Bridge Owners' Forum

# Future Bridges ?

Ian Firth

26th May 2020

# Future Bridges ?

- Are lessons from the past being forgotten ?
- How can we ensure a sustainable future ?
- What must change and what must we start doing now ?

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Milford Haven (Cleddau) Bridge Collapse, July 1970

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West Gate Bridge Collapse, October 1970

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First recommendation of the Merrison Committee:

*"The Engineer's permanent design should be checked by an independent engineer both for the design concept and the method of analysis of stress, and a certificate furnished to this effect and for compliance with the criteria ...."*

*"The independent engineer should have experience and qualifications commensurate with the magnitude and complexity of the design in question."*

Report of the Merrison Committee of Inquiry, 1973

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The Merrison Committee also recommended:

The terms of the Engineer's appointment must make him *"..responsible for the supervision of the works ..."* and must include the requirement for *"..examining Contractors' proposals and details and the checking of the adequacy, stability and safety of the proposed methods of construction and temporary works."*

Report of the Merrison Committee of Inquiry, 1973

# Future Bridges ?

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*Extract from my keynote on Design Checking, IABSE Congress, Weimar, 2007*

- Structures are still failing.
- Are we becoming complacent and in danger of relaxing our guard?
- Do the harsh lessons of previous generations need to be re-learnt?
- Systematic, competent design checking is as vital now as it has ever been.
- The cost of an independent design check is insignificant compared to the value and added confidence it provides.”
- Many countries still have no established culture of independent checking.

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*Extract from my keynote on Design Checking, IABSE Congress, Weimar, 2007*

- Read the Merrison Committee of Inquiry report.
- Establish a full independent checking system.
- Ensure the technical and commercial independence of the checker.
- For large projects (say >£100M) extend the Checker's scope to include an Economic Design Review to reduce unnecessary waste.
- Allow enough time in the programme for a thorough independent analysis and evaluation of the design.
- Designer and Checker interact in a spirit of mutual respect and co-operation, learning from each other and advancing the state of engineering technology.

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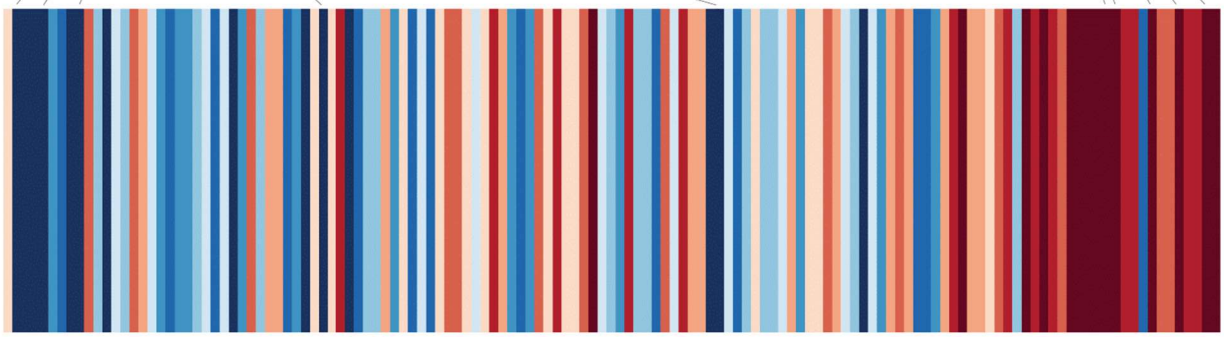
Socialist Alliance
ALWAYS WAS
ALWAYS WILL BE
www.socialist-al
CLIMATE
THIS IS AN EMERGENCY

Met Office

# UK annual temperature

**5 coolest years**
1892, 1888, 1885, 1963, 1919

**5 warmest years**
2014, 2006, 2011, 2007, 2017



1884 1900 1920 1940 1960 1980 2000 2020

London to New York

One-way, economy class

1 ton

Note:
Approximate, 0.85T including radioactive forcing

Credit:
Will Arnold, Arup

Source:
https://www.carbonfootprint.com/calculator.aspx

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# Meat, dairy and beer

## One year's consumption

# 2 tons

Note:
Approximate, 1.7T based on weekly consumption of 1-2 portions each of beef, chicken, lamb, and fish, plus daily 200ml portions of dairy milk and a daily pint of beer

Credit:
Will Arnold, Arup

Source:
https://www.bbc.co.uk/news/science-environment-46459714

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Average family car

10,000 miles

3 tons

Note:

Approximate, 3.09T based on a medium sized average car with 1.4-2.0L engine

Credit:

Will Arnold, Arup

Source:

https://www.carbonfootprint.com/calculator.aspx

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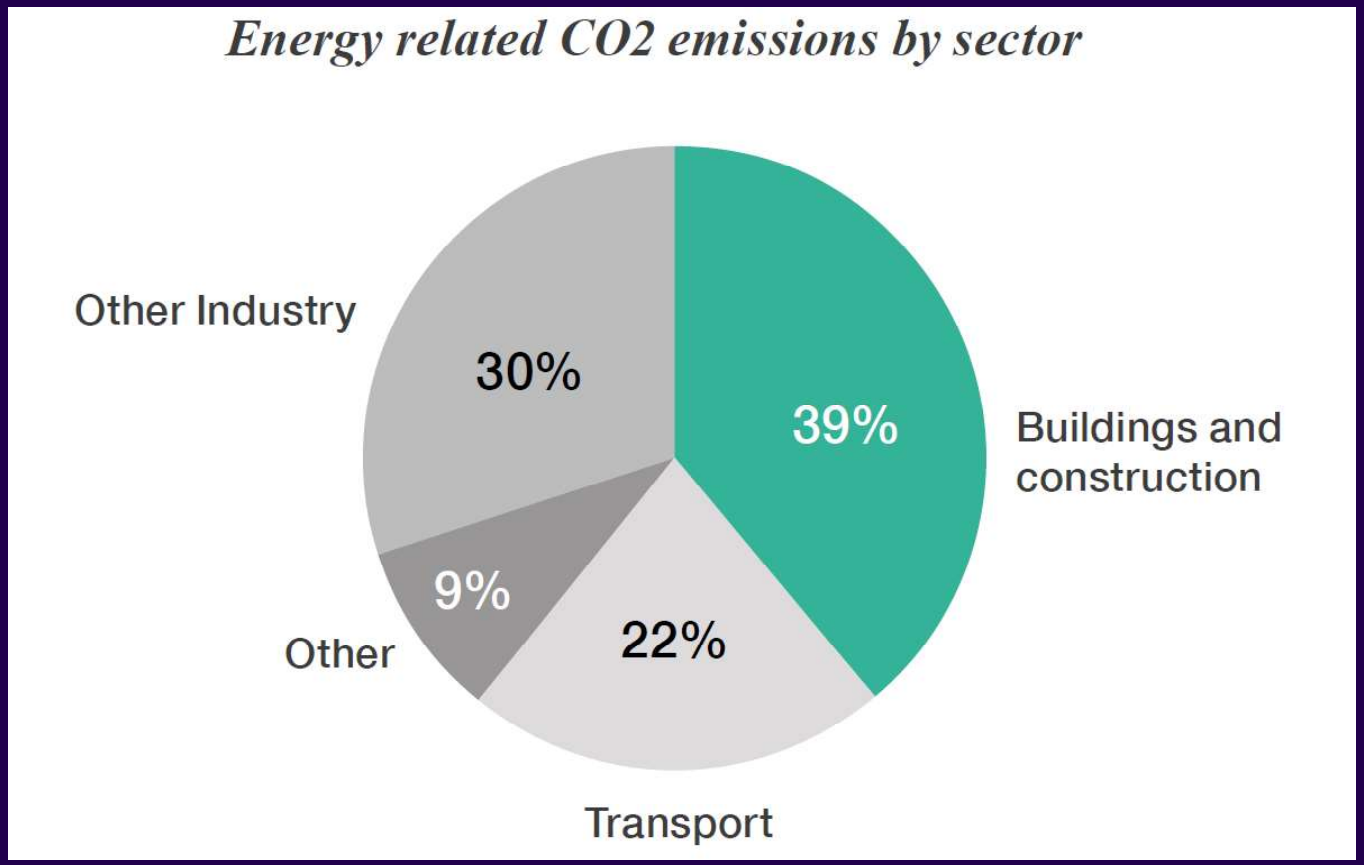


Energy related $CO_2$ emissions

*(source: World Green Building Council)*

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Civil and structural engineers represent the biggest part of the biggest problem for the planet.

Our professional institutions currently do not require us to do anything about it.

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UK Civil
Engineers
Declare Climate
& Biodiversity
Emergency
www.civilengineersdeclare.com
100 organisations have signed (25 May 2020)

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## UK Civil Engineers Declare Climate & Biodiversity Emergency

The crises of climate breakdown and biodiversity loss are two of the most serious issues of our time. Our major infrastructure systems of transport, energy, water, waste, telecommunications and flood defences play a major part, accounting for approximately half of energy-related carbon dioxide (CO2) emissions whilst also having a significant impact on our natural habitats.

Our primary purpose has always been, and remains, enhancing society and well-being. While we have seen major improvements to practice over the last 20 years, for everyone working in the construction and infrastructure industries, meeting the needs of our society without breaching the earth's ecological boundaries will demand a paradigm shift.

*www.civilengineersdeclare.com*

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## UK Civil Engineers Declare Climate & Biodiversity Emergency

Continued ….

Together with our clients, we will all need to commission and design buildings, cities and infrastructure systems as indivisible components of a larger, constantly regenerating and self-sustaining system in balance with wider society and the natural world.

The research and technology exists for us to accelerate that transformation now, but what has been lacking is collective will in government and industry. We urgently need current best practice to become standard practice. Recognising this, we are committing to strengthen our working practices and committing to create complete engineering outcomes that have more-positive impacts on the world around us..

*www.civilengineersdeclare.com*

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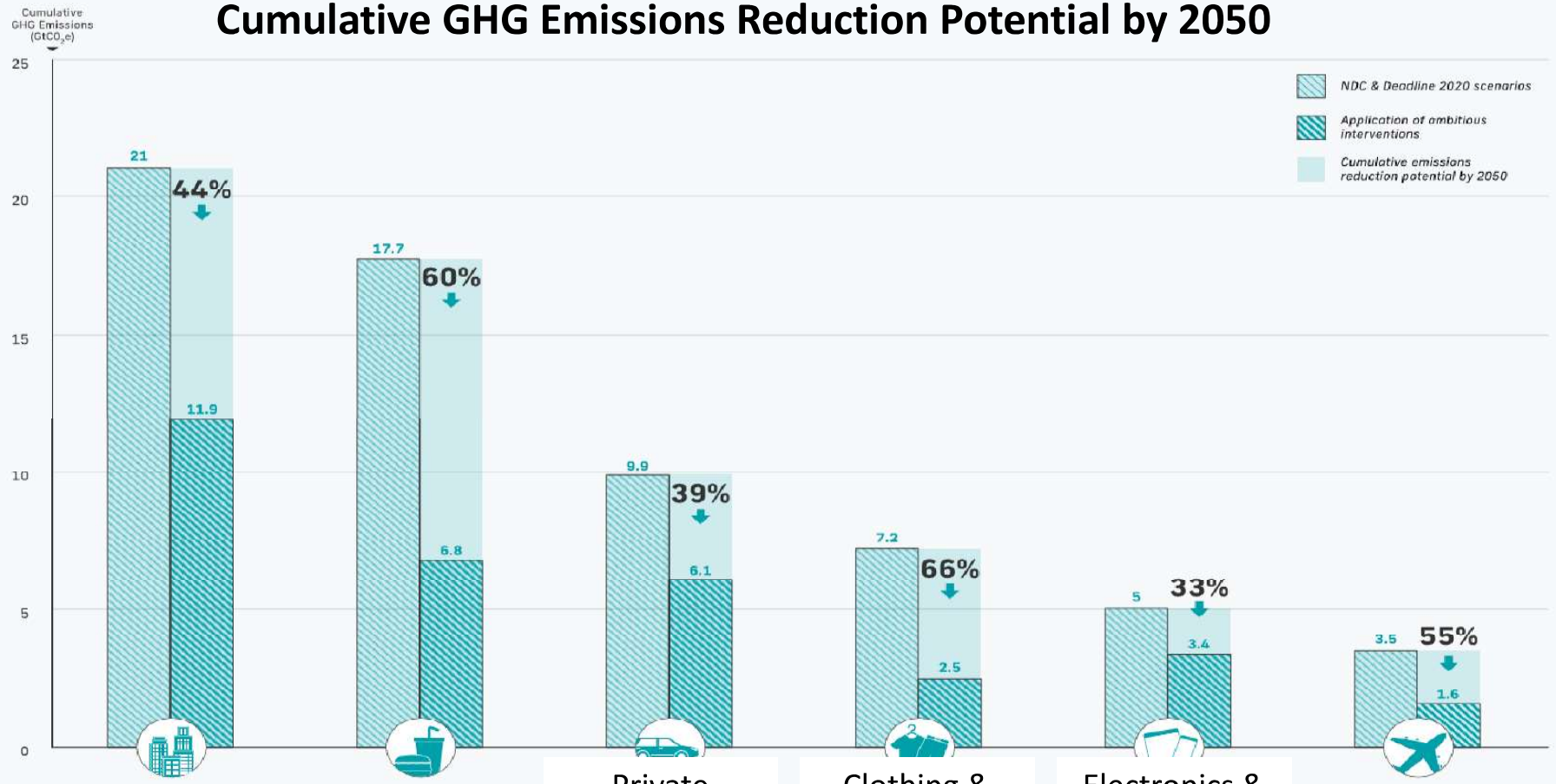
# Cumulative GHG Emissions Reduction Potential by 2050




*Source: Arup report "The Future of Urban Consumption in a 1.5℃ World"*

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- Assume a typical structural/civil engineer is responsible for the design of 5,000 $m^2$ of bridge structure per year
- With an average carbon footprint of 2,000 $kg/m^2$, he/she is responsible for 10,000 tons of CO2 per year
- Achieving 5-10 % reduction in carbon footprint could lead to a saving of 500-1,000 tons of CO2 per year

*Source: Lee Franck & David Knight at Bridges 2020 conference*

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Design and build more efficiently

>500 tons

*Source: Lee Franck & David Knight at Bridges 2020 conference*

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| Material | $kgCO_2e/t$ |
|---|---|
| Concrete (range of strengths and cement replacement) | 50 - 250 |
| Structural steel | 1,550 |
| Steel reinforcement | 1,990 |
| Timber (softwood) | 263 (excl. carbon sequestration) |
| Aluminium | 13,000 |
| Brick | 210 |
| Glass | 1,440 |

Embodied carbon of typical materials

*Source:* ICE Inventory of carbon and energy v3.0 Database

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| Consumption Targets | By 2030 : | Progressive Target | Stretch Target |
|---|---|---|---|
| Material efficiency | Reduce steel use by | 20% | 35% |
| | Reduce cement use by | 32% | 56% |
| Low-carbon cement | Amount of cement replaced with low-carbon alternatives | 50% | 61% |
| Component re-use | Reduction in use of new steel and petrochemical-based materials | 11% | 22% |
| Reduce demand | Reduction in demand for new construction | 10% | 20% |

Suggested consumption targets

*Source: Arup report "The Future of Urban Consumption in a 1.5℃ World"*

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# But is a material-efficient design enough?

Business as usual, even best practice business as usual, is no longer an adequate response.

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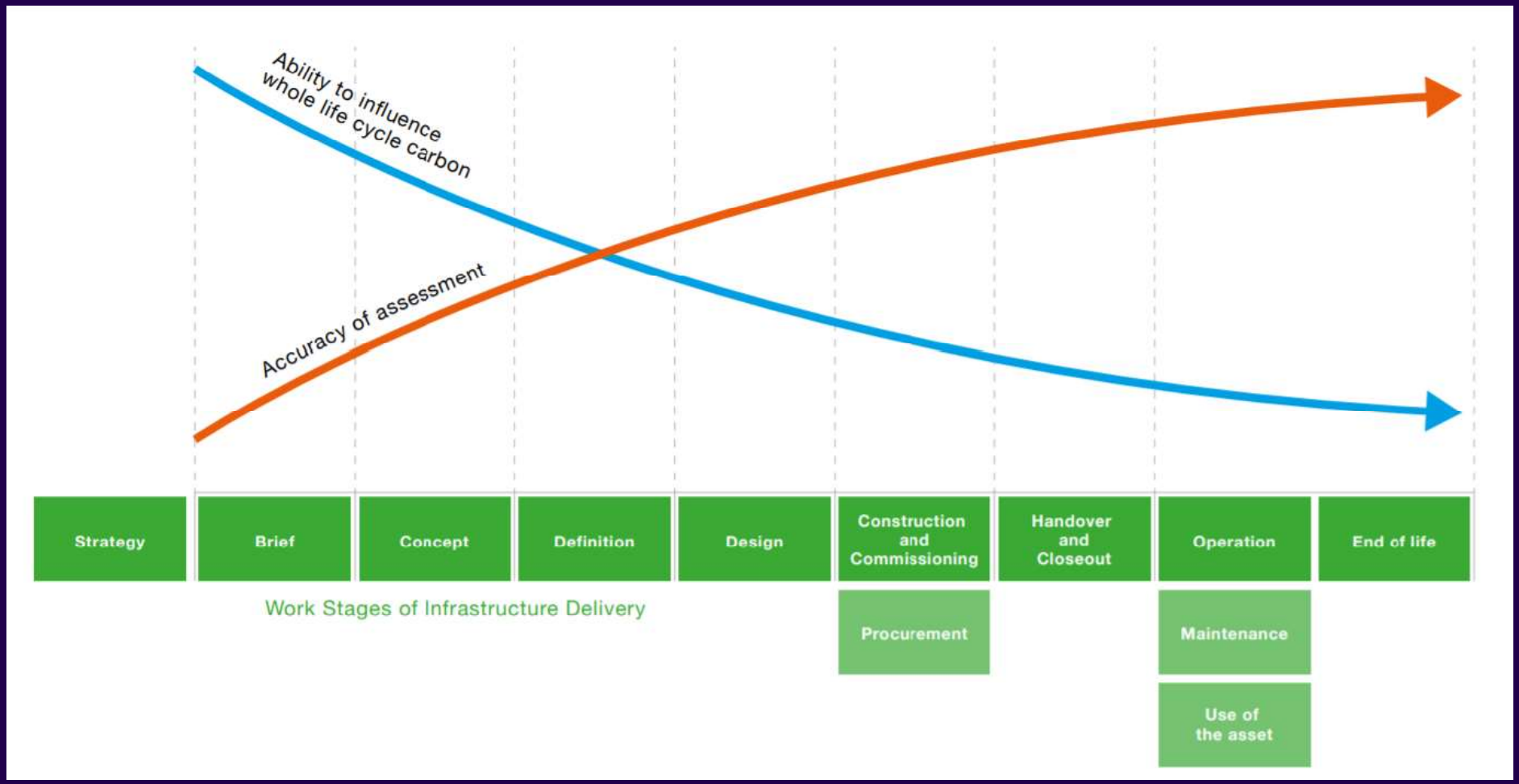


Source:
PAS 2080: Carbon Management in Infrastructure

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**PAS 2080**:2016

# Carbon Management in Infrastructure

Construction Leadership Council

The **Green Construction Board**

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Re-use

Recycle

Reduce

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Refuse

Re-use

Recycle

Reduce

Regenerate

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# Inception

- Does this project need to happen at all?
- How does it fit into a transportation modal shift?
- Instead of building new, can we re-use?
- What are your targets for embodied carbon?
- Can you engage early with the entire design and construction team?

Refuse
Reuse
Recycle
Reduce
Regenerate

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# Concept Design

- Can we use recycled and reused materials?
- Can we make smaller spans?
- Does the deck need to be so wide?
- Can we reduce loading?
- Could we have lower SLS/comfort limits?
- Have we considered lower carbon materials?
- What can we do to make it resilient and durable?
- How can we have a net positive impact on the environment?
- What about renewable energy systems?

Refuse
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Recycle
Reduce
Regenerate

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# Scheme Design

- Have we used embodied carbon as a design tool to evaluate structural options?

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Recycle
Reduce
Regenerate

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# Detailed Design

- Have we optimised our design?
- Have we specified cement replacements?
- Are we using reclaimed steel?
- What about LEDs vs fluorescent lights?
- Have we considered access for future strengthening and adaptability?
- Have we designed for reuse at end of life?

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Recycle
Reduce
Regenerate

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# Construction

- Have we minimised waste?
- Have we minimised transportation?
- Have we minimised energy use in construction?
- Have we documented as-built carbon use?
- Does the as-built information make reuse easy?

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Recycle
Reduce
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# Operation

- Does the maintenance scheme minimise further emissions?

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Recycle
Reduce
Regenerate

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# End of life

- Has extending the life been considered?
- Does demolition allow for maximum reuse?

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Reuse
Recycle
Reduce
Regenerate

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# Typical current model for evaluating project proposals

Tender selection based on

- Quality Design, personnel, experience, management, supervision, programme …..
- Cost $ Including predicted maintenance costs (enlightened clients)

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# Proposed future model for evaluating project proposals

Tender selection based on environmental cost not just financial cost

- Quality
- Cost $
- Carbon content

Maximum permitted thresholds.

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# Future Bridges ?

- 120 year design life?
- 200 year design life?

But we have NO IDEA what we will be designing for or with !

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Flying Car


AIRIS
www.airisaero.com


AIR-ELF
concept aircraft
aluminium alloy frame
baggage compartment
main engine
vice engines
Li-ion Battery
power distribute system
Metal hydride frame
fuel battery
Hydrogen tank
powertrain
air ejector pipe
air-supply line
cooling system



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Future city 2220 ?

Union Chain Bridge, England-Scotland, 1819


19th Century Bridge Loading


*3D printing*


3D printing


Zero Carbon Materials ?
Biofabricated masonry blocks – www.bioMASON.com

# Future Bridges ?

## Cities have a particularly acute problem

- Population growth and creaking public transport systems
- High levels of greenhouse gas emissions

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# Cities have a particularly acute emissions problem

1. Consumption of goods and services within cities is a key factor in global green house gas emissions.
2. Most cities have action plans aimed at cutting emissions produced within their boundaries, but 85% of the emissions associated with goods and services consumed in cities are generated outside the city.
3. To avoid climate breakdown, emissions due to global urban consumption must halve by 2030. This means that major cities must reduce such emissions by two thirds in the next decade.
4. Construction of buildings, bridges and infrastructure is the single biggest contributor to this problem.

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London population (millions) 1800 – 2050 *(source: The Mayor's London Infrastructure Plan)*

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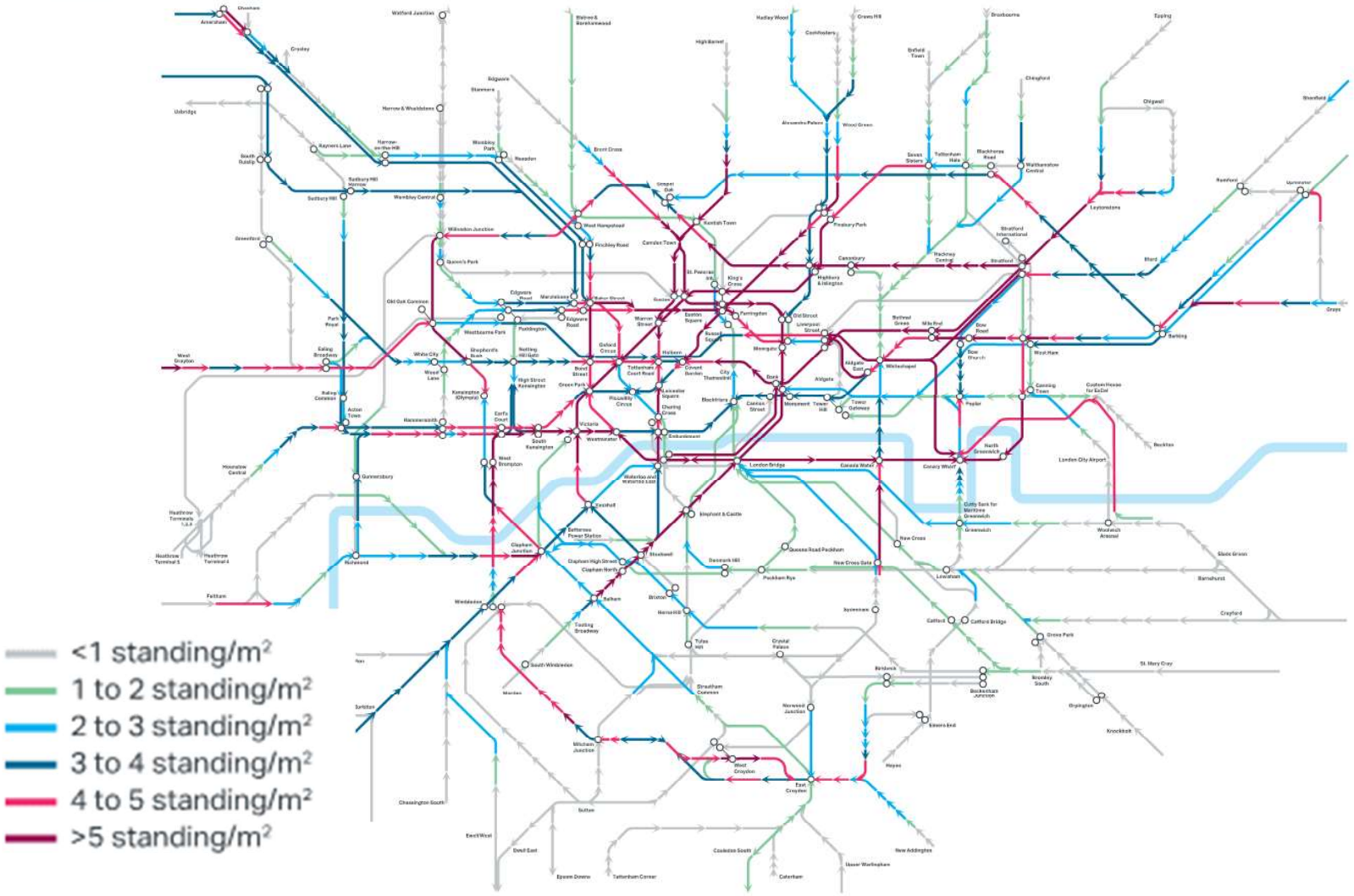
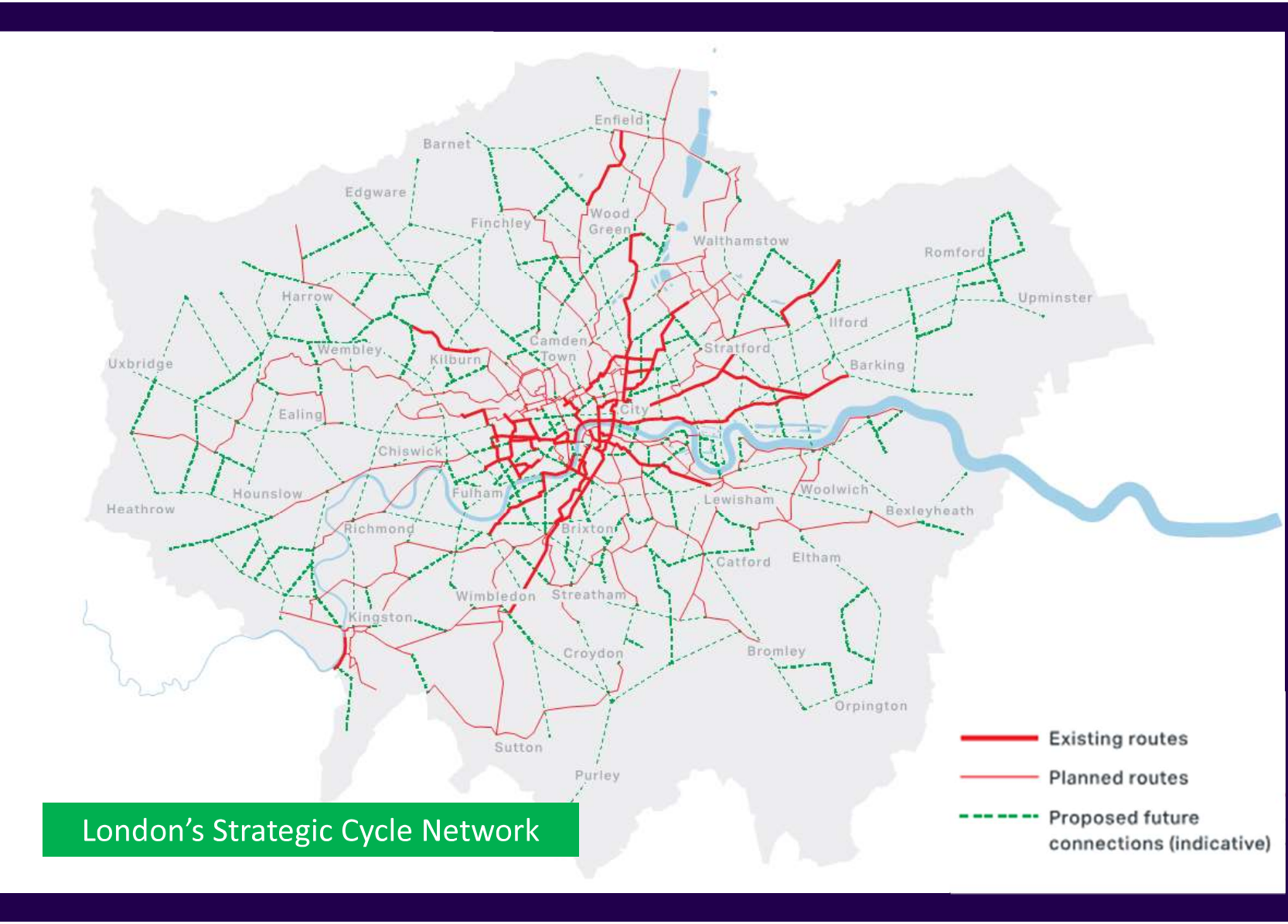
# Crowding on the Rail, Tube, DLR and Tram Network, 2041




London’s Strategic Cycle Network

Nine Elms to Pimlico Cycle Bridge, London *(COWI, Bystrup Architects)*

Rotherhithe to Canary Wharf Bridge *(Knight Architects)*

The “Cycle Snake”, Copenhagen *(source: Dissing+Weitling Architects)*

Inner Harbour Bridge, Copenhagen *(COWI, Hardesty & Hanover, Studio Bednarski)*

Elevated bicycle path, Xiamen, China *(source: Dissing+Weitling Architects)*

# Past and Present Trends

- Light weight – material efficiency
- Off site construction – improves quality, reduces disruption on site, faster construction, greater economy
- BIM – improves collaboration and information control
- Smart structures – built-in sensors for monitoring performance
- Use of drones for inspection
- New materials (and re-discovery of old ones – stone and timber)
- Improving awareness of sustainability – and now particularly the carbon issue

Taplow Footbridge, England (COWI, Knight Architects)

Tintagel Castle Footbridge (Ney and Partners)

Fehrlesteg Footbridge, Germany *(Schlaich Bergermann und Partner)*

Fehrlesteg Footbridge, Germany *(Schlaich Bergermann und Partner)*

GFRP - Halgavor Bridge, Cornwall, 2001. *(COWI, Wilkinson Eyre Architects)*

# Future Trends

- Increase in 3D printed bridges and components
- Mainstream construction by robots and drones
- Adaptable structures
- Integrated AI systems for autonomous vehicle traffic control
- Self-healing materials
- Kinetic pavements and solar highways
- …….???

# To conclude:

1. Change procurement practice (safety, quality, checking, carbon)
2. Measure the carbon content in all projects
3. Adopt a universal philosophy of reduction
4. Regularly review carbon content to track the reduction
5. New (and old*) materials, robotic construction, 3D printing
6. Develop more adaptable and intelligent structures

** Old = stone and timber. Are they experiencing a renaissance?*

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