Key concepts in our shared understanding

The Systems Connective

1. Bringing systems approaches to the built environment

Systems thinking is relevant and valuable across all walks of life, and the central idea here is to adopt the most relevant systems approaches in the real-world applications of the built environment.
Over the years, many different systems-based approaches, methodologies and tools have been developed and proven in other sectors. Now is the time to bring the best of what they have to offer to the built environment:

- **Systems science** – The interdisciplinary study of complex systems in nature, society, and science, focusing on understanding and modelling their behaviour and interactions.
- **Complexity science** – The study of complex systems and problems characterised by unpredictable and emergent behaviour, often using computational and mathematical models.
- **Systems dynamics** – A methodological framework for understanding and modelling the behaviour of complex systems over time, using stocks and flows, feedback loops, and time delays.
- **Systems engineering** – A transdisciplinary and integrative approach to enable the successful realisation, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods. (Reference: https://www.incose.org/about-systems-engineering/what-is-systems-engineering)
- **Cybernetics** – The study of communication and control processes in biological, mechanical, and electronic systems, focusing on feedback, regulation and goal-oriented behaviour.

Recognising and understanding systems

2. Seeing systems in terms of connections and outcomes

Systems thinking is largely about recognising connections – the relationships between assets in physical systems, between people in organisational/human systems, and between data in digital systems.

Essentially, it is 'joined-up thinking'. At its core, systems thinking involves seeing the whole rather than just the individual parts, and recognising that the whole does indeed have more value than the sum of the parts.

Seeing the connections between physical, organisational and digital systems, we can uncover insights that lead to better outcomes. Systems thinking provides a means of understanding how the outcomes relate to the performance of systems: it is a route to achieving better outcomes for people and nature, and doing so more efficiently, using fewer resources.

3.
Recognising the connections between the fundamental systems

Having described the physical, organisational, and data and digital systems separately, it is important to see that they are all connected. These are the fundamental systems of the built environment, and any 'system of interest' that we choose to describe will include some combination of them:

- physical systems
- organisational systems
- data and digital systems

The key relationship between interventions, systems and outcomes applies to any system that we choose to consider. In other words, it applies to any selected System of Interest, at whichever level in the hierarchy we choose to focus.

4.
Understanding the connection between systems thinking and ontology

Ontology is about the nature of being. In other words, it describes things that exist and the relationship between them. Therefore, it has a very close connection to systems thinking which in many ways is also about relationships.

A reductionist approach often assumes a fragmented ontology, where individual entities exist independently of their relationships. On the other hand, a holistic approach suggests a relational ontology, where the essence of entities is defined by their connections and interactions within a larger system. Applying this to the built environment, systems thinking encourages a relational understanding of the built environment:

- Individual buildings and infrastructure are not isolated entities but exist in a complex web of relationships with other physical systems, social systems, the natural environment, and the people who inhabit and use them.
- The value and meaning of individual components within the built environment are derived from their function within the larger system and their contribution to achieving desired outcomes for people and nature.

By embracing a relational ontology, systems thinking offers a more comprehensive and effective framework for understanding, managing, and improving the built environment. It encourages us to see the built environment not just as a collection of physical objects, but as a complex, dynamic, and interconnected system that shapes and is shaped by human activity and the natural world.

Systems thinking in the built environment addresses the foundational relationships between 'being' and 'doing'. The overall behaviour and performance of a system, its 'being', directly influence the outcomes it produces. Therefore, if we want to change the outcomes, we need to change the system itself, which is where 'doing', in the form of interventions, comes into play. This connection is at the heart of how systems thinking translates into practical action and change:

- **Interventions** – These are actions taken to modify a system. They can range from small operational adjustments to large-scale construction projects. The intent is to use interventions to 'nudge' the systems toward delivering the desired outcomes.
- **Systems** –These are interconnected sets of elements that work together to achieve a purpose. It is important to understand the structure, behaviours, and interrelationships within systems, to design interventions effectively.
- **Outcomes** – These are the results produced by a system, representing the changes achieved in the real world. There is a need to focus on outcomes rather than simply on the outputs of individual interventions.

The relevance of ontology to systems thinking runs even deeper when it comes to data and digital representations of systems. A shared ontology is essential to minimise the friction to information flow. Meanwhile, data sharing infrastructure must be secure, resilient and scalable.

Overall, applying ontological principles to data and digital representations of systems within the built environment is essential for:

- Transcending data silos.
- Enabling effective collaboration and knowledge sharing.
- Facilitating informed decision-making based on a consistent understanding of the data.
- Building secure, resilient, and scalable data infrastructure that can support positive systems change.

5.
Recognising the key processes in the built environment

Individual assets have lifecycles, but our built environment does not because it has to keep working for as long as we need it to serve society. Therefore, the key processes in the built environment include both the life-cycle processes for assets and the continual processes for built systems:

- **Use** – is arguably the most important process because this is what enables us to derive value from the built environment. There should be more industry focus on maximising the value in use, because that is what benefits society. The patterns of use evolve over time, and this is reflected in changes to the systems, their value, benefits and disbenefits.
- **Operate and maintain** – are necessary to make the assets and systems available for use. They are continual processes because they are required for as long as the built environment is needed by people.
- **Plan, design and build/decommission** – are only required when there is need to change the built environment in some way, whether that is modifying existing assets, building new or removing old. Any projects to make these changes are 'interventions' on the existing system. New infrastructure needs to adopt future-proofing principles, including potential re-use, modification, upgrades and options for efficient decommissioning. Retrofitting, upgrading and decommissioning are increasingly important aspects to consider in the whole life cycle of built assets. They are

particularly challenging for legacy assets that did not consider use changes, future requirements, life extension or end-of-life in their design stage.

Currently, many of these interacting processes are not well connected and there is often significant friction to the key flows of energy, materials, money and information. To reduce waste, maximise value and improve overall performance of the built environment, this situation needs to be addressed because these processes are what drive the system's behaviour and evolution, and thus the outcomes realised.

6. Recognising the key elements of systems thinking

An appreciation of system characteristics is fundamental to a better understanding of complex systems:

- **Purpose** – The purpose defines what a human-made system is intended to achieve, and it provides direction for the system's operation and development. The purpose is the reason for the system's existence, and it guides its structure, processes and behaviour. However, for many systems, there can be a marked difference between the intended and actual outcomes. Addressing this difference is what should motivate interventions to drive positive systems changes.
- **Boundaries** – Systems are defined by their boundaries and the connections between their components. Understanding the boundaries helps in determining what components are inside the system and what are outside. This concept is crucial for understanding the system's interactions with its environment. "The world is a continuum. Where to draw a boundary around a system depends on the purpose of the discussion." Donella Meadows. Boundaries should not be fixed.
- **Interconnections** – The components of a system can be connected through causal relationships and feedback loops. The connections between the components of a system reveal how changes in one part of the system can affect other parts. The components and connections can be thought of as the structure of the system, and this can change.
- **Hierarchies and levels** – Complex systems often have nested structures with multiple levels of hierarchy. Understanding how these structures and levels interact and influence each other is key to understanding the overall system.
- **Stocks and flows** – Systems always involve some kind of flow between the components, such as the flow of energy, materials, money or information. Stocks are the accumulation of these elements, which can be counted or measured. Together, stocks and flows help in understanding how systems operate over time and how they respond to changes. They are crucial in modelling dynamic systems in fields like economics, ecology and engineering.
- **Processes** – A process is a series of interrelated activities or steps that drive flows within a system. They are essential for a system to function and achieve its goals. Understanding processes is key for knowing how systems perform and interact. Systems can be seen in terms of interacting processes, which are dynamic and can change over time.
- **Feedback loops** – Feedback loops influence the future behaviour of a system. They may be created both deliberately and inadvertently in the

structure of the system. Positive feedback loops amplify the system's behaviour, while negative loops dampen or control the system's behaviour.

- **Emergence** – Interactions within a complex system can give rise to system-level properties that don't exist in any of its individual components. In this way, some outcomes can be seen as emergent properties of a system. For example, safety can be seen as an emergent property of a well-functioning system. Emergent properties are not always predictable and are not always desirable.
- **Nonlinearity** – The non-linearity of complex systems means that changes in input can lead to disproportionately large or small changes in output. The relationship between cause and effect is not straightforward, and there can be multiple layers of connectivity. This means that complex systems behave in ways that can be unpredictable and counterintuitive.
- **Tipping points** – Complex systems can have tipping points beyond which they irreversibly collapse or transition into a new state. Once a tipping point is reached, the system may undergo rapid and dramatic changes. These tipping points can hinder the intended outcomes or potentially contribute positively. Extinction is a tipping point where the system ceases to be viable.
- **Path dependency** – The outcomes from a system are heavily influenced by its historical context. This means that past events and decisions can constrain and shape the present and future possibilities of the system. Therefore, a historical perspective is critical for comprehending a system's current state and anticipating its possible future developments. However, while history matters, it is not a reliable predictor of the future.
- **Degradation** – Systems tend to degrade over time. Degradation is the process by which a system or its components deteriorate, leading to a decline in performance, efficiency or functionality. This can occur due to various internal or external factors, including environmental conditions, usage, or the inherent properties of the system. Systems are transient but can be long-lived.
- **Co-evolution** – A complex system will invariably be connected to other systems. Changes to these other systems may trigger an autonomous response in the system of interest without anyone undertaking a specific intervention on it. In some cases, the system of interest will co-evolve effectively with other systems, but in other cases it may degrade or fail. Detecting why a complex system has changed its behaviours or its outputs can therefore be very complicated.

There are **approaches to understand and nudge systems** toward desirable outcomes:

- **Holism** – Systems thinking considers all the characteristics of a system outlined above. Understanding how a system functions, as a whole, is crucial for comprehending how it relates to outcomes.
- **Leverage points** – Leverage points are strategic places within a complex system structure where a small shift in one part can produce big changes in the whole. Identifying and understanding these points can help in effectively influencing the system's behaviour and achieving desired outcomes.
- **Representation** – Using visualisations to talk about systems (their boundaries, structures, components, flows, processes, behaviours, outcomes and their emergent properties) is essential to convey understanding, identify gaps, expose marginalisation and enable discussion. Improved representation and better understanding can change the behaviour of system participants. Systems mapping makes explicit the assumptions buried in stakeholders' worldviews.

- **Quantification** – Representations should be quantified in computational, mathematical or physical models so that systems can be assessed before they are created or before they are improved through interventions. Systems modelling can be used for careful projection of possible futures and consequences.
- **Learning** – When a change is made to a system, it is essential to measure and assess its effectiveness. This learning can then be positively applied to any future changes. It often makes sense to try smaller nudges before larger interventions are undertaken.
- **Bi-directional flows** – Traditional cause-and-effect thinking needs to be replaced by relational thinking. Flows, including feedback, may be able to change direction. Therefore, information related to the flow is needed to understand it properly.
- **Intelligence** – Local optimisation can lead to sub-optimal outcomes from a complex system because the parts of a system are intimately interconnected and cannot be fully understood in isolation. Over time, some of the complexity of the overall system could be embedded into each component through digitalisation, so that each component becomes smarter and has some knowledge of its effect on the rest of the system.
- **Adaptation** – Complex systems do not always respond to changes imposed on their components, structure, flows or contexts. When the complex system absorbs a change, there is no visible response in the nature of the system and its emergent properties. When the complex system responds in expected ways, the change may have been effective. When the complex system responds in unexpected ways then the changes have failed to take full account of the how the system works.

Describing and representing systems

7. Describing the organisational systems that influence the built environment

Many different organisations play a role in running the built environment. Here are some of the key players:

- Central and local government agencies
- Regulators
- Client organisations and asset owners/operators
- Construction and engineering firms
- Construction materials suppliers and manufacturers
- Professional services providers
- Asset and facilities management companies
- Environmental and sustainability organisations
- Education and research institutions
- Investment, financial and insurance organisations
- Professional bodies and standards organisations
- Community and advocacy groups

These organisations and institutions contribute to conceiving, operating, maintaining and enhancing the built environment. Each one plays a part, but together they have to ensure that the built environment meets the needs of society, including fulfilling the duty to promote sustainability and resilience.

8.
Mapping and modelling systems

Systems mapping and modelling are crucial for gaining a deeper understanding of complex systems and for designing effective interventions. They provide a structured way to visualise and analyse the intricate relationships and dynamics within a system.

- Systems mapping is the process of creating visual models to represent the components of a system and their interconnections. It helps in understanding complex systems by illustrating how different parts interact and influence each other.
- Systems modelling involves creating abstract representations (models) of systems to simulate and analyse their behaviour. It aims to increase understanding of how systems will respond to different conditions and interventions.

Systems mapping and modelling present ways of understanding:

- the context in which new and existing infrastructure is required to operate
- how legacy infrastructure is performing
- changing societal, ecosystem, economic and technological conditions

Mapping and modelling are therefore key tools for getting better performance and value both from what we have already built and new assets.

9.
Describing the physical systems of the built environment

The built environment encompasses every part of the environment that humans have modified. The physical systems of the built environment include:

- **Economic infrastructure** – energy, transport, water, flood protection, waste, telecommunications – the connected networks that provide essential services to society.
- **Social infrastructure** – municipal buildings, hospitals, schools, prisons – the facilities, spaces and networks that support the quality of life and wellbeing of our communities.
- **Private buildings residential, commercial and industrial buildings** – all the other buildings that make up the built environment, none of which could work without connections into the shared infrastructure.

The built environment always intersects with the natural environment, so there are many parts of the built environment at the interface, such as urban and peri-urban green spaces, agricultural land and resource extraction (mines and quarries).

This list is neither exhaustive nor exclusive because the point here is to describe the built environment, not to provide a foolproof definition. Each part is a system and, together, the built environment is a complex, interdependent system of systems. To think of the built environment in terms of individual buildings, sectors or organisations misses how it really works. Systems thinking recognises the interactions between the parts and sees the value of the whole.

Clearly, construction of new assets will continue to be hugely important. However, construction needs to be seen in the broader context of getting more value from what we have already built. And that value is in the use of the services it provides.

Therefore, it is time that we saw the built environment differently, not as a series of construction projects, but as a system of systems whose purpose is to enable people and nature to flourish, together, for generations.

10. Describing the connections to the natural environment

A fundamental aspect of systems thinking is recognising the interdependence and integration between the built and natural environments, and between people and nature.

The natural environment provides ecosystem services to people, which includes providing air to breathe, water to drink, soil in which to grow crops, natural flood protection, living space, places for healthy recreation, opportunities for resource generation and extraction, and a means of removing some pollution. In comparison, the services that the built environment provides to nature are minor, but they include urban habitat and some protection. People are part of nature – we are biological and require a healthy environment to thrive: nature is vital to us.

The natural environment is the context within which the built environment must operate, and this context is changing in ways that will impose constraints and threats that will have systemic implications. For example, more extreme weather events will have a huge impact on the built environment.

And the natural environment is part of the wider planetary system of systems, which includes:

- the biosphere – all living things – green infrastructure
- the hydrosphere – all water – blue infrastructure
- the atmosphere – the air
- the geosphere – all land

The Earth is our home. What we do in the built environment has to be constrained by the Earth's resources, so we must shift towards intentionally operating the built environment within the recognised planetary boundaries [Reference].

11.
Describing the connections to other systems

There are important connections between the built environment and other systems that are essential to society. The built environment is effectively the host to these systems because it provides the context within which they operate:

- Economic system
- Social systems
- Health systems
- Education systems
- Food systems
- Financial systems
- Justice systems
- Defence systems
- Political systems

Understanding the interconnectedness is key.

12.
Describing the data and digital systems of the built environment

Data and digital technologies are an increasingly important part of the built environment, playing crucial roles such as those of enhancing its efficiency, cost effectiveness, safety, equity, sustainability and resilience.

Many digital technologies, such as fibre networks, telecoms masts, and data centres, are part of the physical systems outlined above. However, it is important to distinguish between the physical world and the digital realm of data and information. This digital realm includes the data itself, information management, digital models, data sharing infrastructure and ecosystems of connected digital twins. While these digital elements can all be used to support the physical systems, they deserve separate recognition because, in this information age, the importance of the data and digital world is growing, and it needs more attention. In this context, data sharing infrastructure should be recognised as a class of national infrastructure and be managed accordingly, alongside other national infrastructure. It is part of a cyber-physical system of systems.

The value of data is related to the way it is used, and whoever has access to information has potential agency to act. For example, river campaigners have had the power to drive change in policy because they had access to data about illegal discharges.

Shaping change

13. Understanding ‘value’ in the context of systems thinking

In systems thinking, value relates to the benefits or worth that the system provides to its stakeholders. In other words, value is defined in terms of achieving desired outcomes from the system. The concept of value in systems thinking is not just about monetary gain but also about the overall improvement in quality, economic viability, sustainability, resilience and satisfaction that a system can deliver. In this way, the ‘performance’ of the system should be seen in relation to realising the value of its outcomes.

The presence of siloed budgeting across government, between local and national government, and according to the investment priorities of private sector investors, currently creates incentives for budget holders to externalise costs and thwarts a more holistic view of value creation. One example is the CAPEX/OPEX split in many public-private partnership projects, in which capital costs are defrayed by shifting them onto higher through-life maintenance and operational costs. This frequently results in long-term inefficiencies.

14. Challenging mental models and world views

The real world is complex, therefore we must embrace complexity. In understanding complex systems, we should heed Einstein’s advice that “everything should be made as simple as possible, but not simpler”. Systems thinking provides a way of doing this – it is a better way of engaging with the world as it actually is. However, people tend to over-simplify or over-complicate problems, and the predominant world view is most often reductionist:

- **Reductionist world view** – Breaks down complex systems into their individual components to understand each part separately. This approach analyses parts in isolation, often simplifying complex phenomena to their basic elements; interventions tend to focus on parts regardless of the whole. For example, in medicine, a reductionist approach might focus on treating specific symptoms rather than considering the patient’s overall health.

- **Holistic world view** – Considers systems as a whole, emphasising the interconnections and interactions between the parts. This approach looks at the bigger picture, understanding that the whole is greater than the sum of its parts and interventions are developed accordingly. For example, in medicine, a holistic approach would consider the patient’s physical, emotional, and social well-being, aiming for overall health improvement.

Reductionism seeks to understand by dissecting and simplifying, while holism aims to understand by integrating and considering the complexity of the whole system. We need both. Systems thinking is an integrative approach that combines the detailed analysis of reductionism with the comprehensive perspective of holism.

Deeply ingrained assumptions and generalisations influence how we understand the world and take action. Systems thinking encourages examining and challenging these mental models to better understand and improve systems. Systems thinking considers different perspectives from various stakeholders and disciplines to gain a richer and more complete understanding because there are always multiple perspectives of any system. While no single party can completely understand how the whole system works, it is possible to connect and coordinate communities that understand their parts of it to build a better shared understanding.

15.
Understanding the difference between complex and complicated

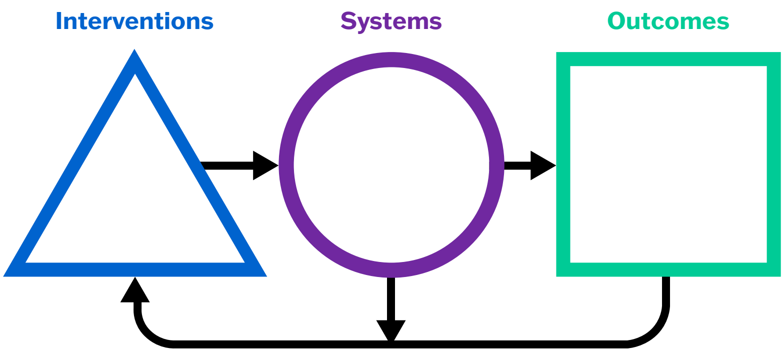
A system is perceived to be complicated, and therefore difficult to understand, if it comprises many parts or subsystems (e.g. an aircraft or a mechanical clock). However, complicated systems can be broken down into understandable components that interact in predictable ways, and these can each be analysed to determine overall performance. The more parts to such systems, the more complicated they are perceived to be. The fewer parts, the simpler such systems are perceived to be.

Complex systems, on the other hand, have interconnected parts. Generally, an increase in interconnections leads to an increase in complexity. that interact in surprising ways, making the whole system performance unpredictable. They may contain parts that behave in fundamentally unpredictable or even capricious ways, and there may be unknown or unknowable parts of the systems. Such uncertainties are typically associated with social and natural systems. In complex systems, an intervention may result in the emergence of unintended consequences.

The real-world systems of the built environment are inherently complex because of their interconnections and context. And they are rapidly becoming more complex as the drive for decarbonisation and digitalisation increases the number of connections.

16.
Understanding change in complex systems

The connection between outcomes, systems and interventions is key to a practical understanding of how to improve outcomes from complex systems.



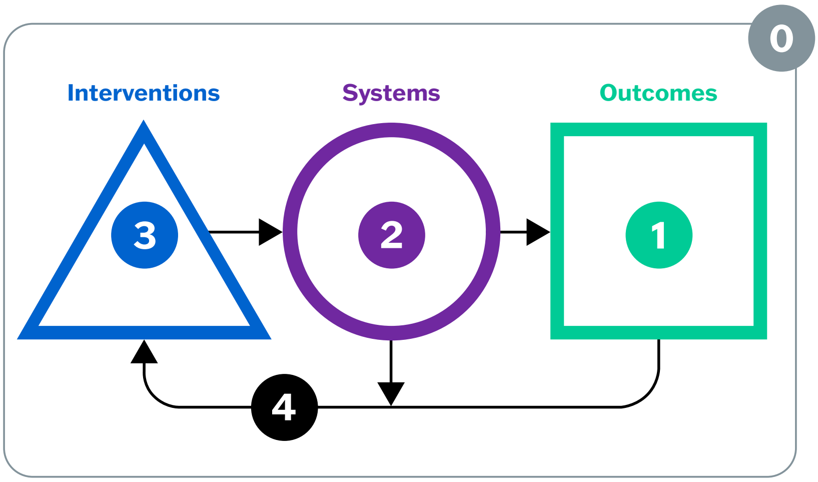
By their nature, complex systems cannot be 'controlled' or 'optimised' in a traditional sense. However, because outcomes can be seen as emergent properties of complex systems, it is possible to understand and nudge complex systems towards delivering desirable outcomes. In this respect, the diagram above should be read two ways:

- **Right-to-left – the direction of intent**: targeting improved outcomes requires change to the systems, which defines the required interventions.
- **Left-to-right – the direction of effect**: interventions modify the systems, which deliver changed outcomes as a result.

There is a driver for change if the desired outcomes are different to the actual outcomes from an existing system.

A theory of change (ToC) is an explicit model of how interventions lead to impacts and outcomes; it makes a clear distinction between the 'output' from an intervention and the 'outcome' from the system. To be effective, a ToC must reflect how the world actually works. In other words, the ToC is not just about change, but about relating change to real world systems.

Therefore, a ToC must be based on an understanding of how outcomes, systems and interventions are connected. Additionally, a ToC must be dynamic, allowing for continuous learning and adaptation to new insights and challenges. Continual learning is an essential part of systems thinking.



This diagram shows how a simplified theory of change relates to the systems that need to change.

The relationship between interventions, systems and outcomes relates to any system that we choose to consider, at whichever part of the hierarchy we want to focus on. It also relates to any kind of system, whether that is physical, organisational or digital, or any combination of them.

Many well-established theories of change mention inputs, outputs, outcomes and impacts (including the UK's HMT Magenta Book). These terms and their related metrics can be very useful, so it is important to see how they relate to the model of interventions, systems and outcomes:

1. **Inputs** – These are the resources, such as time, money, personnel, and materials that are invested to carry out an intervention. In the built environment, inputs are what is needed to undertake a project.
2. **Outputs** – These are the direct results from the intervention, and they are

typically measurable and tangible. In the built environment, outputs would include new assets – the results of undertaking projects.

3. **Impacts** – These are resulting changes to the systems. The impact of an intervention on a system may be broader and more far-reaching than the output. In the built environment, impacts can affect the performance of the whole system. The distribution of impacts across place and society are important systemic considerations.
4. **Outcomes** – These are the overall results. It is meaningful to consider outcomes at different levels in the hierarchy, for example at a local, regional, national or global level. In the built environment, the relevant outcomes are usually a mix of environmental, social and economic outcomes. A systemic understanding requires analysis of distributional factors affecting who, where and when outcomes are experienced.

17.
Understanding the complementarity between systems thinking and systems engineering

Systems thinking helps us to understand the broader built environment context within which interventions are carried out, employing systems engineering. Both are needed. Systems thinking is applicable across all systems in the built environment and is ultimately concerned with achieving better outcomes. Systems engineering is most applicable in delivering the outputs of complicated infrastructure projects successfully.

- Systems thinking is “a framework for seeing the interconnections in a system and a discipline for seeing and understanding the whole system; the ‘structures’ that underlie complex situations”. It is an approach that emphasises understanding the big picture and how all the parts of a system interconnect and influence each other. It is most useful for understanding systems so interventions can be developed that are most likely to improve outcomes.
- Systems engineering is a specific discipline that uses a structured approach to design and deliver engineered systems against requirements. It is most useful for ensuring that the outputs of interventions meet their requirements.

Identifying blockers and enablers

18.
Understanding organisational constraints and incentives

Each organisation works within constraints and towards incentives that have usually been defined by others. For example, contractors operate within the constraints of the contracts with their clients; utility operators work within the constraints set by their regulators; and regulators work within the constraints set by the relevant government departments. When this chain of constraints and incentives is not aligned with the desired outcomes, those outcomes cannot be achieved. Even if well-meaning individuals and organisations have the best intentions, they are obligated to work within their constraints towards their given incentives.

This 'agent constraint' relationship between organisations defines how the overall organisational system functions. And, at present, it often does not work. It is essential to understand these relationships to design more effective layers of constraints and incentives that are aligned with the desired outcomes.

19. Recognising organisational and sectoral silos in the built environment

Many organisations serve the built environment, but they operate in organisational and sectoral silos, which inevitably leads to sub-optimal outcomes. This includes the vertical disconnections that span from policymakers through regulators and owner-operators to the ultimate end users. It also includes the horizontal disconnections across infrastructure sectors such as energy, transport, telecommunications, water, flood protection and waste management. By addressing these silos, organisations can achieve better results for themselves and improve outcomes from the overall built environment.

Rather than talking about 'breaking silos', it is more constructive to use the terminology of 'making connections', and a key strategy to achieve this is to enable a secure, resilient information flow across the silo boundaries. This 'boundary spanning' requires key capabilities such as partnering, collaboration, brokering, knowledge transfer and integration.

We must develop effective leadership and governance in our organisational systems. This will involve connecting organisational systems with better information and improving understanding between them, to enable better decision-making that takes account of uncertainties and risks. This approach will involve 'learning our way forward' by making incremental changes and improvements, conducting pilot and demonstrator projects and through living 'lab' types of approach. We will need improved evaluations to allow sharing and scaling up of successful developments.

All this will require visionary, boundary-spanning leadership – leadership that embraces complexity. Effective industry leadership will be systems leadership.

20. Shifting the mindset and culture of the industry

The construction industry views the built environment as a series of construction projects. Likewise, its emphasis on project delivery focuses on breaking problems into component parts and translating them into outputs; it tends not to consider how components come together into an overall solution that improves outcomes. In this way, the predominant world view of the industry is reductionist rather than holistic.

Adopting systems thinking would give us a bigger picture that focused on outcomes – achieving better results with fewer resources in more lasting ways. At an individual level, this requires a shift in mindset and, at an industry level, a shift in culture.

Currently, the norms, values and beliefs that characterise the construction industry are leading to poor outcomes. In order to achieve better outcomes, the organisations and institutions that serve the built environment need a shared view of how the world actually works – a worldview that recognises the role of systems. It requires an approach that is outcomes-focused, systems-based and community-enabled. It also requires challenging and changing the industry processes (the constraints and incentives) that currently lock in poor behaviour.

Good practice that shifts mindset should be shared across the sector. For example, the South West Infrastructure Partnership brings organisations and professionals together from across the South West of England to debate and advocate for new ways of delivering resilient and sustainable net zero infrastructure in their region.

21.
Being prepared for shocks

There is intrinsic value in being prepared for possible shocks, such as those that will come from climate change or enemy action. Such shocks have 'explosive materiality' in that there is no issue, until suddenly there is a huge issue. This necessitates increasing the resilience of our built environment. Being prepared for change means deliberately anticipating what might be coming towards us, using horizon scanning and risk analysis, and understanding trends. With this understanding of possible futures, we should explicitly prioritise and invest in resilience, seeking it as a desired outcome from our built systems. By adopting strategies such as smart technologies, sustainable materials and green infrastructure, we can create a built environment that not only withstands shocks but also thrives in the face of uncertainty.

Shaping sustainable solutions

22.
Moving towards a circular economy

Systems thinking aligns perfectly with moving towards a circular economy because it views economic activities as interconnected processes that continuously recycle resources. This approach focuses on maximising the 'value in use' of resources, products, assets and systems.

From the reverse perspective, a circular economy in the built environment cannot be achieved without systems thinking.

23.
Seeing new opportunities and solutions

Systems thinking in the built environment opens opportunities for new solutions that are simply not possible as isolated solutions. Enabling co-investment for co-benefits is a collaborative approach where multiple stakeholders invest resources together to achieve benefits that wouldn't be possible if they acted alone. It's essentially a win-win situation for all involved. For example, a city council, a developer, and a community group co-invest in creating a park. The city benefits from reduced stormwater runoff. The developer increases property values, and the community gains a recreational space and improved air quality.

24.
Choosing a 'both/and' approach rather than 'either/or'

In systems thinking, there is often benefit in bringing apparently conflicting ideas together. We need to mix methodologies to suit the issues under consideration. This includes:

- top-down and bottom-up
- part and whole
- micro and macro
- left brain and right brain
- individual and society

For example, a bottom-up approach to planning approval might take the proposal for a new building and focus on considering how it would impact local stakeholders. In contrast, a top-down approach would take the objectives for an area and consider how new buildings could help to achieve them. Both approaches are needed together.

Systems thinking provides us with an approach to our built environment that enhances our prevailing management approaches, which tend to be siloed. It does not replace detailed reductionist analysis but complements and connects the information and understanding that these analyses create.

25.
Addressing potential futures

Systems thinking inherently involves future thinking because it focusses on improving outcomes that are necessarily in the future. A 'whole systems, full futures' approach would intentionally blend systems thinking and future studies, using methods such as:

- Scenario development: exploring a range of plausible futures in order to make more informed decisions.
- Back-casting: envisioning a desired future state and working out what would need to happen to make it real.
- Visioning: painting a rich picture of an agreed desirable future that becomes the inspiration for back-casting.
- Three horizon model: considering current activities, emerging opportunities, and the potential for transformative innovations, to balance short- and long-term goals.

While it is not straightforward to address both the worst and best cases at the same time, it is necessary because we must aim for the best and prepare for the worst.

26.
Applying living systems principles

Incorporating 'living systems' principles would aim to create infrastructure that is not just functional but also harmonious with the natural world, contributing to the well-being of both the environment and the people who use it. It's a holistic approach that seeks to create systems that are resilient, adaptable, and capable of regenerating the ecosystems of which they are part. In this context, it is helpful to see human communities in terms of ever-evolving ecosystems, embedded in larger, natural ecosystems.

Fritjof Capra's work on living systems principles articulates how life is interconnected and interdependent, integrating biological, cognitive, social, and ecological dimensions. With this view, our global problems are systemic and interconnected, requiring a holistic approach to address them. This includes recognising that there are limitations on 'business as usual' industrial growth on a finite planet and promoting sustainable practices. There is a need to shift the direction of growth towards more efficient ways of generating beneficial outcomes by allowing natural processes to fulfil human needs.

With this view, regeneration must be seen as part of the outcomes we aim for. Rather than 'not damaging nature', we can shift to seeing how the built environment can enhance it, for example via living buildings and renaturing the city [Reference: Designing Regenerative Cultures, Daniel Wahl].

The question with restoration is what condition we're restoring to. Each generation tends to set a benchmark based on a point in time within their own lifespan. Taking an intergenerational view of the future, we need to aim for a point further in our collective past, restoring to a much richer benchmark than we've experienced in our own time.

These ideas challenge conventional views and provide a new foundation for ecological policies aimed at building sustainable communities. It is a call to rethink our relationship with the natural world and adopt a more integrated and sustainable approach to living.

27.
Addressing trade-offs

Systems thinking is essential for coping with the dilemmas that arise in practice. For example, designers often face a difficult choice between resilience and efficiency – 'just in case' versus 'just in time'. In practice, there are many other criteria that also compete for priority, including: sustainability, timing, cost types (CAPEX, OPEX or whole life), safety and equity. Ideally, we would like to maximise all these criteria in our solutions, but trade-offs are inevitable. Systems approaches help in project appraisals to focus on improving the overall outcomes, rather than just optimising local criteria that relate only to the output. It would expose the context and the consequences, increase the transparency of decision-making and enable better trade-offs.