development needs, a more achievable approach involves smart planning and technology utilization to reduce the demand for new construction. The combined effect of limiting embodied carbon and net positive operational carbon will allow us to work towards full decarbonisation in the built environment. We must learn to stop replacing what we already have and place greater value on our existing assets, valuing the carbon investment they represent.

"Every existing building has the right to be heard."

Golden Mile Complex
Also known as Little Thailand, the building is slated for redevelopment. Designated as a conserved building by the Urban Redevelopment Authority, its physical structure is expected to be preserved.

Understanding the 'carbon value' of existing buildings is key to its use as a broader decarbonisation lever in the built environment. Embracing an existing building hierarchy, which prioritises reuse, adaptation, and careful deconstruction over demolition, offers substantial carbon benefits.

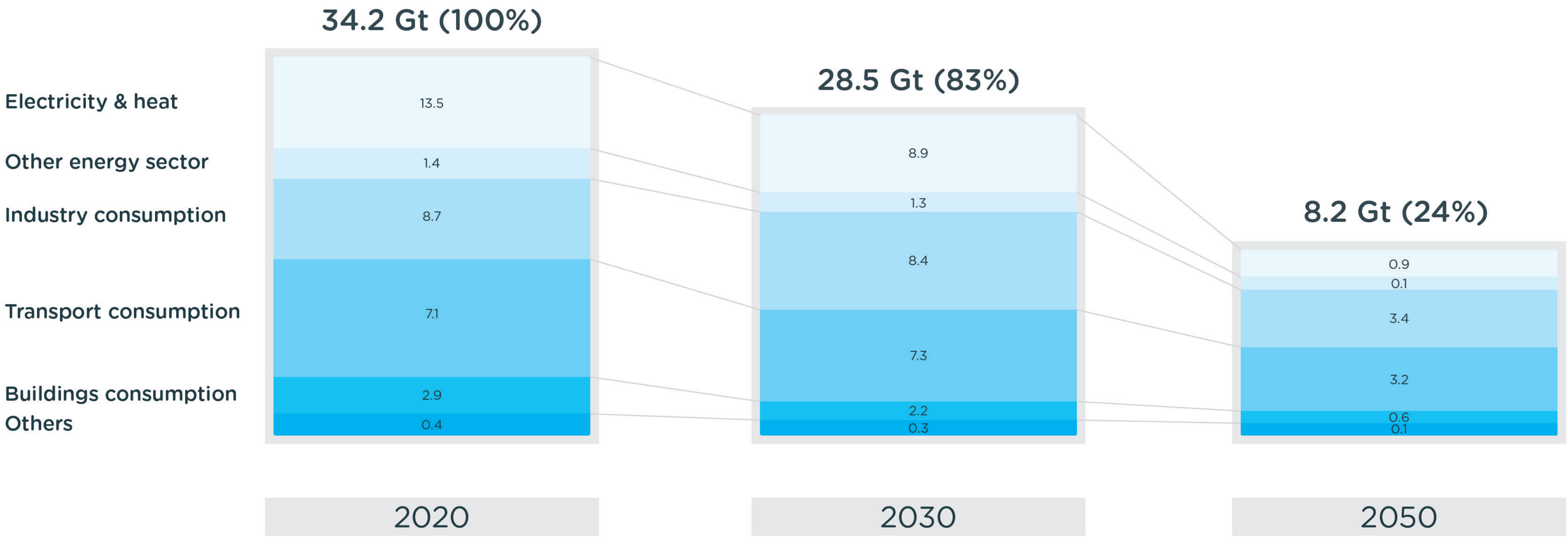
Reusing and adapting existing structures avoid carbon emissions by reducing the material demand of new buildings. In addition, it cuts down on waste generation and supports the principles of a circular economy. Whilst not all buildings will be suitable, every effort must be made to see our existing buildings not as a constraint, but a catalyst for creative design. We must take advantage of the history of a building to tell a story, or possibly reuse its elements in a new way. Existing buildings offer us many opportunities for the future, and if we are to meet our climate goals we must make full use of the life they still have to give.



"Longevity of the buildings we design is by default a decarbonisation strategy."

Decarbonisation of Energy and all...

"In our efforts to decarbonise the built environment industry, decarbonisation of energy is key."



The industry is highly energy-and electricity-intensive. Globally, over 80% of annual GHG emissions come from energy sources. The predominant component of operational carbon is the energy footprint. Embodied Carbon (EC) of most construction materials is essentially their energy footprint.

Concrete, which is an exception to this, has approximately 60% of its embodied carbon attributed to the sources of energy used to extract raw material, transportation, heating, and grinding clinkers in cement factories. Over 90 percent of EC of normal concrete is in the cement alone. The other 40% of EC of normal concrete comes from the carbon release due to the pulverisation of base clinkers, and from the actual hydration process leading to the hardening of cement/concrete.

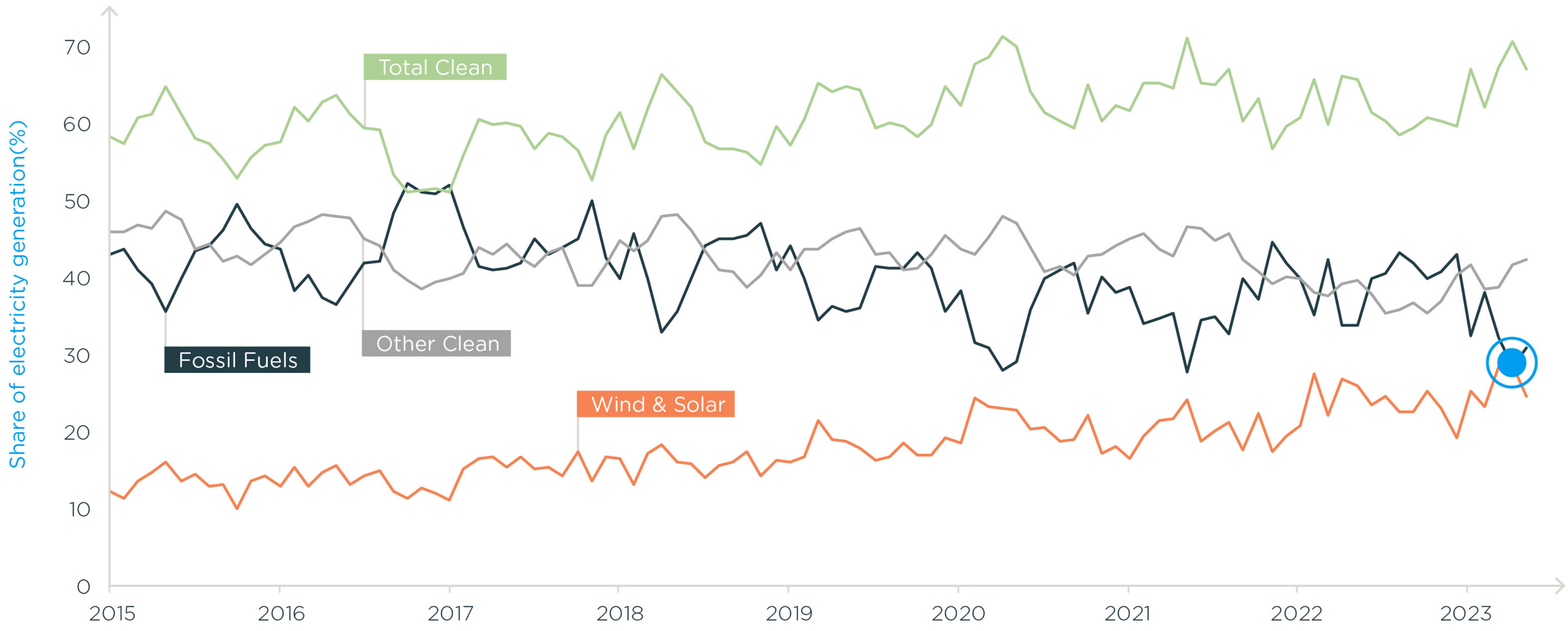
The energy sector must therefore lead in the decarbonisation of the industry. Projections for such reductions by the IEA are encouraging. It is projected that GHG emissions in the energy sector will drop by 17% by 2030. The reduction is projected to continue until 2050 when it will be reduced by 76% from the baseline figure of 34.2 Giga ton in 2020. With such large reductions, the built environment, our buildings and bridges, etc, will have a fraction of their current EC by 2050.

Percentage of carbon footprint in relation to year 2020

Source: Internatinal Energy Agency (IEA), World Energy Outlook 2021

Wind & Solar produced more EU electricity than Fossil Fuels in 2023

On this journey, the electricity production sector is making great strides. As recently as last year, the EU electricity production crossed an important milestone; the EU is now producing more of its electricity from renewable sources than from conventional fossil fuel sources. Conversely, it is now cheaper to produce electricity from a brand new wind/solar-powered power station than from a brand new coal-powered equivalent. Challenges with the current grids, and their adaptability to renewably sourced power remain persistent, but solutions are within reach.



Energy

Huge strides have been made in the energy performance of our buildings and as a result it is now possible to create buildings that are net zero in operational energy – meaning they have such low energy demand that this can be met through onsite and offsite renewable energy sources. Passivhaus levels of performance are also starting to become increasingly common, and it is clear that there are technical and commercially suitable solutions for new buildings. This does not mean the problem is solved; delivering these projects is still challenging and requires the necessary skills, knowledge, supply chains and most importantly, the drive to ensure they are a success.

There is now also a recognition of the sheer size of the refurbishment challenge – there are a vast number of existing buildings that require deep refurbishment. Many of these buildings have cherished heritage that must not be disturbed but most are simply rather stubborn and unyielding to modern construction; their successful and effective refurbishment requires the only source we have in abundance – human ingenuity.

One of the key challenges in the deep refurbishment of buildings, especially at a portfolio level, is understanding the best suite of options to implement.

There are a large number of different operational system options as well as fabric upgrades that can be undertaken – which is the most efficient and lowest risk?

Ramboll has been developing a tool to address this challenge. Zebrafish (as featured in Edition 6 published in September 2023) is a system that allows the rapid analysis of thousands of potential system upgrades to determine the most appropriate options for a client.

Other Clean: hydro, nuclear, bioenergy and other renewables
Fossil Fuels: Coal, gas and other fossil fuels
Total Clean: is the sum of Wind & Solar with Other Clean.

Source: Monthly Electricity Data, Ember

Decarbonisation through Design Excellence, Disruptive Innovation, Technology and Regenerative Design

The best approach to decarbonising buildings is to just use less material. This can be achieved through excellence in design.

High labour costs in the late twentieth century represented a departure from thousands of years of ambition to use less material in buildings. But now, using less is resurging, encouraging a return to craft in design and construction.

Modern engineering has accomplished incredible architectural monuments. But defying gravity comes with enormous carbon cost, which becomes increasingly corporately and socially unacceptable. A well-designed building is an elegant resolution between competing requirements. Engineering must be purposeful and a vital part of the genesis of the idea, rather than an exercise in post-rationalisation which disproportionately adds carbon to buildings.

Excellent design starts with challenging the design brief. Can the design be contextualised differently? Can it ask for less physical ambition without diminishing the experience? Can it better serve the client and also the environment? The challenge to clients and collaborators promotes time to reflect on whether the business-as-usual is still relevant. Design is rooted in empathy, so the communication and narrative that connects clients to engineers and designers are completely vital.

Design excellence then promotes creative thinking to establish better, and new ways to form buildings. Innovation is borne of big ideas that use less materials and therefore less carbon. Business-as-usual cannot credibly continue in a carbon-conscious world. Disruptive innovation is therefore vital if buildings and the construction industry are to remain credible.

Optimisation of building elements and systems to remove unnecessary material is vital for low-carbon outcomes. The reputation of engineers as cautious designers is not unfounded, and we promote the incremental gains that arrive with optimisation. This can be taken further by advanced optimisation and technology in the design process to produce lower-material designs that contain less carbon. Topological optimisation spatially arranges material where it is most needed, and the use of evolutionary solvers allows designers to test an exhaustive range of options and allow natural selection to perfect the design. For designers looking to adopt new but tried-and-tested techniques, biomimicry allows designers to take inspiration from nature to create a regenerative design paradigm.

Forming optimised and unusual shapes requires craft from contractors. Such techniques are evolving quickly, and advanced forms are becoming viable, facilitated by advanced and additive manufacturing; all serve to provide a practical delivery of advanced design thinking.

Advanced and Additive Manufacturing
Experiments on 3D printed concrete fin walls

SUTD Additive Manufacturing
A 3D-printed clay mold used to cast concrete in. Once the concrete is cured, the clay was washed off to reveal an elegant sculpted concrete structure

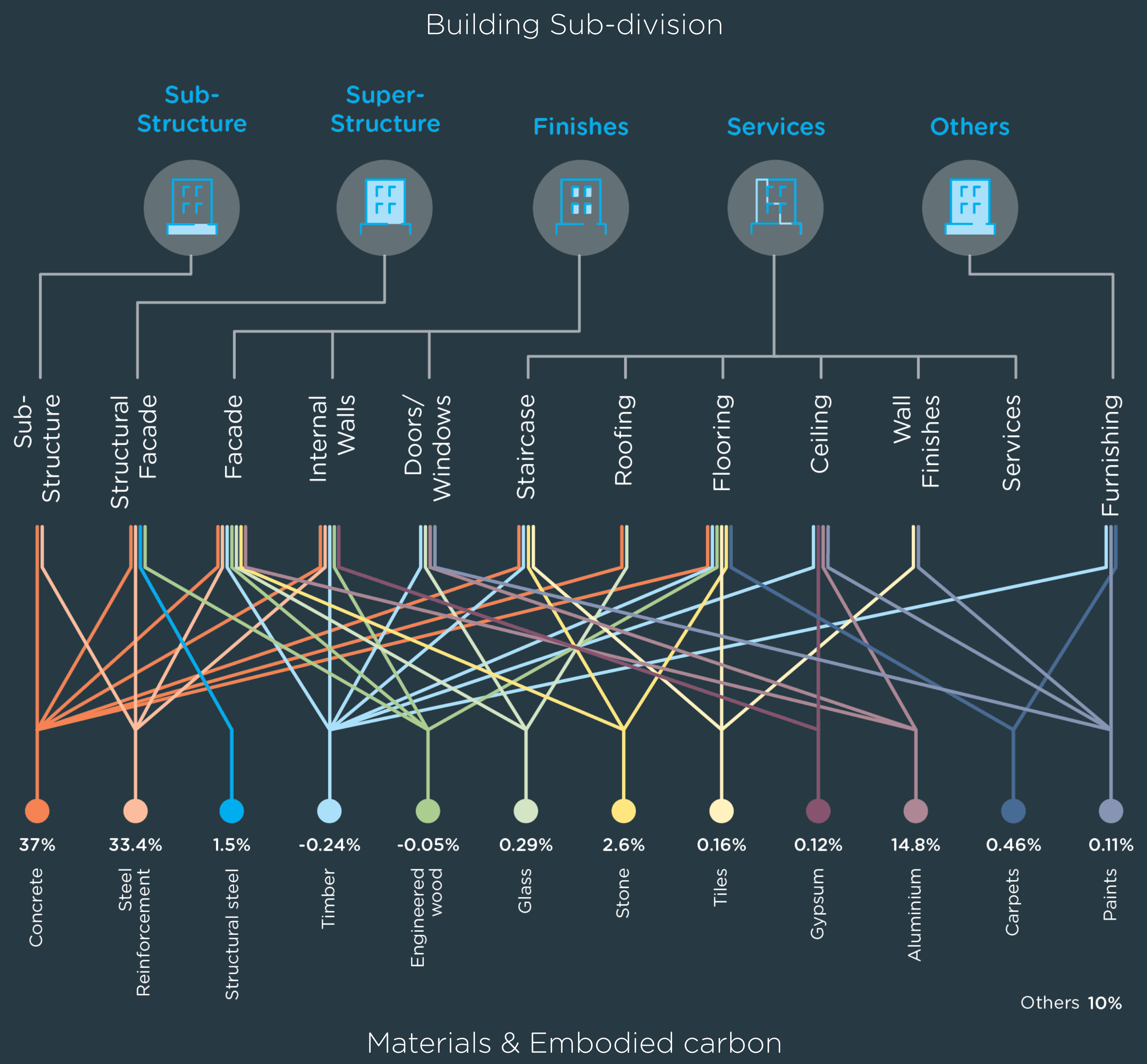
Decarbonisation in the built environment is about using design as a lever of innovation. Operational energy and carbon associated with existing buildings and infrastructure must be addressed, but the materials used to achieve this, as well as those required to meet ongoing development must not excessively draw down our carbon budget. Through brilliant design approaches, we can achieve the retention and refurbishment of our existing assets, continue development, whilst meeting our carbon goals, though it is not going to be easy.

Carbon Distribution

Concrete
37%

Steel
35%

"Over 2/3rd of all carbon in most buildings come from 2 materials!"



Carbon Matrix
The Embodied Carbon (EC) distribution of Hotel Equatorial, in Malaysia

Materials

Traditional Materials

The embodied carbon associated with the creation of new construction materials has started to come under a lot more scrutiny, as its relative contribution to a building's whole-life carbon has grown following the progress in reducing operational carbon. There is now a vast swathe of guidance and information on the embodied carbon of materials. However despite this awakening, 20th century engineering materials still dominated, with concrete and steel making up the majority of the carbon in new materials.

Concrete and steel are also some of the most difficult materials to decarbonise, they both require energy-intensive processes that traditionally involved burning large quantities of fossil fuels. Cement is the active ingredient of concrete, which also represents the majority of the embodied carbon. The production of conventional Portland cement requires high temperatures, mainly met through the burning of fossil fuels.

There is a huge amount of research going on to identify other materials that can replace traditional cement, some based on innovations in existing technology and some developing wholly new chemistry. However, the biggest challenge in concrete is the sheer volume produced and used, at relatively low cost. The materials of traditional cement are abundant and there is a vast existing infrastructure in place. Technologies that seek to disrupt or replace this face many challenges.

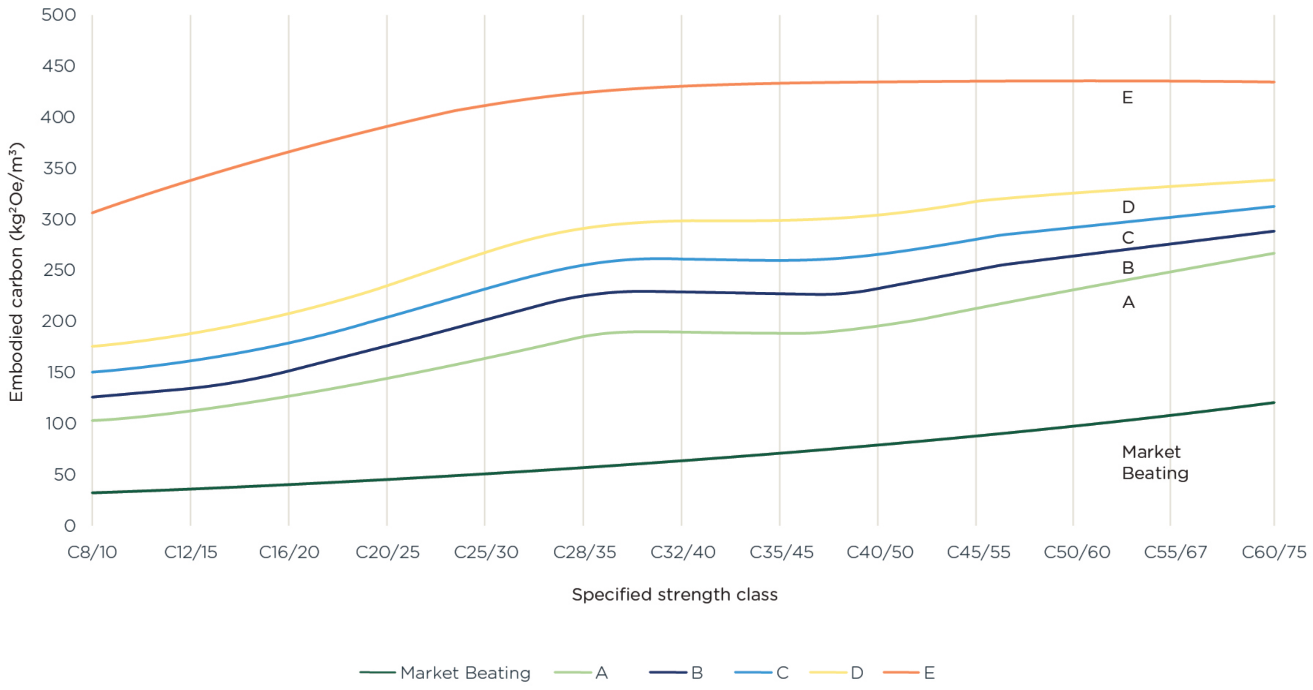
Primary steel production is still dominated by the blast furnace, utilising metallurgical coal to provide enough heat to extract the iron from ore and provide the carbon to create the alloy of steel. The remelting of recycled steel offers a longer-term solution to meet our apparently insatiable demand for steel; however, we still require primary steel, and there will always be a need for some high-performance primary steel. There are technical routes to produce low-and-even zero-carbon primary steel using hydrogen, which has been produced using renewable power. Several steel manufacturers are developing the associated technology for this, and a pilot facility was launched in Sweden in 2023.

In addition to efforts to fundamentally reduce carbon in the production of concrete and steel, both industries are also targeting Carbon Capture and Storage (CCS) technology to achieve their long-term net zero goals. While this technology presents significant technical and commercial challenges, it may be a necessary step in continuing to utilise the benefits of these materials and stay within our 1.5 degree carbon budget.

SMU Connexion (MKPL Architects)
A five-storey institutional building designed as a net zero energy building and constructed using mass engineered timber.

World of Volvo, Gothenburg, Sweden
by Henning Larsen, Optima Engineering, BRA Group and Wiehag

Modern meets tradition: Sweden's rich heritage of wooden architecture is blended with innovative glulam construction.



Carbon intensity benchmark for concrete based on specified strength class

Source: LCCG Market Benchmark for Embodied Carbon, Normal Weight Concrete, LCA Stages A1 to A3 (2023 Version 2.1)

Alternative Materials

While it is important to decarbonise traditional engineering materials we must also strive to use less common, lower carbon materials as well. Particularly, where these can offer other benefits, such as carbon sequestration, improved air quality, enhanced biodiversity and broader positive sustainability impacts.

In this respect, timber plays a key role in replacing some of the higher carbon materials in construction. There is a lot of good information on use of timber, in industrialized forms such as Cross-Laminated, Glulaminated or others. Examples of successful deployment of these as structural materials in buildings are aplenty. (see SMU Connexion, and World of Volvo featured here)

Mycelium-based materials are low-cost, lightweight, biodegradable, fire-resistant, acoustic, and thermal insulators. When combined with an organic mixture to create an innovative building structure or material, mycelium can grow without requiring any additional energy input. Furthermore, at the end of the structure's life cycle, it can be composted, resulting in zero waste or by-products.

Another example is Bamboo Veneer Lumber (BVL), a high-performance structural lumber synthesized from bamboo fibres and a bio-compatible binder. It is suitable for constructing modular prefab buildings' structural beam applications. BVL is up to 3 times stronger and more dimensionally stable than timber. It is weather-resistant and resistant to decay and rot.

This figure is the Low Carbon Concrete Group's carbon intensity benchmark for concrete based on real mix data from the UK. Following publication in the Low Carbon Concrete Routemap, of which Ramboll is a co-author of, the LCCG's carbon benchmark has become a key reference to understanding carbon in concrete. Whilst a concrete mix must be assessed in the context of project-specific criteria, the benchmark helps to inform its relative performance and focuses attention on its embodied carbon. Ramboll has started to use this benchmark to specify carbon performance for concrete as part of a project-specific lower-carbon concrete plan which sets out all opportunities to save carbon on a project.

Decarbonisation through Behavioural Change

As the world wrestles with climate change, our approach at Ramboll's SMART Futures revolves around leveraging SMART technologies and behavioural design techniques to transform human interactions with our surroundings. A sustainable future depends not just on the design of our built environment, but on how we engage with it.

Imagine a building where user decisions are subtly steered towards greener choices. For instance, by integrating real-time weather data with SMART technologies, we can encourage users to open a window instead of relying on air conditioning, providing contextually relevant nudges for sustainable action.

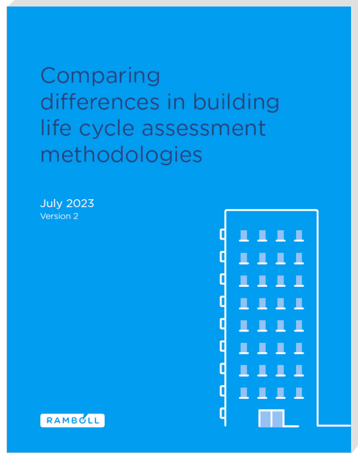
With a focus on individual projects for our clients, we have conceptualised tools like a Carbon Wallet application for a healthcare client in Singapore. This unique initiative turns sustainability into a compelling, interactive endeavour, making being green not just appealing but almost addictive.

Collaborating with architects, Ramboll brings a thorough understanding of user behaviour to the design process. We select materials and propose designs that psychologically trigger sustainable behaviours. Our goal is not just reduced energy consumption or waste; it's about inducing a deep-seated change in how people perceive and relate to their environment.

Closing the gap isn't just about design; it is about redefining lifestyles and driving behavioural change towards a decarbonised future.

Fusing technology with natural beauty
This data-driven holographic sculpture resonates with urban dwellers, reflecting the community's environmental impact and inspiring a shift in perception and behaviour towards a more regenerative relationship with our surroundings.

Delivering Decarbonisation



Ramboll's whitepaper - LCA of Buildings
Comparing differences in building life cycle assessment methodologies

Scan this QR Code for the full document

We cannot meet our decarbonisation goals without the ability to easily and consistently measure the carbon associated with the materials and operation of our built environment. Furthermore, we must have a clear trajectory for decarbonisation that aligns with our carbon budget. Ramboll's carbon assessment and LCA experts across the globe have been working together for several years to develop a reliable internal benchmarking database which allows us to collect our carbon assessment data and accommodate a large number of different measurement methodologies. Ramboll's white paper on this topic has provided insight on the significance of different methodologies and what they can mean when comparing different designs or buildings.

We have set out clear strategic goals for the decarbonisation of buildings designed by us: This is relative to our 2021 designs and is applicable to all buildings over 1000m².

We call this the #Ramboll50%

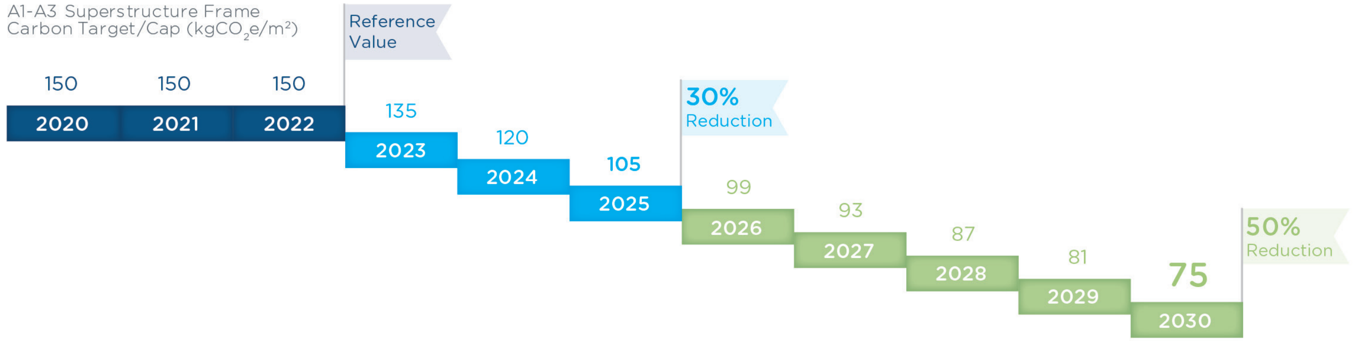
Many other industry players, some with genuine, self-motivation, and conscientious concern for the environment, have made similar pledges.

This is a good start.

Such commitments to reduction are now in urgent need of hard, fixed, and verifiable numbers on the actual quantitative amount of embodied and operational carbons of the projects we are engaged with. A 50% reduction in embodied carbon by a certain date in the future, is meaningless and can smack of potential "green washing", if this is not directly linked to a specific number.

The question is 50% of what? When do we know we have achieved 50% if we do not actually have a defined and reliable starting number? How do we know we have arrived, if we do not have a defined destination?

Of Small Steps and Giant Leaps



A voluntary carbon reduction commitment by Ramboll

To respond to such valid and plausible questions and concerns, Ramboll is committing to a hard limit/ceiling on the embodied carbon of all our building projects. Our 2021 reference value is: 150kg CO_2e/m^2 GFA.

This relates to:

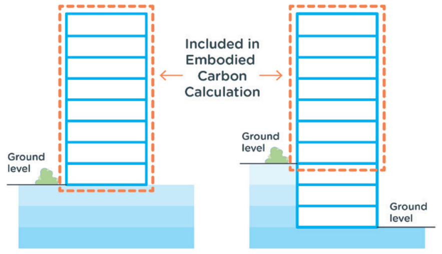
- Stages A1 to A3 cradle-to-gate of LCA,
- Portions of the structural frame that are above ground level,
- Residential buildings with spans of up to 6m, and up to 10-storey high,
- In areas with low to moderate wind speeds, and no seismicity.

Appropriate "multipliers" are also devised to account for other building genres, like taller buildings, offices and mixed developments, buildings with larger spans, etc.

While many of our current building designs, particularly those in the Nordics, are doing better than these limits, we encourage all our buildings globally to work within these limits, and invite all our industry partners to join us on this small step, helping to transform this into a giant leap as we expand the scope of this commitment to all disciplines, and all stages of LCA.

We will include additional aspects of the building in the future as carbon assessment becomes more mature. Our targets reflect the fact that different markets, locations and clients are starting the decarbonisation journey at different points, but the ambition of reduction is the same for all.

Our target is not a minimum performance level; we see it as a ceiling that we must stay below of. We do not have all the answers yet, but we are building the skills, tools and capabilities to partner with our clients to ensure that we all collectively work within our shrinking carbon budget.



Embodied Carbon Calculation
Superstructure above Ground level is included in our computation of Embodied Carbon

Modern Methods of Construction

STATE OF THE ART

Modern Methods of Construction (MMC), refers to innovative techniques, materials, equipment, and technologies often involving manufacturing, prefabrication, and the use of advanced materials and technologies to streamline construction and deliver projects

Contributing writers:
Alessandro Marzucchini
Lai Wan Sing
Hossein Rezai-Jorabi

07

Executive Summary

Modern Methods of Construction (MMC) involves the use of manufacturing and industrialised processes to significantly reduce the project execution time, while improving the safety and sustainability.

Conventional construction presents challenges, such as being labour and time-intensive, requiring high carbon footprint and producing significant levels of noise and waste. The use of industrialisation and prefabrication can overcome such challenges, offering a wide range of solutions, from prefabrication of structural elements to the manufacturing of pre-finished components such as panelised, volumetric, MEP or bathroom pods or hybrid systems.

The edition will investigate various aspects of prefabricated modular construction that need to be considered while opting for MMC technologies for a given project. Some of the factors that will be discussed include the importance of a competent team, project-specific constraints, location, schedule, budget, site and logistics constraints, design ambition, and compliance with local codes

This edition of DESIGN is one part of a two-part publication on Modern Methods of Construction (MMC). This special edition explores the trajectory of MMC through various phases in history and presents the state-of-the-art of this technology to reflect on the global challenges, limitations, and potential improvements in the current approach.

The second part, slated for publication in June 2024, will cover MMC in a more general and informative manner for all who are interested in the topic.

MMC technologies adhere to the industry's highest quality standards, offering precision-built solutions with adaptability to a broad spectrum of architectural ambitions. Modular building designs are created using an interoperable digital platform including parametric tools, Finite-Element and Building Information Modelling enhancing material optimisation with a minimal amount of waste, designed for quick assembly and flexibility. This design process promotes efficiency and repeatability while preserving the building aesthetics, making MMC technologies suitable even for highly

ambitious architectural designs. In recent years, we have witnessed a rapid increase in adoption of MMC technologies, from prefabrication of 1D elements to prefinished volumetric modular units, particularly in regions undergoing rapid urban development. This marks a notable departure from the past decades when several countries experienced significant urbanisation relying on conventional construction methods. The current shift reflects a transformative trend towards innovative design and construction practices.

MMC has the potential to reshape the future of the built environment, promising up to 50% increase in construction speed, reduction in project costs, enhanced design efficiency, improved quality and safety, lower carbon emissions, and the creation of a more resilient urban landscape.

KAJ16 (Dorte Mandrup & Ramboll)
A multi-storey mixed-use residential and commercial building uses hybrid concrete and timber solutions and reuses materials from the site's original structure.

Introduction

Understanding the Terminology

Before delving into the edition, it is crucial to clarify and distinguish the **terms used in this paper** for better understanding.

Modern Methods of Construction (MMC),

refers to innovative techniques, materials, equipment, and technologies often involving manufacturing, prefabrication, and the use of advanced materials and technologies to streamline construction and deliver projects with enhanced quality and speed, such as the use of automation and the development of a manufacturing production line.

Prefabrication

describes a manufacturing process involving the production of modules in a controlled manufacturing environment. A prefabricated building describes a complex system which components are constructed either partially or fully in a factory environment. Once manufactured, such components are delivered to the site where they are installed or assembled to form the final building system.

Design for Manufacturing and Assembly (DfMA)

is an innovative design approach focused on simplifying and optimising manufacturing and assembly, promoting efficiency and constructability.

Modular Construction

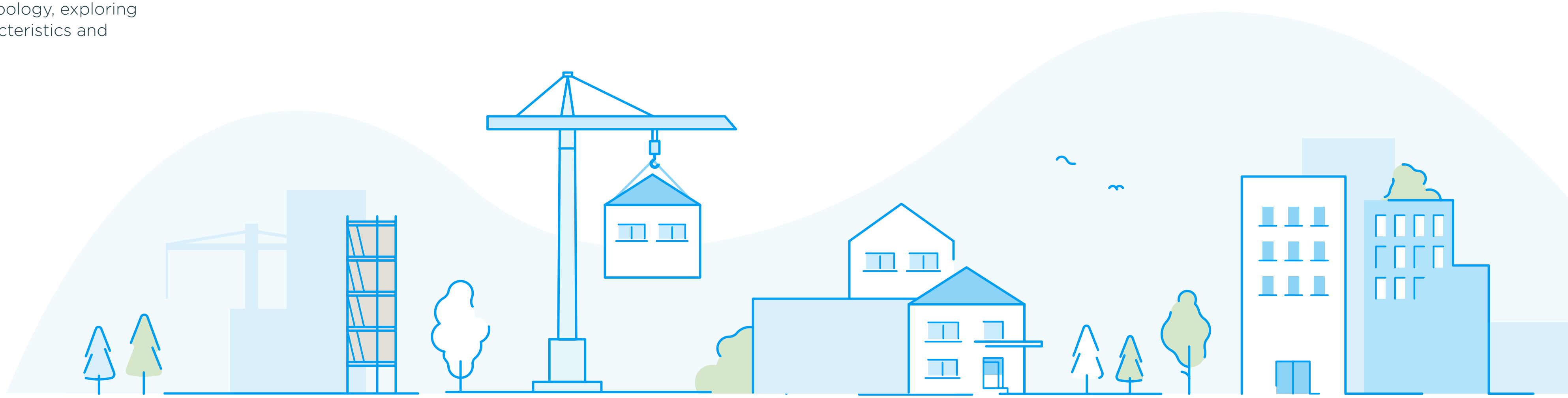
is an approach where specific or all components of a building are replicated, referred to as modules. These modules can encompass various system typologies, ranging from 1D single prefabricated structural components like beams or columns to 2D panelised systems, and even complete 3D volumetric systems that include structural, services and architectural fit-out components. The repetition of modules aids in the standardisation of design, achieving economy of scale and enhancing productivity.

1D Elements, 2D Panelised and 3D Volumetric Systems

represent distinct MMC system typologies within the space of Modern Methods of Construction (MMC). These classifications arise from the assembly of various components in factories, each offering unique advantages in prefabrication and construction. In the next sections of this document, we will expand on each typology, exploring their specific characteristics and applications.

From Construction Site to Assembly Site

MMC	›	Holistic and Innovative Method of Construction
DfMA	›	Design Approach
Prefabrication	›	Manufacturing Process
1D, 2D, 3D, PPVC	›	System Typologies
Modular Construction	›	Construction Methodology



MMC: What and Why

Challenges with Conventional Construction Methods

Traditional construction methods come with a set of challenges that have long been rooted in the industry's practices. The conventional in-situ construction, marked by its time-consuming nature and labour-intensive processes, often results in prolonged project durations and increased labour costs.

This approach, reliant on manual labour and vulnerable to weather conditions, poses safety concerns and contributes to the generation of significant material waste.

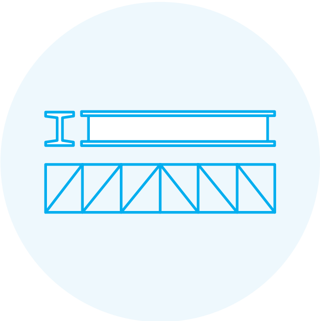
Furthermore, the traditional in-situ construction practices rigidly delineate responsibilities with much elaboration on the consequences of failure. This context fosters risk-averse behaviour, leading to a lack of collaboration and an adversarial construction culture.

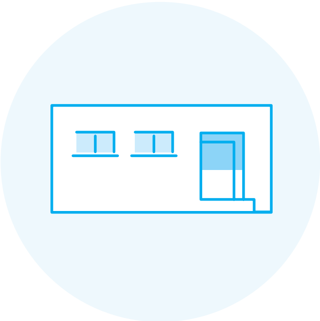
This affects all the stakeholders at various levels. Owners face monetary losses due to last-minute changes caused by uncoordinated designs, while architects and engineers strive to achieve the envisioned quality of work. Contractors bear financial burdens and risks in this fragmented process.

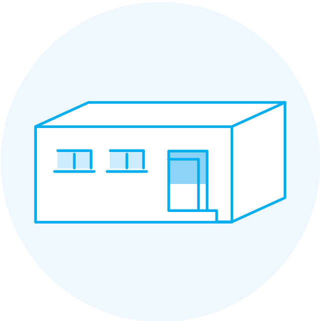
This fragmentation has been quantified in terms of waste and productivity.

Keilaniemen Portti, Finland
(Architects Soini & Horto and Ramboll)
Standing at 60m, Keilaniemen Portti will be the tallest timber building in Finland and one of the tallest timber office buildings in the world. The use of timber in the project helped to minimise carbon emissions while enabling a high degree of prefabrication, which reduced the number of deliveries to the site and decreased the number of construction workers required on-site.

MMC System Typology







1D Elements

consist of individual structural components, such as beams or columns, which are prefabricated in a factory environment and assembled on-site. This approach significantly contributes to reducing the construction waste, while enhancing standardisation and improving productivity.

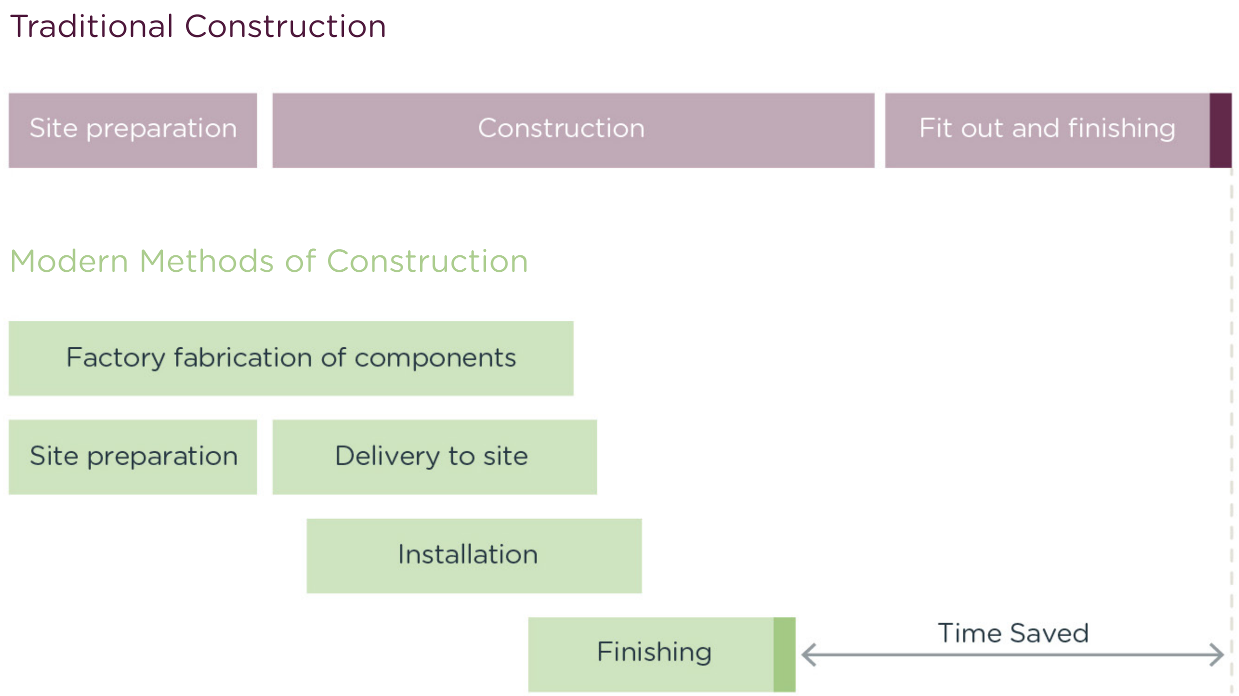
2D Panelised Systems

involve the prefabrication of building components, like walls or floor panels, which are then transported and assembled on-site. These prefabricated panels may incorporate various finishes, such as cladding, insulation, and interior surfaces, during the manufacturing process. This helps to streamline the construction process and ensures that a significant portion of the building's elements, potentially including finishes, are pre-assembled before being transported to the construction site.

3D Volumetric Systems

revolutionise construction by prefabricating components and assembling them to create complete volumes. The volumes are pre-assembled in factories and then transported to site for installation. This offers the benefits of reducing on-site work, connections, promoting efficiency and ensuring the repeatability of the modular units. To maximise the advantages of 3D volumetric construction, the assembly of these volumes may extend to include structural, services, and architectural components, to form fully assembled volumetric units. This system typology is known as Prefabricated Prefinished Volumetric Construction (PPVC).

Advantages of MMC



Comparison between Traditional Construction and Modern Methods of Construction schematic roadmaps.

1. Accelerating Construction Programmes

Prefabrication can proceed in parallel in the factory while other on-site activities are ongoing to streamline the construction process. Construction programme savings ranging from 15% to 50% have been demonstrated through numerous projects, attributed to concurrent site and factory work, faster factory production, quick on-site installation and elimination of uncertainties such as weather delays and subcontractor sequence delays associated with on-site construction.

2. Productivity Improvement

On-site construction activities can be significantly reduced through the use of prefabrication, potentially achieving over 40% productivity improvement in terms of manpower and time savings, depending on the project complexity. Projects involving prefabrication show up to 30% increase in labour productivity compared to traditional on-site projects, ultimately reducing risks associated with on-site construction. The productivity improvement intricately reduces project and construction risks. By shifting a significant portion of construction activities to a controlled factory environment, MMC minimises on-site risks such as accidents, delays due to adverse weather conditions, and disruptions caused by site constraints.

3. Better Quality Control

Prefabrication ensures that the majority of the final product is crafted within a controlled factory environment, resulting in heightened reliability and superior-quality of finishing, while reducing the risk of structural flaws. This approach allows for more efficient planning of the work sequence, facilitated by improved logistics coordination.

Lighthouse tower in Aarhus (3XN Architects & Ramboll)
The 44-storey building utilised hybrid precast concrete columns to expedite construction while maintaining the same strength capacity as a monolithic connection.

4. Reduced Disruptions and Better Construction Environment

Reducing disruptions and improving the conditions of the construction environment are critical considerations for any construction project, particularly those in noise-sensitive areas. MMC offers a solution by significantly reducing noise pollution. By conducting a substantial portion of construction activities in factories, MMC minimises disturbances for nearby residents and businesses. Moreover, MMC leads to fewer inconveniences such as road closures and less dust, enhancing the overall construction process. This approach ensures a quieter and more comfortable environment for stakeholders.

5. Reduction of On-site Manpower and Improved Safety

By replacing a significant amount of on-site construction activities with prefabrication, the workers will be working in a controlled factory environment with reduced safety hazards and minimised risks. Furthermore, fewer workers will be engaged in on-site activities, resulting in fewer accidents and less downtime. Therefore, improved safety conditions are achieved by reducing on-site construction time and individual man-hours working at height.

6. Advancing Circularity

MMC is pivotal in advancing circularity within the construction industry. The MMC approach minimises material waste by relocating a significant portion of the construction process to a factory environment. Prefabricating repeated forms reduces the likelihood of material waste while promoting a more sustainable operation. Transporting factory-produced modules to the site minimises material deliveries, reducing fuel waste and easing road congestion around the site. On-site waste is reduced by between 70% to 90% compared to traditional on-site construction.

Furthermore, prefabricated components can be easily repurposed, extending their lifespan and minimising the need for new resources. Moreover, MMC prioritises recyclable materials, facilitating the closure of material loops and promoting a more sustainable approach to construction. By optimizing resource use and creating durable structures, MMC fosters a circular economy where materials are conserved, waste is minimised, and environmental impact is reduced.

7. Improved Sustainability

The adoption of MMC holds promise for enhancing sustainability within the construction industry. The use of MMC can significantly reduce the carbon footprint of buildings, primarily due to the opportunity it provides to utilise more sustainable materials and minimise the amount of concrete compared to conventional designs and construction processes. By embracing MMC, construction projects can leverage innovative materials and construction techniques that prioritise environmental conservation and resource efficiency.

Challenges and Constraints of Prefabrication

Embracing MMC holds a significant potential and can be the key enabler for efficiency and innovation in the construction industry.

However, this paradigm shift introduces some inherent difficulties that may hinder the benefits that MMC can offer to our projects and communities. It is imperative to address such challenges and constraints with appropriate consideration at both project and wider industry levels to ensure successful implementation. Some of these challenges are the following:

1. Selecting a Competent Project Team

This responsibility extends beyond the designers and involves stakeholders at different levels and responsibilities, including developers, contractors, manufacturers and installers. This challenge encompasses various considerations such as ensuring that the best engagement models are in place, including planning and implementation of contractors and manufacturer involvement, such as Early Contractor Involvement (ECI) to enhance coordination and collaboration, system integration, improve interfaces while promoting opportunities for value engineering and aligning stakeholder interests to achieve project goals.

2. Initial Investment Costs

Upfront costs for setting up manufacturing facilities and acquiring equipment can pose significant financial challenges, especially for smaller businesses or start-ups. These costs may deter companies from considering the adoption of MMC solutions, potentially limiting innovation and industry transformation.

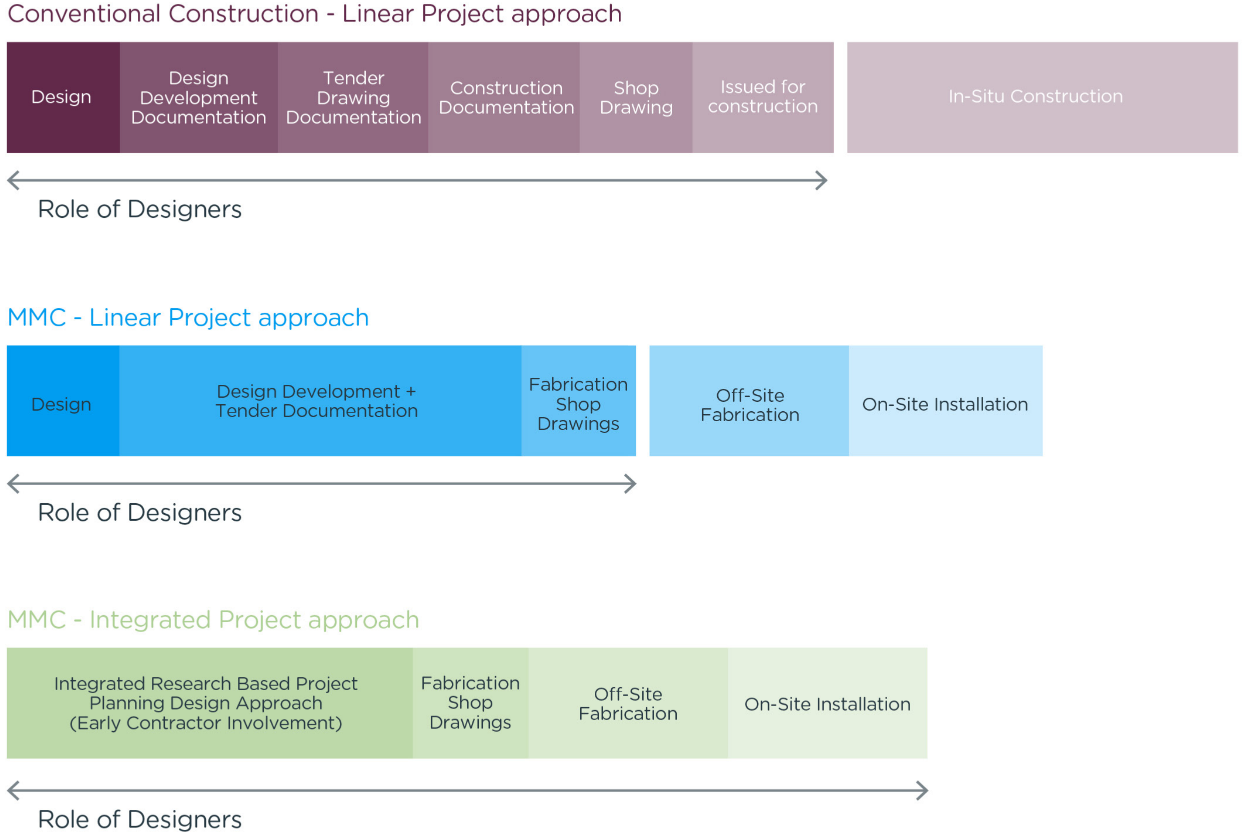
It is imperative for companies to carefully assess these costs, cash flow, project pipeline, and all associated risks, evaluating the return on investment as part of their business case analysis.

3. Efficiency and Standardisation Challenge

This challenge represents a specific aspect within the broader spectrum of design constraints outlined previously. While the adoption of MMC technologies has the potential to achieve cost-effectiveness, unlocking this potential requires design efficiency. Designers play a crucial role in selecting MMC systems that best suit project-specific requirements, considering various design aspects, constraints, and opportunities. The goal is to enable standardisation through efficiency and optimisation, in order to achieve both cost effectiveness and economy of scale. This aspect is critical to the achievement of efficiency, constructability and cost-effectiveness.

4. Technology Adoption Challenges

The complexity of transitioning to new technologies presents a considerable challenge for companies exploring MMC and manufacturing opportunities. This category includes the requirements for specialised training and skill development for staff involved in the design, manufacturing, assembly and installation of MMC technologies. Furthermore, lack of regulatory frameworks can represent an additional challenge that stakeholders at various levels of the value chain face when adopting MMC.



Comparison of conventional construction (linear project approach) and MMC (integrated project approaches).

5. Design Constraints

Design constraints require early coordination with all designers and consultants on board. Such constraints comprise various factors, including the impact of MMC systems on floor and ceiling heights, as well as net floor efficiency. Understanding these complexities is essential for developing efficient design schemes that align with architectural expectations. Failure to address these constraints upfront can lead to conflicts, abortive work, delays, and inefficiencies during the design and construction phases of MMC projects. Effective communication and collaboration among project stakeholders are essential to optimising design solutions and minimizing project risks.

6. Logistics Constraints

Challenges related to transportation, handling, and coordination of materials, components, and finished products in the manufacturing process can significantly impact project efficiency. Factors such as limited transportation infrastructure, long lead times for deliveries, and complex supply chain networks may increase costs and lead to delays. Optimising logistics processes is essential to overcoming these challenges and reducing overall construction time.

Bella Sky Comwell Hotel, Denmark (3XN & Ramboll)
The Bella Sky Hotel consists of two towers leaning in opposite directions at a gravity-defying 15-degree angle. The superstructure consists entirely of prefabricated elements.

Current Barriers and Opportunities with MMC

In today's construction industry, stakeholders throughout the value chain are recognising the enormous potential of MMC to revolutionise project delivery and enhance industry efficiency. However, despite this increased awareness, there are still several barriers impeding the widespread adoption of MMC worldwide.

Addressing these obstacles is imperative to unlock the full potential of MMC. With the right vision, competence, and mindset, these challenges can not only be overcome but can also transform into opportunities, fostering innovation in construction. Below we explore the current main barriers preventing the implementation of MMC technologies at larger scale.

1. Regulatory and Approval Processes

The lack of suitable regulatory frameworks can create barriers to adoption. Proactive measures are essential, such as: collaborations with authorities to update building codes and approval processes; investing in R&D to demonstrate compliance with standards; government initiatives to streamline approval processes fostering MMC adoption, like in Singapore, Hong Kong and Dubai.

2. Lack of Appropriate Collaboration Models

The implementation of efficient project collaboration models presents a challenge that can prevent the development of MMC within the industry. Overcoming these barriers requires embracing more collaborative procurement models, such as Early Contractor Involvement (ECI), to enable contractors and manufacturers to contribute to the design phase. This fosters stronger partnerships and communication channels among stakeholders, ensuring seamless integration and maximising the benefits of MMC.

3. Scale and Market Maturity

Despite an increasing interest in MMC, the industry's current scale and maturity may not be sufficient to maximise its benefits. This can act as significant barriers, slowing the pace of MMC adoption and delaying the realisation of its potential advantages across the industry. Addressing these challenges requires concerted efforts to expand market reach, enhance industry collaboration, government support to promote awareness of MMC's advantages.

4. Skills and Workforce Development

The transition to MMC demands a proficient workforce in modern technologies and construction methods. However, shortages of trained workforce and lack of standardised training programmes can result in a barrier to widespread MMC adoption. Addressing these gaps through education and training initiatives is imperative for the development of a skilled workforce capable of driving MMC implementation forward.

Tate Modern, London, UK (Ramboll)
From the one-of-a-kind geometric structure to the striking brick façade, every aspect of this building has been planned and engineered with staggering precision using kit-of-parts components such as precast columns, precast cladding and soffit panels

5. Perception and Risk Aversion

Knowledge gap and resistance to change and challenge traditional practices can impede MMC acceptance. Stakeholders may perceive MMC as unable to meet the standard of quality, durability, and long-term performance compared to conventional methods. Overcoming skepticism requires demonstrating MMC's benefits through successful projects and promoting awareness of its advantages and capabilities within the industry.

6. Higher Initial Capital

Implementing MMC often requires upfront investment in equipment, technology, and training, which can be a barrier for companies accustomed to traditional construction practices. However, MMC often offers long-term cost savings. Strategic planning, thorough feasibility studies, cost-benefit analysis and value engineering exercises can optimise efficiency and costs, while assessing and mitigating business risks.

7. Supply Chain Development

The success of MMC projects relies on a well developed supply chain. Disruptions can cause significant delays. While the MMC supply chain has evolved, further enhancement is required. Such improvements can result in cost reductions while enhancing sustainability, particularly by mitigating carbon emissions associated with transportation.

Design for Manufacturing and Assembly

Focused on optimisation of product design, Design for Manufacturing and Assembly (DfMA) is a disruptive innovative design approach with the primary focus on promoting ease of manufacturing and assembly.

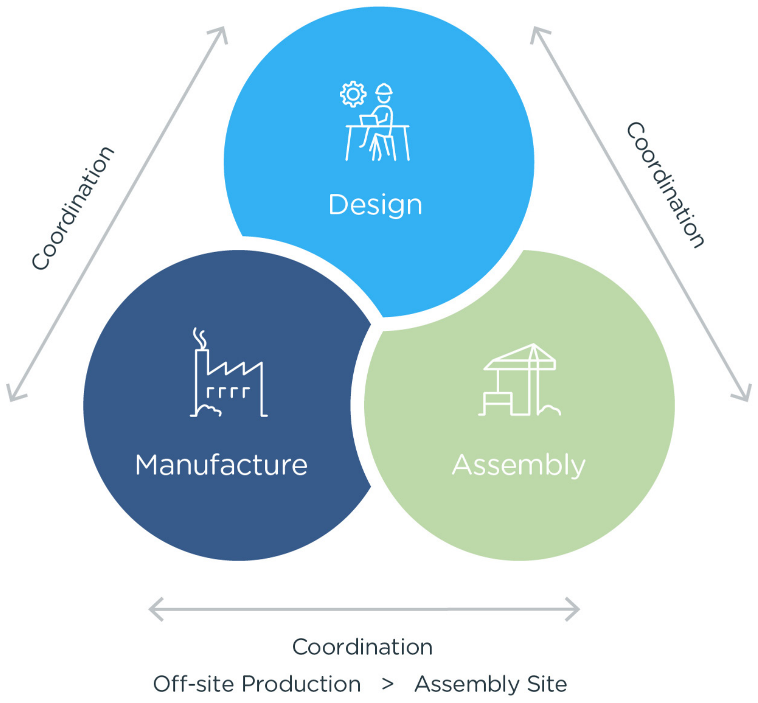
Key aspects related to DfMA include:

1. Simplicity and Standardisation

Simplifying product designs and standardising components wherever possible can reduce manufacturing complexities and costs. By minimising the number of unique parts and ensuring interchangeability, assembly becomes more efficient. This aspect overall improves the product efficiency and cost-effectiveness through the achievement of economy of scale.

2. Material Selection and Optimisation

Choosing appropriate materials to meet project specific requirements, such as strength, serviceability, sustainability, durability, cost, and manufacturability, and optimising material usage to minimize waste. Modern Methods of Construction (MMC) offer a significant opportunity to promote the use of low-carbon-emission materials, further enhancing sustainability efforts.



Design for Manufacturing and Assembly
Streamlined collaboration throughout design and construction.

3. Digital Design

Utilising advanced software tools can create, analyse, and optimise product designs in a virtual environment. Developing an inter-operable digital platform can enhance material optimisation, enabling faster iteration and streamline the design process, facilitating the integration between analysis, deliverable production and BIM, from the design to the manufacturing and assembly.

4. Design for Manufacturing

Optimising product designs to streamline the manufacturing process, including selecting cost-effective manufacturing processes and minimizing material waste. Additionally, design for manufacturing shall consider designing components for easy access during maintenance and repairs.

5. Design for Assembly

Designing products with ease of assembly in mind, prioritising safety for the team installing the components while minimising the number of assembly steps and the need for specialised tools or skills. This involves conducting detailed crane studies and planning the installation sequence to ensure efficiency and safety.

6. Early Collaboration

DfMA requires a collaborative approach among stakeholders to align the design with the proposed systems. This collaborative effort demands the implementation of the right engagement model, often involving Early Contractor Involvement (ECI), ensuring a seamless integration of design and construction processes.

7. Life cycle Considerations

Considering the entire life cycle of a product, including manufacturing, assembly, use, and disposal, will promote design decisions based on efficiency, sustainability, and cost-effectiveness. Design considerations should also include the disassembly, facilitating the removal of components and promoting the potential repurposing of the building at the end of its life cycle.

8. Design for Logistics

DfMA is crucial in identifying the most suitable logistics strategies tailored to project-specific requirements and site constraints. This includes route studies, from the factory to the site, considering limitations in size and weight. Additionally, the prefabricated products have to be designed for all the temporary loading scenarios, including manufacturing, transportation, storage, hoisting and site-assembly to preserve safety and avoid damage that can compromise the product's quality.

Exploring New Materials

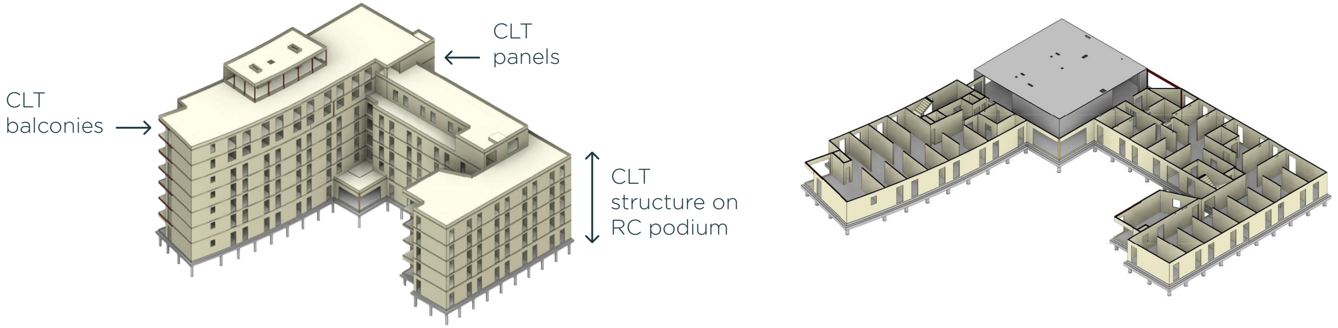
Timber is growing in popularity; preconceptions about fire, longevity, mortgages, insurance, and availability are being long forgotten, replaced by the material's many advantages. Also stacked in its favour are the benefits of shorter construction programmes due to prefabrication, good thermal and fire performance properties, lighter buildings' requiring smaller foundations and sustainability benefits, where we are often able to create a carbon neutral structure.

Furthermore, when large areas of a cross-laminated timber (CLT) structure are left exposed, it can create a striking architectural feature. Not only does this add great aesthetic value to the building, but it can also yield many savings in interior wet trades as the large timber panels eliminate the need for a significant quantity of interior blockwork partitioning and plastering.

Timber is the only truly renewable building material. Using one cubic metre of wood in place of other materials results in the sequestration of 0.8 tonnes of CO_2.

By increasing the use of timber in construction, we are contributing to carbon storage in forest products. Coupled with the inherent properties of wood that make it thermally efficient and its ability to improve air tightness in CLT construction, timber becomes the most sustainable choice for construction. In addition to the immediate environmental benefits, construction sites built in timber are significantly less disruptive, creating a better working and surrounding environment, with quieter and cleaner site works, fewer trades required on site and fewer deliveries. This results in less noise and congestion, improving air quality.

In addition the efforts to fundamentally reduce carbon in the production of concrete and steel, both industries are also targeting Carbon Capture and Storage (CCS) technology to achieve their long-term net zero goals. While this technology presents significant technical and commercial challenges, it may be a necessary step in continuing to utilise the benefits of these materials and stay within our 1.5 degree carbon budget.



Dalston Works, Hackney, London, UK (Waugh Thistleton Architects & Ramboll)
The world's largest cross-laminated timber (CLT) project, employing more timber than any other scheme worldwide by volume. Except for the concrete podium, the entire structure is built of CLT, including floors, walls, and elevator cores.

History of Prefabrication

“ The past is a foreign country: they do things differently there.”

L.P. Hartley

Prefabrication has evolved from stone cut blocks, wooden beams or metal structures made in workshops or other locations using traditional tools and techniques.

The advancement in technology, materials, industrialisation and innovations, has transformed modern methods of construction. In the following chapter, we would focus on modularity and 3D volumetric PPVC.

Ancient Rome
5000 BCE

Natural cut

Blocks of stone were cut and transported to the construction site and assembled

16th Century
1624

Panelised Wood House

First panelised wood house from England to Massachusetts

Post Industrial Revolution
After 1840

Standardized 1D Elements

Metal parts of the Eiffel Tower were prefabricated (traced, cut and drilled) in a workshop. Two-thirds of the 2,500,000 rivets were inserted at the factory using machines

19th Century
1903

2D Panelised Elements

First prefabricated precast concrete panelled apartment blocks pioneered by John Alexander Brodie

Postmodern Era Habitat '67
1967

3D Volumetric Boxes

The large apartment building was featured in the Montreal World's Fair. It consisted of prefabricated concrete boxes referred as “modules” which were lifted and stacked by cranes and post-tensioned to create the stepped form

Early 21st Century The Clement Canopy
2016

Prefabricated Prefinished Volumetric Construction (PPVC)

65% of the superstructures of two 40-floor tower blocks were constructed using PPVC making it the world's tallest concrete PPVC building

Recent Applications

Recent Applications

3D volumetric construction methods, and particularly PPVC systems, are amongst the most efficient in the field of modular construction. In the past, 3D Volumetric Construction was associated with temporary or relocatable modular pods, such as construction site trailers and communication pods.

Currently, modular construction is widely used for residential buildings of 4 to 8 stories.

More recently, modern technology and advancements in design, manufacturing, and installation capabilities have made it possible to apply modular volumetric construction to high-rise buildings.

In this chapter, we will explore the global scenario and provide examples of recent 3D volumetric applications.

Spacebox, The Netherlands (Mart de Jong)
The Spacebox is a student accommodation. It consists of colorful prefabricated boxes stacked up to 3 storeys high, with $18m^2$ per unit. Each apartment unit is fully equipped with a shower, toilet, bedroom, and a kitchen.

The Student Residence at Wong Chuk Hang, University of Hong Kong

Architect: AD+RG.
MiC Architectural Consultant: Alda Consultants
MiC Structural Engineer: Ramboll
Fabrication Specialist: iMax SG

The Student Residence at Wong Chuk Hang, University of Hong Kong (HKU), is one of the first examples of the implementation of Modular Integrated Construction (MiC) in Hong Kong.

With a gross floor area of approximately 25,000 m^2, the project comprises two 20-storey modular buildings.

It features two 17-storey modular towers supported on a non-residential three-storey podium.

Utilising 952 MiC units with only five variations of module sizes, the Student Residence at Wong Chuk Hang prioritises efficiency, streamlined construction timelines and cost effectiveness.

The MiC units were prefabricated and prefinished at a modular factory located in mainland China and subsequently transported to Wong Chuk Hang for on site installation.

The podium, which consists of a large multi-purpose hall, recreation rooms, library and activities room, serves as a transfer system for the above modules and is designed and constructed using conventional reinforced concrete construction method.

Reinforced concrete core walls are located at the centre of these buildings to serve as the lift core, fire staircases and MEP services as well as providing lateral stability.

Crowne Plaza Changi Airport Extension, Singapore

Architect: WOHA Architects
Structural Engineer: RSP Architects Planners & Engineers Pte Ltd (C&S)

The hotel's new extension was constructed using prefabricated Prefinished Volumetric Construction (PPVC) method.

PPVC method significantly reduced manpower required on site by 40%, from 75 workers, when using conventional construction techniques, to only 45 workers with the PPVC method.

It has nearly halved the needed manpower to construct its new extension, and reduced the time required for on-site works, to a third of the time needed by conventional methods.

The extension of the hotel, developed by OUE Limited, will be the first private-sector commercial building in Singapore to be completed using the PPVC method.

Off-site production of 252 units were carried out in Shanghai, China, before it was shipped to Singapore, to be assembled on-site. With the 100% off-site completion of the finishing works of the modules, PPVC resulted in minimal on-site works for the lobby and mechanical, electrical, plumbing and fire protection connection works to be completed. An average of ten (10) PPVC modules are assembled per day from 10pm to 5am.

Conventional method › 75 workers

PPVC method › 45 workers

40% ↓
Less manpower

Citizen M Hotel, Tower Hill UK

Architect: Sheppard Robson
Structural Engineer: Ramboll

Tower Hill will be a flagship location for CitizenM's London offer, comprising a 370 bedroom hotel in the setting of a UNESCO World Heritage site.

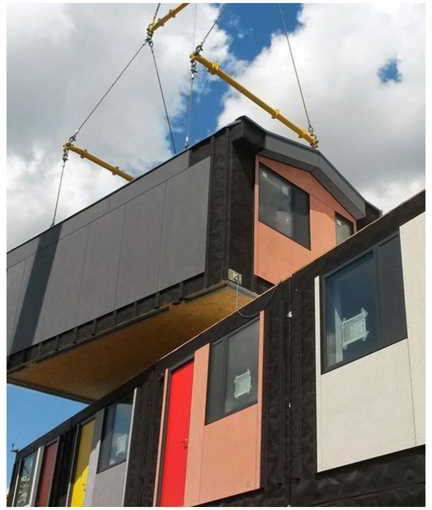
The new nine-storey hotel is partly built upon the former site of a five-storey 1960's office on the roof of Tower Hill station.

Lightweight construction was key. The new load paths from the new modular hotel had to compare favourably with the previous load from the office and the capacity of the existing station structure.

Modular construction was adopted to reduce weight, speed up construction, enhance quality and reduce wastage on site. The modules were manufactured in Poland, stored off-site in the Port of London dockyards, then brought into the City during the night for installation on site.

As part of the development agreement with London Underground, new step free access has been formed for the station. There are two ticket offices, one under the new hotel and themother in a separate building to the south. Each location has a new lift and stair access from platform to ground level.

Y-Cube, United Kingdom



Architect: RSHP
Structural Engineer: AECOM

The Y:Cube is an economical housing solution, developed by Roger Strik Harbour + Partners in South London in 2013.

The units are 26m^2 one-bed studios, for single occupancy, that arrive on site as self-contained units.

Each unit is constructed in the factory with all the services already incorporated.

Therefore, the water, heating and electricity can be easily connected to existing facilities or to other Y:Cubes already on site. This 'plug and play' approach results in a modular, demountable system of apartments that are perfectly designed for brownfield sites. Additional units can be added if needed and whole developments can be taken apart and rebuilt in new locations. This modern method of construction makes for a neighbourly, clean and quiet site.

Each unit is constructed from high quality, eco-efficient materials (primarily renewable timber).

The factory conditions in which the pods are assembled ensure tolerances of 2mm, creating accommodation that is so well insulated that they require little or no heating, even in winter months.

Y:Cube Housing is a modular system using volumetric technology that enables the factory-made units to stack easily on top and/or alongside each other, making it completely adaptable to the size and space available and therefore perfect for tight urban sites, creating semi-permanent communities.

461 Dean Street, Brooklyn, New York

World's Tallest Volumetric Modular Apartment Building

Architect: SHoP Architects
Structural Engineer: Arup

The size of a modular unit is: up to 4.57m width, from 6.10m up to 15.24m length, 3m height.

The average production speed is 4 modules a day, equivalent to one (1) floor per week.

32 floors, 109.4m

One of the illustrative example of high-rise building using volumetric modular system is the residential building 461 Dean Street, pacific park complex, Brooklyn district, New York. It is highest modular building in the world (32 floors, 109.4m).

In total 930 modular blocks we used for the construction of the building with 363 apartments. 225 types of modulus were designed and produced at the plant which was specially built for the building. The average production speed is 4 modules a day, equivalent to one (1) floor per week. It is to be noted that the production speed was not very high, but at the same time the projects showcases the possibility to achieve high quality and fully fit-out PPVC structure.

The fully fitted modules (including MEP services and finishing items) were delivered to the construction site by special trucks and installed at night. All parts of the building are fixed on steel columns with additional transverse crossbars to strengthen the structure.

An adaptation of this technology is to design a 'podium' or platform structure on which the modules are placed. This way, open space is provided for retail or commercial use or car parking. Support beams should align with the walls of the modules and columns are typically arranged on a 6 to 8 m grid (7.2 m is optimum for car parking).

Future of MMC

Prefabrication can deliver a variety of building and construction types such as education, housing, health care, office, government, institutional, dormitory, retail, and hospitality. When understood and deployed by stakeholders intentionally, with early project planning, it is a well-suited solution to control project schedules and budgets while increasing quality and reducing environmental impact. Prefabrication is especially effective when employed to shorten building cycles, on repetitious or unique projects, and with teams that are prepared to embrace the challenges and opportunities associated with its delivery.

The Regenerative High-rise (Haptic Architects and Ramboll)
It is built on a modular logic. It has a main structure frame consisting of three-story-high structural decks. Each deck can support either three intermediate floor plates or three levels of versatile pods.

Among the various MMC System typologies, 3D volumetric and particularly PPVC represents a large opportunity to construct infrastructure in a quicker timeframe, use less manpower, concentrate skilled workers in one location, minimise dust and noise pollution on site, and improve sound insulation. The current challenges facing the 3D volumetric systems are a battle against inertia within the construction field, several logistical issues, higher costs, and a potential limitation of architectural design.

However, these challenges are being confronted. Government subsidies or mandates are encouraging the industry to try this new method, logistical planning can be done with a commitment to MMC technologies early on, innovation in module design can reduce the limitations for architectural design. Furthermore, the higher costs will likely be reduced as the PPVC is adopted on a larger scale.

MMC in its current usage is reflexively associated with modularity and hence it becomes mundane and restrictive for designers. However, to the letter of its definition, MMC doesn't have to be confined, or need to always have association with modularity.

With the changing times of digital fabrication, and in a future where the bespoke need not cost more than the repetitive, the MMC method is well poised to dramatically revolutionise the construction industry by combining the benefits of assembly line technology with the future of digital fabrication.

Further research of the MMC method should focus on ways to lessen the challenges involved. By researching new module designs and structural systems for MMC buildings, more cost effective designs could be found and more architectural designs could be realised with MMC. With better strategies to better plan for MMC's logistical challenges, projects will be more likely to reap the full benefits of adopting the MMC method.

This next generation of bespoke MMC, may play a key role in delivering many of the construction industry's current socio-economic responsibilities – not limited to the climate crisis and global housing crisis. MMC can advocate equality in manpower, by elevating those most at risk at site to higher skilled operators within the construction industry. Furthermore, the MMC method, with its plug-and-play assembly could be developed for deployment in refugee crises and disaster relief efforts. With research providing innovative solutions to the current inertia and drawbacks, MMC will ultimately become a more efficient process and a stronger alternative to traditional construction.

Health by Design

Bridging the gap between cognitive and environmental psychology, neuroscience, design, and engineering of the built environment can produce places optimized for human health, happiness, better performance, and wellbeing. We can design healthier environments by closely mimicking the daily conditions of our natural environment.

Contributing writer:
Ali Heshmati, Henning Larsen

08

The Complexity between

Health and Space

An unintended consequence of urbanisation, noise pollution can lead to stress, sleep disruptions, and cognitive impairments.

A noisy environment can trigger the release of stress hormones, which in the long term can contribute to chronic health issues such as hypertension and cardiovascular diseases. Controlled noise environments, however, can promote mental tranquility, enhance focus, and support cognitive performance.

Poor indoor air quality can lead to a range of health issues, including allergies and respiratory disorders.

Research shows CO_2 buildup and reduction in oxygen affect the cognitive domain by, reducing the ability to make decision-making tasks, concentration, and focus, and impairing both short-term and long-term memory. Even a few degrees of temperature difference can affect our cognitive performance and mental acuity.

Bridging the gap between cognitive and environmental psychology, neuroscience, design, and engineering of the built environment can produce places, optimized for human health, happiness, better performance, and wellbeing.

We can design buildings that promote health, schools that enhance children's learning abilities, homes and offices that foster positive moods, productivity, and relaxation as needed, hospitals that expedite healing processes, and care and work facilities that reduce accident rates and promote overall health.

We can design healthier environments by closely mimicking the daily conditions of our natural environment.

Then there is light

Among the various aspects of the built environment, the impact of light on our health, physical and mental performance is exceptionally significant. More than a mere source of illumination for vision and visual task performance, light is the main environmental cue, regulating our circadian rhythms, sleep cycles, mood fluctuations, sustained vigilance, and cognitive performance.

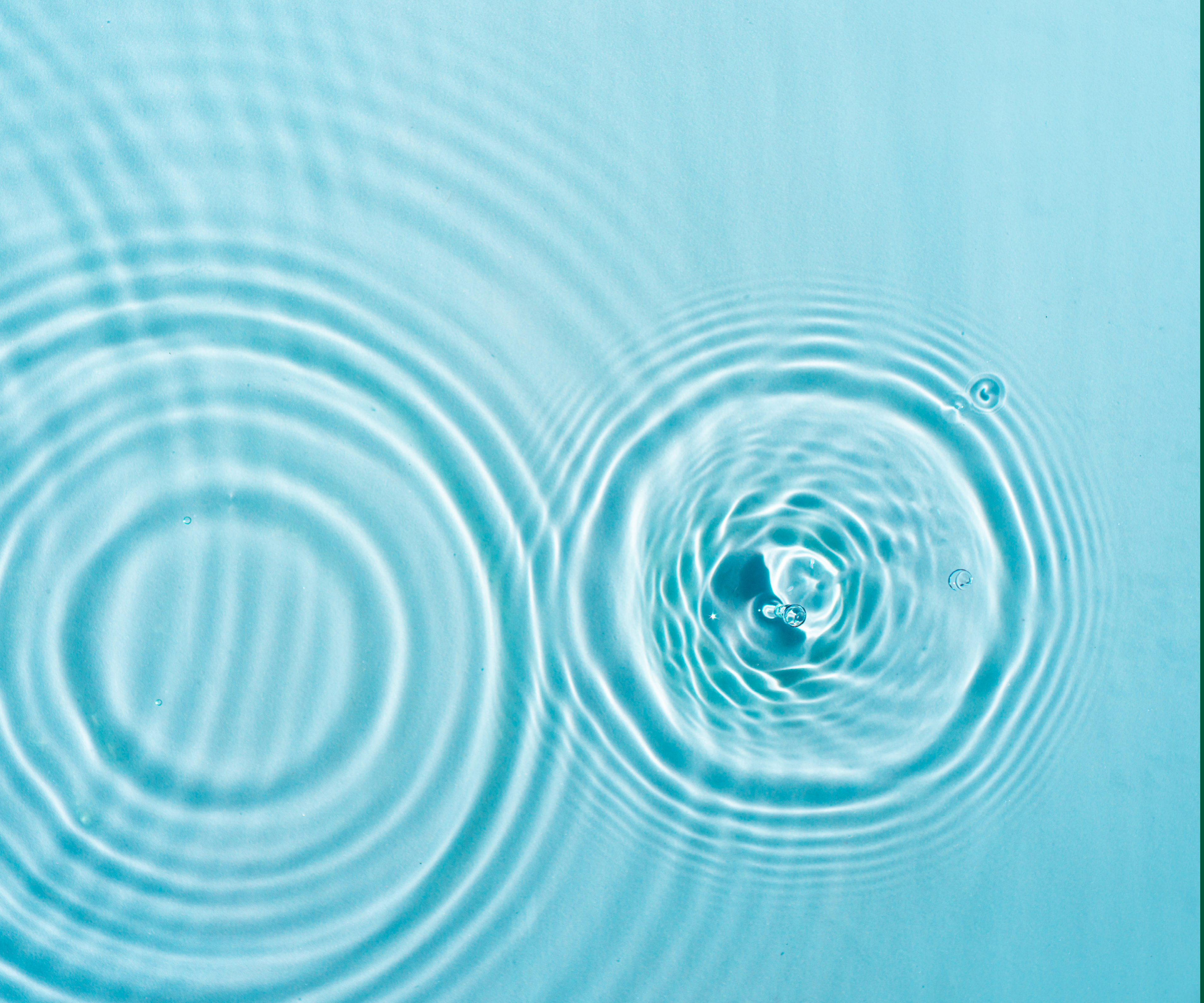
Our biological rhythms are finely tuned to the daily cycle of natural light, disruption of which can lead to sleep disorders and a whole host of acute adverse effects and chronic diseases.

Called photoentrainment, exposure to daylight entrains or synchronizes our circadian rhythms, for improved sleep quality and duration. The disruption of sleep and circadian rhythms influences a wide range of physiological processes, including metabolism, hormone regulation, and immune function.

A well-lit workspace or learning environment can boost alertness, focus, mood, vigilance, cognitive performance, and productivity.

While most interior environments are dimly lit during the day, excessive exposure to bright electric light at night, disrupts our circadian rhythms, leading to sleep disorders and associated health problems.

Exposure to daylight enhances alertness and cognitive function, while insufficient light can lead to fatigue and decreased focus. It is equally important to avoid bright lights at night as they can have a disruptive and delaying effect on sleep and the timing of the circadian rhythm.



Multiplicity of Clients

The notion of the diversity of clients suggests that in our business-as-usual practice, operating within the framework of a sustainable development, each project has a contractual client who approaches with the location, a brief, and an ambition.

Contributing writer:
Hossein Rezai-Jorabi

09

Multiplicity of Clients

Multiplicity of clients is one of the concepts in regenerative design.

The notion of the diversity of clients suggests that in our business-as-usual practice, operating within the framework of a sustainable development, each project has a contractual client who approaches with the location, a brief and an ambition. It is our responsibility to assist the contractual client in achieving their development goals. However, many of us limit our focus to this aspect, believing that fulfilling these objectives fulfills our professional obligations.

The concept of the multiplicity of clients asserts that the streets themselves are our clients; we are obligated to ensure that they improve because of our projects. Similarly, the neighbourhood is our client, and our projects should contribute to uplifting the entire community.

We consider the urban grid as a client. If there is a precinct or district under our influence or which we have control over, and the grid of the city has been broken, it becomes our responsibility to rectify and enhance it. The whole city is our client. Sometimes, through a single project, one can elevate the whole city - the Bilbao effect. In fact, the whole country is our client; we have a duty of care to the country in which we work, and of course, ultimately we have a duty of care to the planet.

When we express concern about the environment, we should prioritise the interests of the planet in the same manner. The planet and the trees surrounding our sites, the birds nesting in the trees, and even the ladybirds residing on the site are our clients. Therefore, we advocate for biodiversity conservation; we have a responsibility to care for everyone and everything.

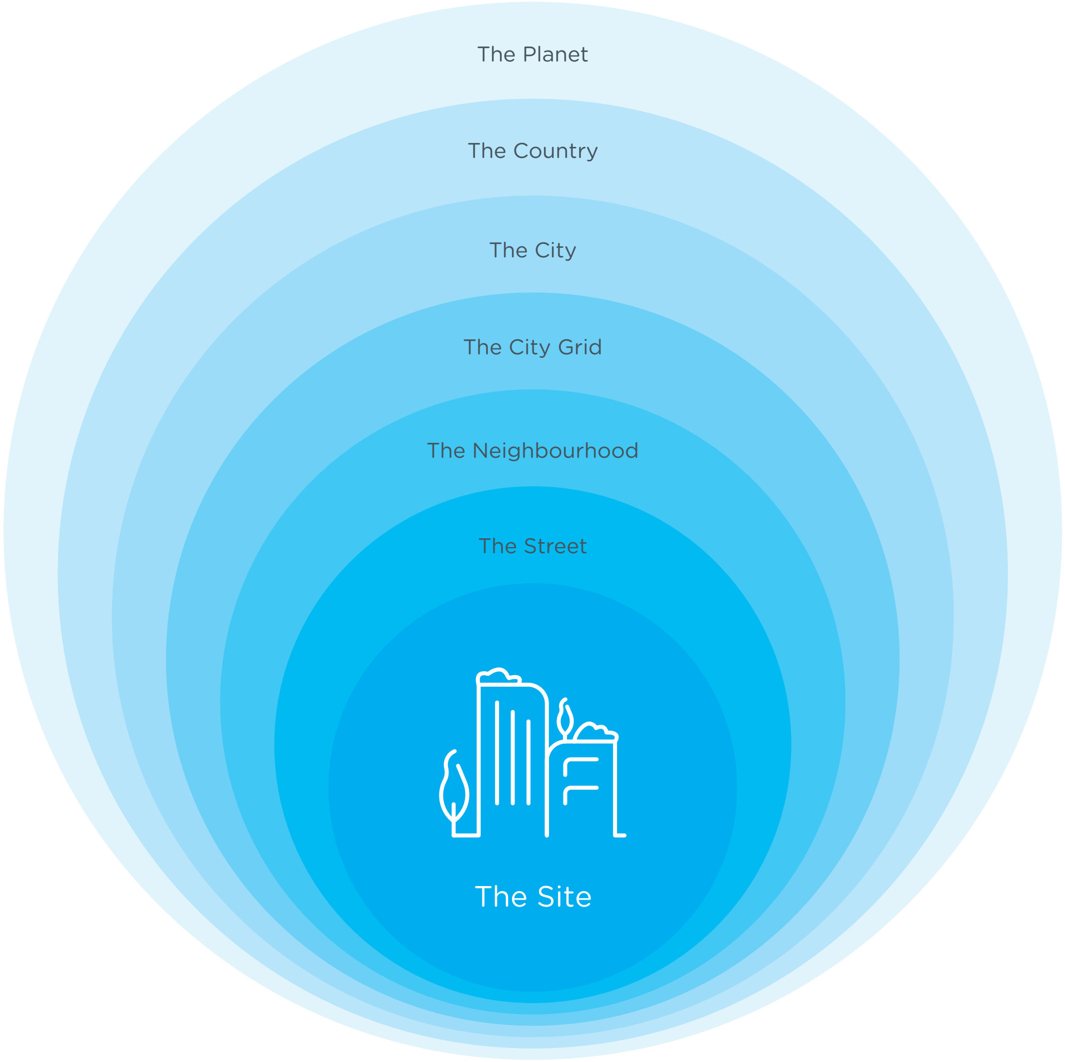
Nine out of these ten clients are recurring and are relevant to nearly every project, with only one client - the paying client — varying from one project to another.

With this perspective, Ramboll's approach to our clients and projects may deviate slightly from the conventional business-as-usual or sustainability paradigms.

The Tree

The Bird

The Ladybird




Børge Johannes Rambøll (left)
Johan Georg Hannemann (right)

A brief journey back to the future

Rambollians today deserve to know more about the legacy of the man whose name they carry into the four corners of the world; a man, clearly ahead of his time, and in pursuit of excellence, the excellence which exists in all of us, and which ought to be put into practice with the same vigour and enthusiasm as the two founders practiced and preached...

Contributing writer:
Hossein Rezai-Jorabi

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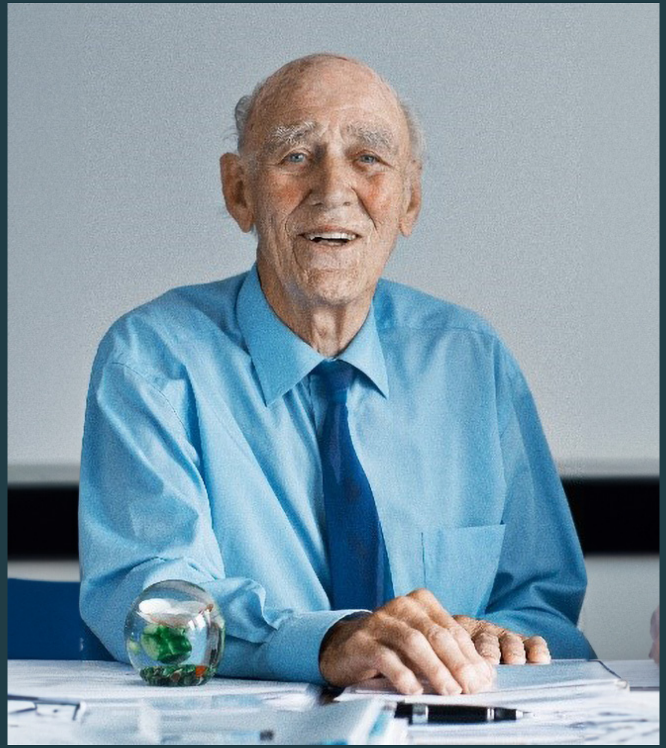
Børge Johannes Rambøll

A journey through his thoughts, a force for change, and a beacon of light



An original thinker, a committed pacifist, and a visionary engineer...

...Børge Rambøll's contribution to engineering, the built environment, and society at large, deserves a rigorous study and recognition.

An upcoming book slated for publication in 2025 will be a positive step in that direction.

This book will cover his journey and growth after the war when he started Rambøll and Hannemann with Johan Hannemann, another exceptional engineer and educator whose legacy continues to inspire many.

Early chapters of the book will trace the initial steps on the journey that we rambollians continue today...

His ideas on the then contemporary issues like regional conflicts, the natural environment, and social justice will be examined in light of their connection with today's challenges of similar nature.

Børge's books and writings like "the webs we weave", "one night the trees will burst into bloom", "the criss cross web", "wide outlook", and others will receive in-depth reviews, to pose pertinent questions about the lexicon he used all those years ago.

Furthermore, the impact of his critique of major global issues like "... continuous economic growth...", the sustainability of the brundtland report, the separation of the natural and the built environment, and others will be studied, and contemporarised.

Rambollians today deserve to know more about the legacy of the man whose name they carry into the four corners of the world; a man, clearly ahead of his time, and in pursuit of excellence, the excellence which exists in all of us, and which ought to be put into practice with the same vigour and enthusiasm as the two founders practiced and preached...

"It must be right to set up a goal even if you don't succeed in netting the ball every time."

Børge Johannes Rambøll

On Børge Rambøll, and striving for Excellence

The current design excellence initiative in Ramboll pays homage to the excellence that the founders of Ramboll pursued all those years ago, as far back as the late 1940s.

Børge Ramboll and Johannes Hannemann, both young engineers, thinkers, and academicians, started Ramboll with the optimism that prevailed in the post-war era. Europe was in desperate need of reconstruction, and the two young engineers wanted to be part of that reconstruction movement, not only in Denmark but also elsewhere in the world.

In these endeavors, purposeful design and differentiation were highly ranked in their ambitions.

Their writings, primarily by Børge Rambøll, and the manifesto of the company, were clear indications of their intent to use engineering and the company in the best interest of all stakeholders; societal, corporate, and environmental.

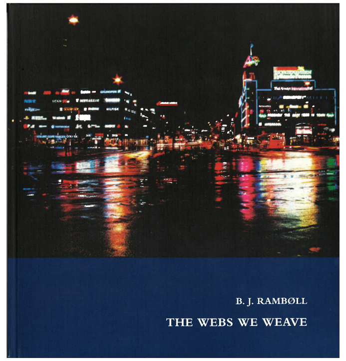
The Webs We Weave - a book by Børge Rambøll, 1995

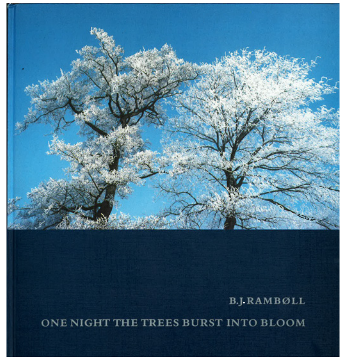
This is a collection of a number of essays by Børge Rambøll.

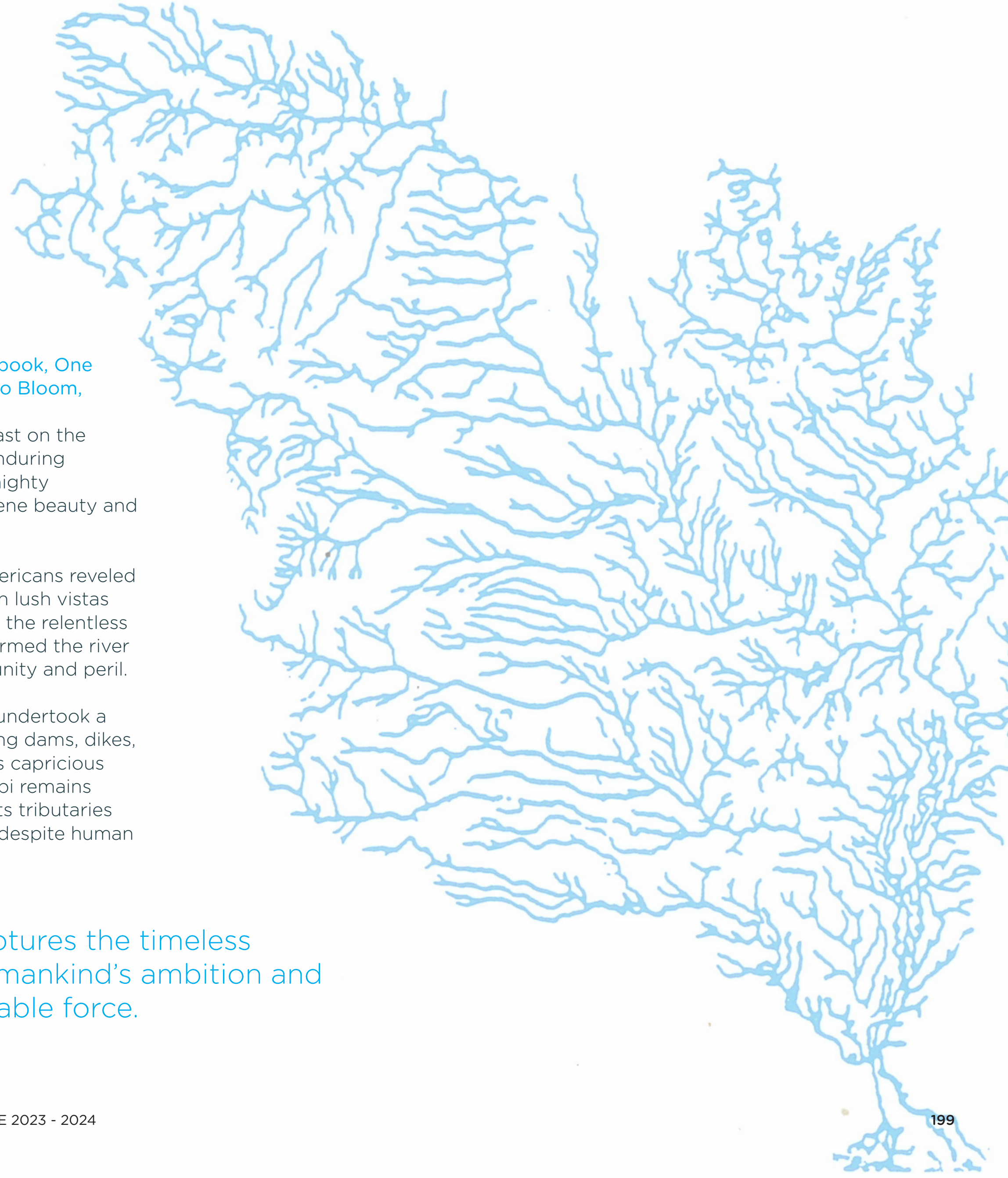
The book starts with 'They returned home 50 years ago", then covers contemporary topics like The Brundtland Report, The greenhouse effect, the sustainability of continuous growth, Nature's superiors, The information technology age and Linking the connections' in which he makes statements like;

"Corelations are a concept that calls for a focusing of the attention", and "Information technology advises us about movement in the world around us and when we know about them, we decide which path we ourselves are going to walk and tread in".

These are the ideas of a man way ahead of his time. ideas which we intend to celebrate in a book in 2025 to commemorate the 80th anniversary of the establishment of our company.







In Børge Rambøll's 1981 book, One Night the Trees Burst into Bloom,

a story titled "A Wild Beast on the Loose" delves into the enduring struggle to master the mighty Mississippi, a river of serene beauty and treacherous fury.

Before the Civil War, Americans reveled in river cruises, basking in lush vistas and tranquility. Post-war, the relentless pursuit of wealth transformed the river into a symbol of opportunity and peril.

The Corps of Engineers undertook a monumental task, erecting dams, dikes, and reservoirs to quell its capricious nature. Yet, the Mississippi remains an untamed giant, with its tributaries threatening devastation despite human ingenuity.

This account captures the timeless dance between mankind's ambition and nature's indomitable force.

Epilogue

A thought experiment: of walkers, swimmers, boat builders, and flyers...

Picture yourself strolling on a sandy beach, the serene whispers of waves harmonizing with your steps. The edge of the water brushes tenderly against the shore, teasing the boundary between land and sea.

As you traverse along this border, a subtle realization dawns upon you - the sea, once a distant melody, is now a rising crescendo. With each passing moment, the water encroaches upon your path, engulfing the once-solid ground beneath your feet. From dry sand to wet soil, the liquid embrace climbs higher, first caressing your ankles, then climbing to your knees - a relentless tide of change.

As the water continues to rise higher above your knees, you feel walking in the rising water is becoming more strenuous. As the waters ascend further, a disquieting realization grips you - this is not a fleeting wave but a permanent phenomenon.

A wisdom from the indigenous tribes echoes in your mind, reminding you that when the waters reach your hips, it's time to contemplate swimming, a seemingly audacious yet essential act of adaptation (though they insist "when the water reaches your shoulder level...").

There are numerous lessons in this simple proverb.

The first one is about "timing". You see, you can really only start to swim if the water level is as high as your shoulder level. One could barely swim in the shallow waters before that.

The other one is about converting obstacles into opportunities. While the rising water is an impediment to walking, it turns into an asset for swimmers.

Now, imagine you are not the walker, but an observer, and are looking at a landscape of hundreds and thousands of walkers in the rising water.

You realise how slower they each become as the water rises.

You observe how they get together to try to help each other along; the stronger help pull or push the weaker... Bonds form, hands extend, and a collective effort to navigate this new reality emerges.

A group organizes a leadership conference to brainstorm and present their latest findings on the best techniques for walking in rising waters. Some in think-tank groups and laboratories put their heads together and invent propellers, that others can wear as a vest (with propellers facing backwards) to help them move forward in the rising water, ...team-building activities are organised to motivate all to persevere and walk on.

You are fascinated with the resilience and audacity of these people.

But amidst this symphony of perseverance, you notice another group of people in the distance, smaller yet determined, who are learning how to swim.

The spectacle is not an elegant one. As they are all beginners in swimming, none of them swim as elegantly as some of the walkers walk, but they attempt to stay afloat. Some succeed, others fail and drown!

By this time, almost all the walkers had drowned in the deep waters!

As you are moved by the scene of dead bodies floating on water, you note that in the far distance, there is another group of people who are not swimming, but building boats!

This third group has come to the realisation that there is no point in swimming when there is no coast to swim to! So they explore the new techniques of designing and building objects that can float on water, and which can save their lives and livelihoods in the future...

By now, all the swimmers are also dead! They were exhausted, swimming to nowhere!

...And as we approach the end of our thought experiment, as you gaze upon the vast panorama, you see a fourth group of people who are thinking about and planning for a life beyond waters. They are dreaming about flying into the future...

Which of these 4 groups do you resonate with?

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Creating Value

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Design Excellence

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Ramboll Design System

Edition 4
Regenerative Worldview

Edition 5
In Praise of Retrofit

Edition 6
AI for Augmented Intelligence

Edition 7
Decarbonisation In Depth

Special Edition
Modern Methods of Construction

Edition 8
MMC - Construction Site to Assembly Site

Ramboll Design
Excellence 2022

Ramboll is a global engineering, architecture, and consultancy company founded in Denmark in 1945. Across the world, our 18,000 experts create sustainable solutions.

We combine local experience with a global knowledge base to create sustainable cities and societies, driving positive change for our clients, stakeholders, and society. We enable our stakeholders to realize their goals and navigate the transition to a more sustainable future.

We call it:

Bright ideas
Sustainable change.

This book contains a collection of essays and articles written in 2023 - 2024 by contributing writers from across Ramboll. Some of these have been published in the form of Ramboll DESIGN periodicals in 2023 - 2024.

The book contains a total of 10 chapters/articles on topics relating to Design, Environment, and other pressing issues of our time.

The periodicals and this book, together with the Ramboll Design Excellence 2022 book which was published in November 2023, form part of a new initiative at Ramboll to produce and share information, knowledge, and insight on design and the environment, and to contribute to the much-needed ecosystem of thought within Ramboll, and within the industry at large. It is hoped that our efforts, as well as those of our industry partners, will collectively help us achieve the design and environmental ambitions we all have for a better future for all living forms...

Featuring
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Lars Ostenfeld Riemann
Michael Stevns
Ollie Wildman
Alessandro Marzucchini
Lai Wan Sing
Robert Bamford
Andy Brahney
Paul Astle
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