ARUP

Towards net zero land transport

Introduction

The journey to net zero will deliver dramatic emissions reductions. It will also deliver significant benefits for the transport industry and beyond.

This report uses three lenses to identify the impact different actors can have on transport decarbonisation. It zooms in on ten actions serving as a starting point to accelerate the transition to net zero land transport.

Globally, transport is responsible for roughly one quarter of total carbon emissions[1]. Fuel and electricity powering the movement of people and goods on land account for roughly half of these emissions, while additional carbon is embodied in land transport infrastructure. Collaboration among the many diverse actors in the transport value chain is essential to achieving net zero land transport. This presents a challenge and an opportunity to realise system-wide benefits.

Around the world, roughly 140 countries have committed to, or are agreeing to, net zero targets. This covers close to 90 per cent of total global emissions. Decarbonising transport is imperative to achieve these goals. The lifecycle stages of transport – from material production and infrastructure construction, to use, and then end of life – cut across many sectors. This makes transport decarbonisation a complex task.

Solutions exist in many forms and include reducing carbon embodied in materials, avoiding journeys, shifting to lower carbon modes, lowering energy intensity and reducing the carbon intensity of fuels[2]. In its sixth assessment report, the Intergovernmental Panel on Climate Change (IPCC) adopts the Avoid-Shift-Improve framework to prioritise actions to reduce greenhouse gas emissions. Interventions which reduce the activity causing emissions (avoid) have the greatest long-term potential for social and environmental benefits. Avoiding and shifting travel behaviours to less energy intensive modes can be achieved through policy measures. Improving the efficiency of travel to reduce emissions requires technological interventions.

Role of technology

Technology and policy go hand-in-hand to harness solutions in each of these domains. Technology provides opportunities to reduce the need for travel through online shopping, optimised freight and working from home. New materials and engine technology can reduce the energy intensity of motorised transport. Renewable fuel sources such as electricity and hydrogen, can be used to power vehicles and reduce the carbon intensity of fuel. Such technologies exist and are rapidly becoming more available, widespread and affordable. Many technologies considered as emerging a decade ago have now become mainstream.

Role of policy

The future of transport can deliver a new vision: one in which mobility is sustainable, inclusive and on a scale that lets people interact and prosper safely. Achieving such a vision requires a new approach to delivering infrastructure projects.

Policy can also deliver solutions and ensure benefits beyond mobility are delivered alongside transport decarbonisation. Long-term strategies that integrate transport and land use, can reduce travel distances and make travel by lower carbon modes viable,

1 16.2% of global carbon emissions is attributed to electricity and fuel to power transport. Further emissions are embodied in the use of energy in industry, cement production and waste disposal associated with infrastructure (Ritchie et al. 2020)

2 IPCC and Liu et al. 2022

while also reducing the scale of infrastructure required to facilitate mobility. Transport pricing can also encourage efficient use of road space, for modes with the highest occupancy rates. Procurement policies can prioritise local content to reduce freight mileage. Applying a wider lens and longer timeframe for project appraisal is also important for facilitating long-term planning that can reduce emissions and deliver further benefits spanning health, liveability and inclusion.

Going beyond business as usual

Many solutions already exist. This report highlights some of the policies, infrastructure and technologies adopted globally and applicable in a broader context. However, new approaches are also needed which establish a clear vision for the equitable and sustainable future mobility networks we need. We can 'decide and provide' in planning and designing the infrastructure and policies to bring about these visions.

Going further will drive a more integrated approach across transport modes. This means:

– ensuring we are using the capacity we have effectively and efficiently,

– providing a smooth cross-modal experience that delivers what users want, and encourages the use of cleaner modes,

– sweating our assets and prolonging the life of our infrastructure through improved approaches to operation and maintenance, and

– actively directing and harnessing new business models, such as private micro-mobility providers, to fill gaps in the traditional land transport network to deliver an integrated net zero network.

Going further is also about transport playing a more active role in driving outcomes beyond transport. For example, urban rail offers mobility, but can also shape more compact and lower carbon cities. Transport can also help to create demand and stable long-term offtake for new green energy sources..

A systemic shift

Transport decarbonisation is complex, because it involves actors with differing levels of control over the lifecycle stages of transport infrastructure. Whereas city mayors may influence policies that affect modal choices, they cannot change the carbon embodied in their existing infrastructure. An engineering company delivering new infrastructure may influence emission reduction by designing and selecting materials with the lowest embodied carbon and least resistive road surfaces. Operators of road networks and fleets can ensure that their assets are running efficiently.

Each of these actors may be required to report on emissions associated with different lifecycle stages, or scope 1, 2 or 3 emission boundaries. However, decarbonising to maximise environmental, social and economic benefits may require cross-boundary, multi-actor thinking and collaboration. Thinking in systems can help actors identify their sphere of influence, relative to the appropriate lifecycle stage. Technology and policy solutions associated with each lifecycle stage can then be chosen according to feasibility in different organisational and contextual settings.

This document situates different participants in the transport value chain in relation to:

1. Transport lifecycle
2. Spheres of influence
3. Organisational maturity levels

Thinking systematically and cooperatively can help actors successfully implement solutions with the greatest potential for decarbonisation and wider benefits.

Decarbonisation is driving the transport industry's biggest change in half a century. The scale of the challenge is vast, but so are the potential benefits.

Three lenses for decarbonisation action

To achieve net zero land transport, we need to think about where we can have impact and what interventions are appropriate, and where. This will help us prioritise our efforts and target the right actions, for maximum impact.

1 Transport lifecycle

Targeting appropriate action based on where we are in the transport business or project lifecycle. Action can be taken at each stage, but will be different at each stage.

2 Spheres of influence

Understanding the different scales at which transport players can have impact – from the physical asset itself, to user carbon and beyond, to wider mobility impacts and carbon impacts beyond transport.

3 Organisational maturity levels

Assessing an organisation's maturity level helps to understand what action is truly deliverable, recognising that some actions may sometimes need to wait until the organisation is more mature.

1. Transport lifecycle

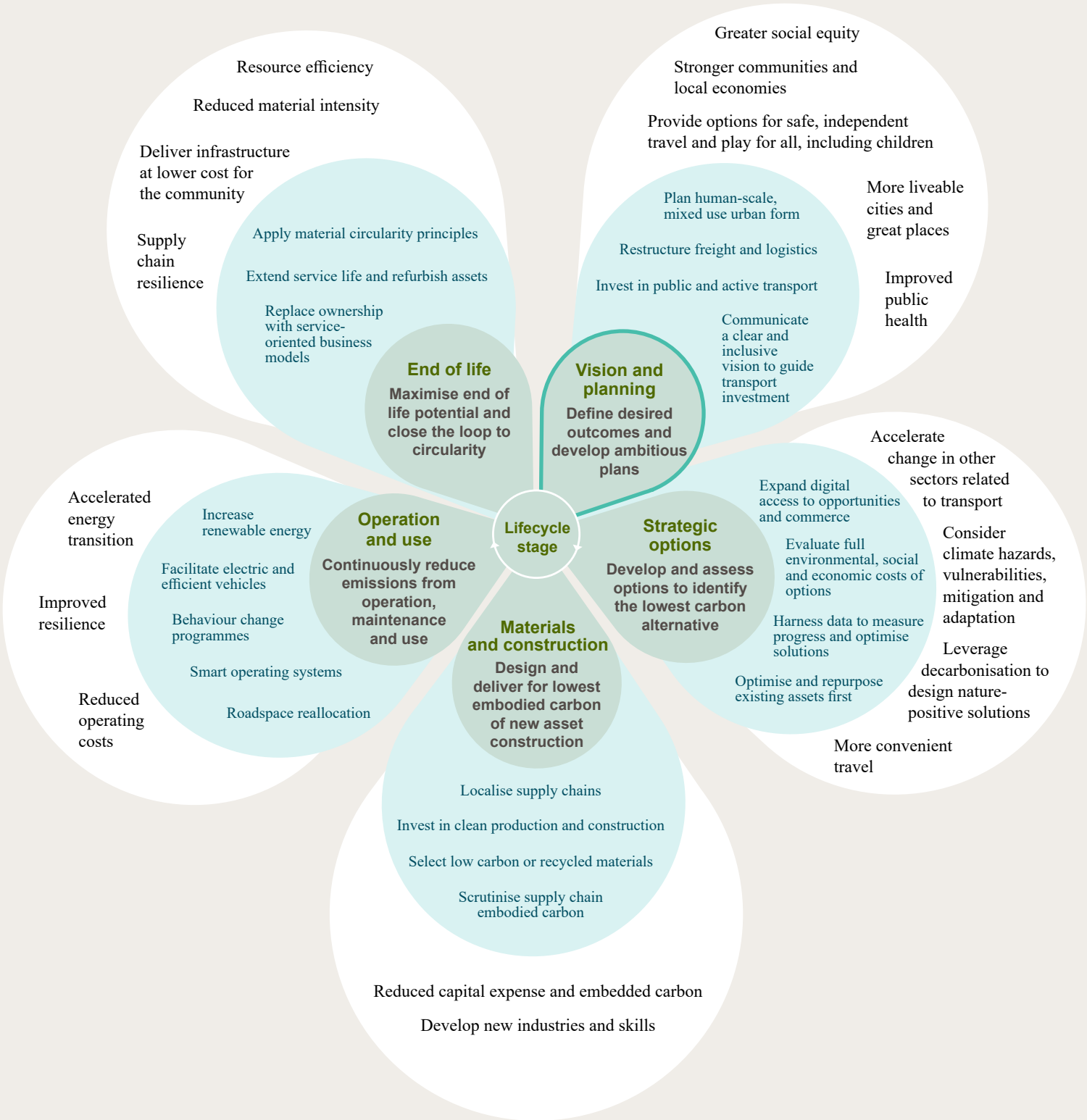
Transport infrastructure projects can be broken into lifecycle stages. This helps map out emissions in the project lifecycle.

Setting a vision for mobility, and then planning and designing to deliver the vision, is a necessary precursor to any new transport asset. It is at this initial lifecycle stage that the overall movement strategy is developed. The greatest potential for avoiding emissions occurs during the vision and planning stage. Reduction then becomes the primary strategy for achieving net zero at later stages in the transport lifecycle.

Other key stages include material production and construction, operation and use, and end of life. These three stages can also be differentiated according to whether carbon is embodied (production and construction, and end of life) or operational (use).

Transport may also enable emissions in sectors other than mobility. It is important to consider these when developing and assessing strategic options.

The figure below illustrates actions that can be taken at each lifecycle stage to reduce emissions. Just as transport may enable emissions beyond mobility, so too can it bring about wider benefits. These wider benefits are illustrated as the outermost layer of the transport lifecycle diagram, and elaborated on the following page.



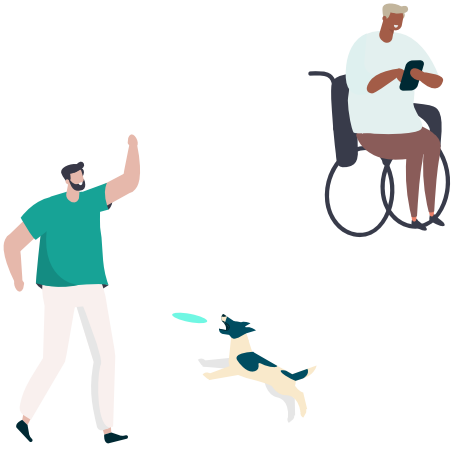
Legend **Lifecycle stage** **Actions towards net zero transport** **Wider benefits beyond transport**

Net zero land transport is about more than just transport.
It influences and is integrated with broader systems, including:

Health: Access is closely related to community health. Planning for a decarbonised transport system offers new possibilities for health, wellbeing and safety outcomes. Examples include improved air quality through decarbonised fleets, improved road safety through redesigned urban infrastructure, reduced disease burden through more active travel and more inclusive places where all groups can benefit from and participate, in community life.

Energy: Renewable sources of energy for fleets and vehicles are essential, to achieve net zero emissions. This includes using battery-electric vehicles or green-hydrogen fuelled options, with hydrogen generated from renewable energy sources such as offshore wind. Transport will need robust green energy supply, and may compete with other industries for these resources.

Equity: Public and active transport ensure those without private vehicles have equitable access to opportunities. Transport network planning and decarbonisation across cities can benefit disadvantaged populations and significantly increase quality of life.



Nature: The transport system plays an important role in establishing a nature-positive, net zero future which restores ecosystems. Transport systems suffer from the worsening effects of climate change, including floods and fires. Infrastructure operators and owners have the opportunity to enhance biodiversity, rethink their role in restoring nature, and use nature to increase resilience to extreme weather events.

Place: Roads and streets function as places in their own right. In many cities, roads and streets make up over three quarters of all public space. Transport interventions impact how people access places in cities, and how they support daily life. Net zero land transport can contribute to quieter, cleaner and more vibrant places that allow children to play, and increase safety for all.

Industry: Transport is fundamental to the movement of goods and people. Net zero transport options create benefits for people and the planet, and are seen as a competitive advantage, as global consumer markets look towards a net zero future. Low-carbon transport networks that enhance the public realm also contribute to local prosperity, by encouraging people to linger and engage with activated retail frontages.

Case study: Singapore

Singapore has established a series of carbon reduction targets and initiatives which can be mapped across the transport lifecycle stages.

Vision and planning

– Target 90 per cent of all peak period journeys to be completed using walk-cycle-ride transport modes by 2040, finished in less than 20 minutes.

– Introducing a carbon tax in 2019. The key strategy for the energy sector is to harness four supply switches, namely:

1. Natural gas
2. Solar
3. Regional power grids
4. Emerging zero-carbon alternatives

Materials and construction

– Implementing Green Mark award scheme – design of transit stations with environmental sustainability focus to cut down carbon footprint (e.g., high standard for energy performance, use of environmentally-friendly materials, seamless connectivity and accessibility).

Operation and use

– Aim to phase out internal combustion engine vehicles by 2040 and have all vehicles running on cleaner energy.

– All new public bus purchases will be cleaner energy buses, including fully electric or hybrid models by 2040.

Beyond transport

– Establishing a Zero Waste Masterplan and Resource Sustainability Act (RSA) to design waste out of the economy.

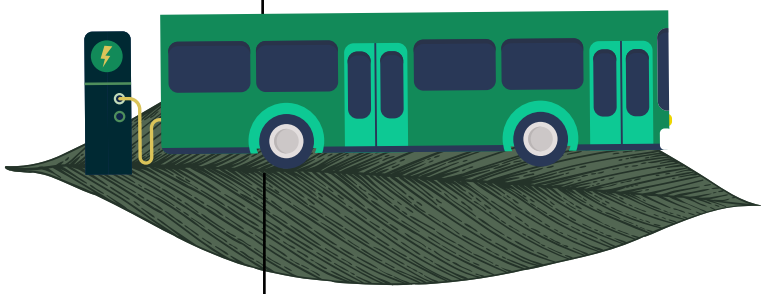
– NEWSand is key to closing Singapore's waste loop. Trials using NEWSand, a material made from municipal solid waste, as a road base or sub-base material in road construction projects.

Facts and figures

Economic cost of air pollution and health damage attributable to PM10

3.95bn

2% of Singapore GDP (SGD)
2019



Emissions from domestic transport

12.9%

Private cars were the largest contributor
2017

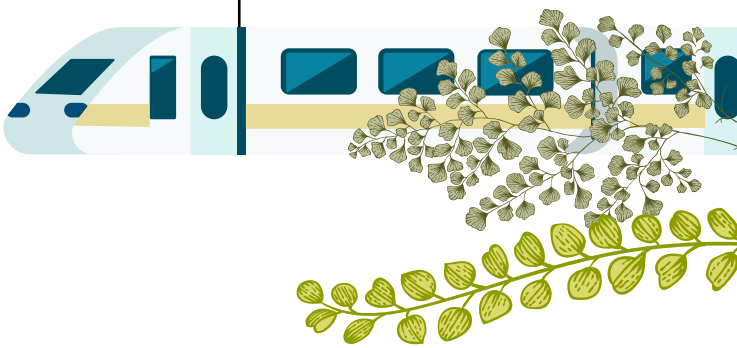
Expanding the rail network

230km

2017 - total length of rail network

360km

2030 - target length of rail network



2. Spheres of influence

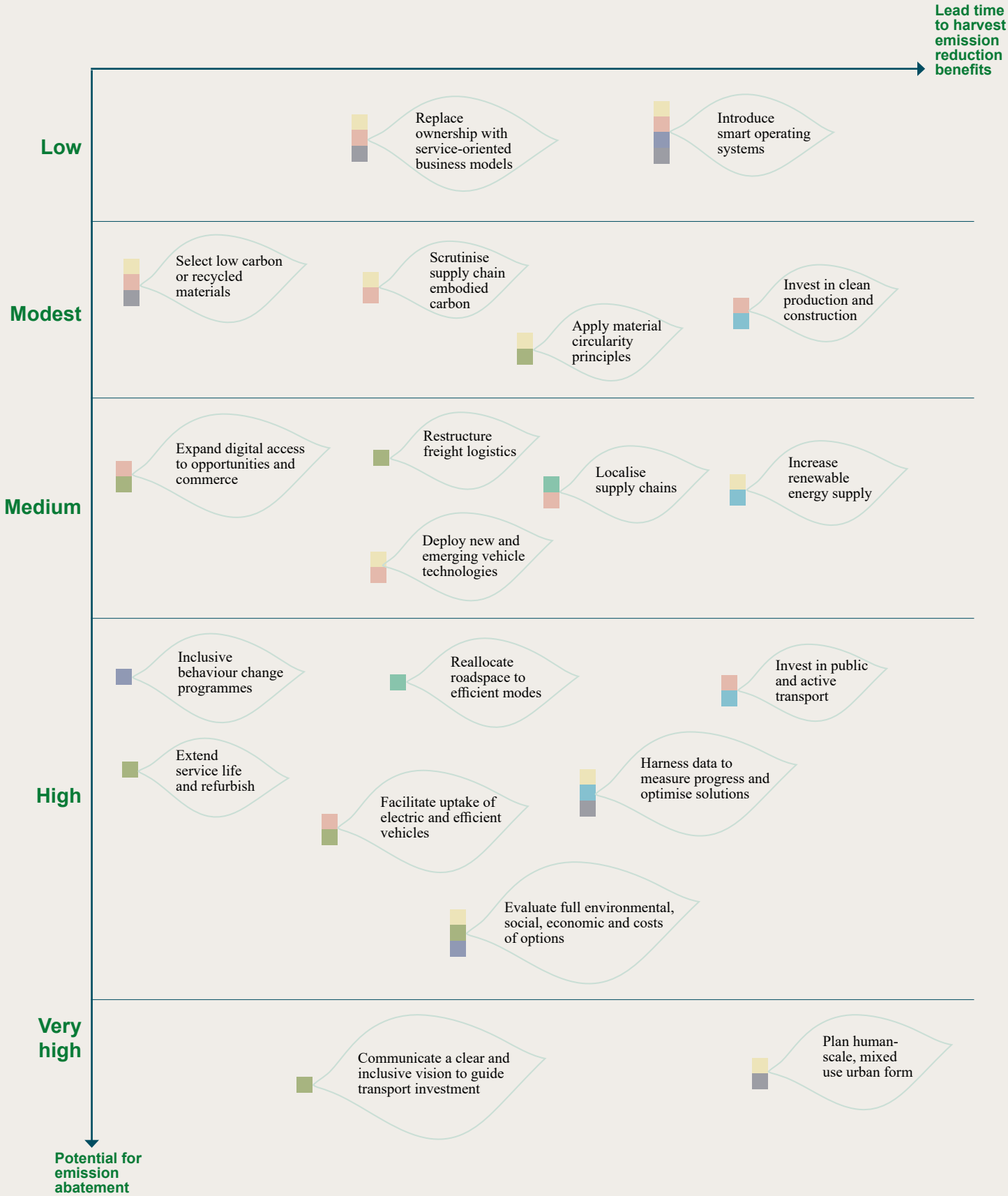
Understanding an organisation or project's spheres of influence is the second step for decarbonisation action and involves indentifying feasible actions. Actors in the transport value chain exert influence over different sets of actions. Some stakeholders' influence may be narrow and relate to a single lifecycle stage. Other participants may have influence that transcends scope boundaries and lifecycle stages. All actors have a role to play, and the cumulative result of targeted action is reduction of carbon across the entire transport project lifecycle. Recognising the extent to which any one organisation can control emissions is key to optimising decarbonisation efforts.

The figure on the facing page illustrates the different actions that can be taken at different transport project lifecycle stages. It also conveys the complexity, in terms of lead time required to achieve emission reduction, of different actions, and potential for emission reduction. Often it is the actions that occur during the vision and planning stage that have the greatest potential to reduce emissions. It is these same actions – such as integration of transport and land use to achieve compact city form that reduces the need for travel – which require the longest lead time to see a reduction in emissions. The influence of six different actors are also conveyed in the figure.

Some actions are relevant for multiple actors, such as public awareness and education for behaviour change and workforce transitions. This demonstrates the potential for collaboration across sectors to increase the effectiveness of actions. Other actions are typically only within the sphere of influence of one actor. For example, government typically conduct long-term vision and planning for cities. Given the complexity of this task, identifying opportunities to involve other actors, who are affected by the downstream impacts of vision and planning, could be a useful way to share the responsibility and arrive at mutually agreeable actions for all in the transport value chain. In this way, the spheres of influence framework can be a tool for mapping control over the transport lifecycle and devising a system-wide strategy for emission reduction. It recognises the contribution of all actors while also empowering individual participants to take action, in the context of a wider, coordinated effort.

The spheres of influence framework is based on a whole-of-systems approach that incorporates physical assets, travel behaviour, urban form and other systems to holistically consider the transport lifecycle.

Balancing complexity and impact through spheres of influence

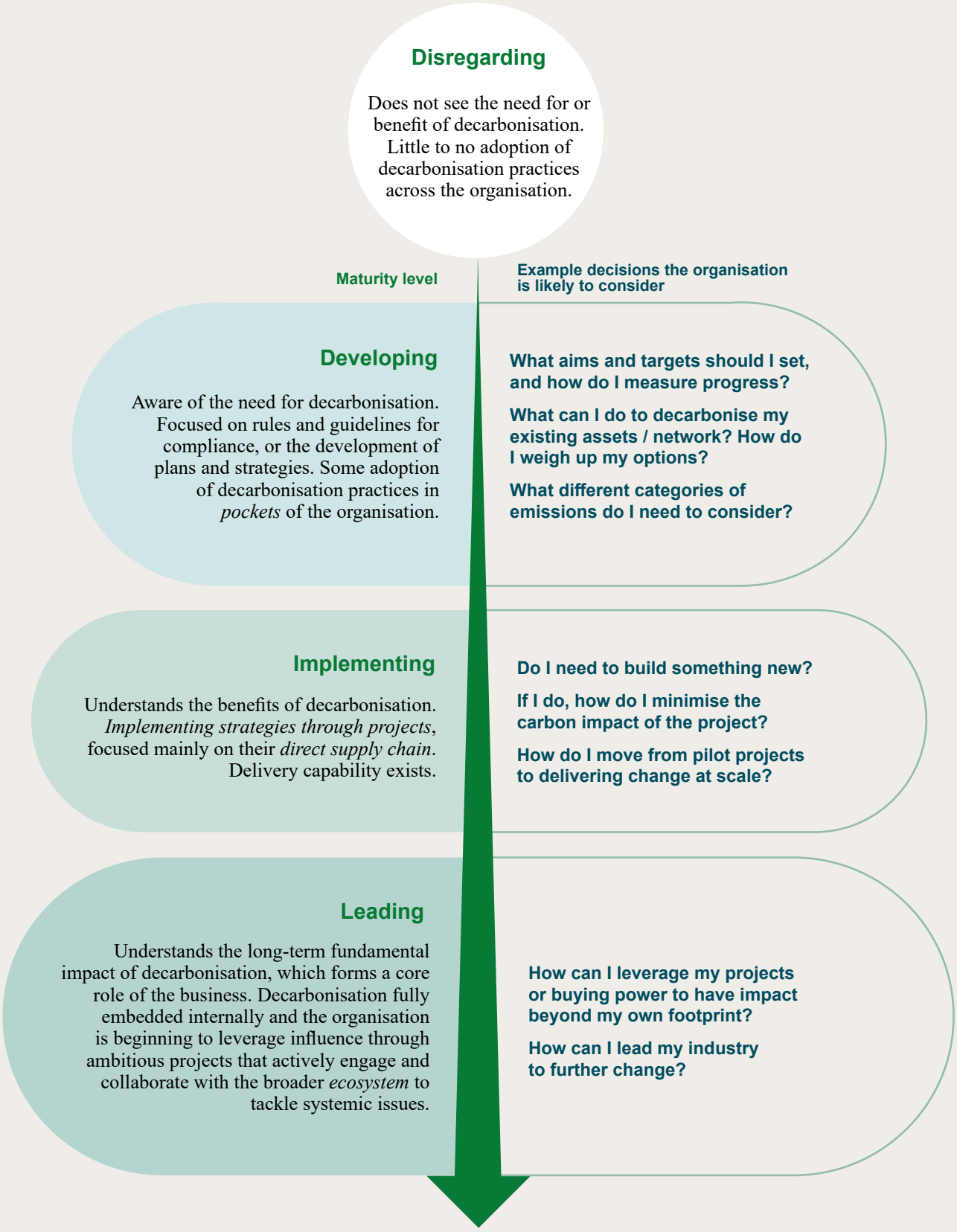


Legend

Actors Elected officials · Planners · Transport operators · Construction / engineering companies · Energy sector · Freight companies · Public

3. Organisational maturity levels

As a third lens on decarbonisation, we must consider organisational maturity at each stage of the decarbonisation journey. We have developed organisational maturity levels to illustrate this, and to support organisations in understanding their level of ambition and capability in each phase.



Case studies

Case studies

SEStran Strategic Network, Scotland

Creating a healthy, connected and sustainable Scotland

The Southeast of Scotland Transport Partnership (SEStran) Strategic Network is a comprehensive plan to create a region-wide walking and cycling network. We determined the optimal network for high-quality active travel routes within the SEStran region.
This network will ensure Southeast Scotland is well connected, healthy and ready for a more sustainable and environmentally sound future. Estimates show the project will result in a 7,000-tonne annual reduction in CO_2 emissions.

Stage of lifecycle
Vision and planning

Action	Invest in quality active transport infrastructure to encourage mode shift to low carbon transport
Wider benefits	Improved health outcomes through mode shift to active transport More inclusive mobility options Place and economic activation on strategic active transport links

Transport Decarbonisation Advice, Wales

Quantifying the carbon gap to drive ambition

In partnership with Transport for Quality of Life, we worked with the Welsh Government to provide advice on decarbonising the transport sector through modal shift to active travel and public transport, increased remote working and road user charging. This involved quantifying the carbon gap between current policy commitments and the level of intervention required to meet Wales' carbon budgets. The emissions reductions achievable through different interventions, the cost of abatement and cost effectiveness of these, were also analysed.

Stage of lifecycle
Strategic options

Action

Assess baseline carbon
Set clear and measurable targets
Decide and provide when planning transport

Wider benefits

Reduced capital expense and embedded carbon
More convenient travel options
Increase in liveable cities and great places

Cityringen Metro, Denmark

Copenhagen's environmentally-friendly mass rapid transit

Copenhagen is one of the most densely populated areas of Denmark. The new metro expands the city's existing system and is a key part of the city's drive to become carbon neutral by 2025. We led the architectural design, taking a user-centric approach and using intuitive minimalism every step of the way. The new line seeks to encourage residents out of their car and onto a more environmentally-friendly mass transit network.

Stage of lifecycle
Strategic options

Actions	Minimise station footprint to reduce emissions associated with materials and demolition Invest in quality public transport to encourage mode shift to low carbon transport
Wider benefits	Inclusive wayfinding for all users Improved health outcomes through mode shift to active and public transport

Next-generation Mobility Pricing, London, United Kingdom

Informing road use and mobility for London

In February 2003, London introduced congestion charging zones. We supported the Centre for London think tank to investigate London's next-generation road pricing. Working with leaders and the community, we helped guide the direction and principles of road pricing in the city. The result was a constructive and progressive discussion about the future of road use and mobility in London, to inform road pricing. This has now evolved to higher charges, low emissions zones (LEZ) and ultra-low emissions zones (ULEZ).

Stage of lifecycle
Strategic options

Action	Use transport pricing to incentivise the use of low carbon alternatives
Wider benefits	Establishes a precedent for pricing carbon impacts; that may serve to accelerate change in other sectors Improved health outcomes through mode shift to active transport Creation of more people-centred and attractive places Improve air quality and health Place and economic activation through land use integration with transport

Electric Vehicle Infrastructure, Indonesia

Enabling Indonesia's EV ecosystem

Indonesia has developed an electric vehicle policy and regulatory framework to help the country achieve its sustainability and decarbonisation agenda. However, Indonesia faces key challenges across its emerging EV ecosystem, including capacity development and complex power grid challenges. We undertook a study and identified three enablers to support this ecosystem, including accelerating partnerships, a strong holistic framework and skills and capacity development.

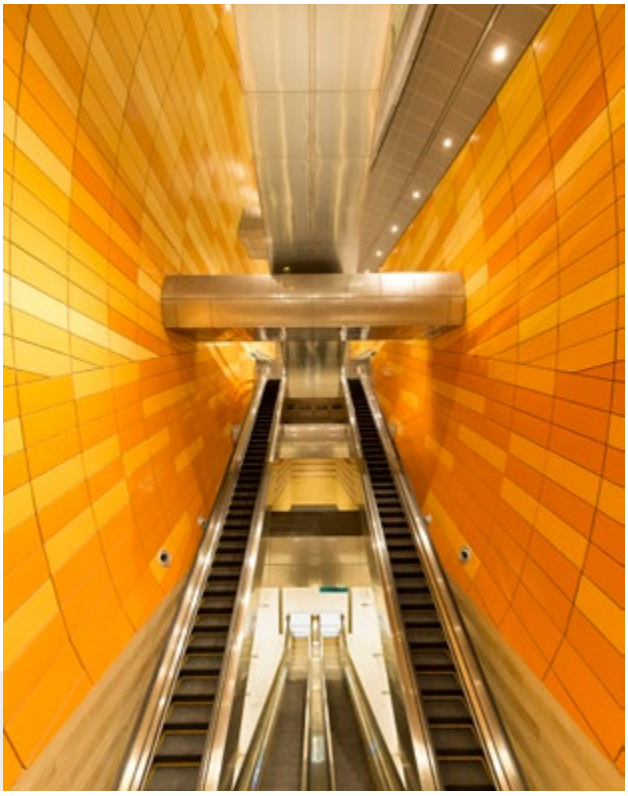
Stage of lifecycle
Operation and use

Action	Facilitate electric vehicle uptake to reduce tailpipe emissions
Wider benefits	Reduce vehicle running costs Improve air quality and health Reduce reliance on fossil fuels Quieter, more attractive places

Bencoolen Street and Bencoolen Station, Singapore

Inclusive transport system for Singapore

Singapore is delivering a world-leading sustainable transport system based on convenient and well-connected public transport and active mobility. We envisioned Bencoolen Street and Station into Singapore's first public transport and active mobility priority streets. This work is facilitating a modal shift to non-motorised transport and safeguarding heritage from private vehicles. This project is helping Singapore create a more inclusive transport system, as well as a healthier population and environment.



Stage of lifecycle
Operation and use

Action	Reallocate space to make roads more attractive for low carbon transport users
Wider benefits	Improved safety outcomes for active transport road users Improved health outcomes through mode shift to active transport Creation of more people-centred and attractive places Improve air quality and health

Circular Economy Plan, Transport Infrastructure Ireland

Closing the loop on Ireland's sustainable transport roadmap

Circular design of infrastructure, asset procurement and management, are two key components of Transport Infrastructure Ireland's (TII)'s holistic approach to reduce transport emissions. We mapped material flows and project processes across TII, to set the baseline for implementation of circular principles and identify key actions for reduction of material input and emissions. Pilot projects included the implementation of circular economy plans for the Luas Green Line light rail, Dublin; and the N4 Carrick-on-Shannon to Dromond Highway, as well as the incentivisation of reduction and reuse of pavement materials as part of an analytical pavement tool.

Stage of lifecycle
End of life

Action

Apply material circularity principles
Select low carbon or recycled materials
Scrutinise supply chain embodied carbon
Invest in clean production

Wider benefits

Resource efficiency and infrastructure delivery at lower cost for the community

Actions for impact

Decarbonising land transport requires system-wide change. Both technology and policy are critical to create this change. How can any organisation effect change, irrespective of their sphere of influence and maturity level?

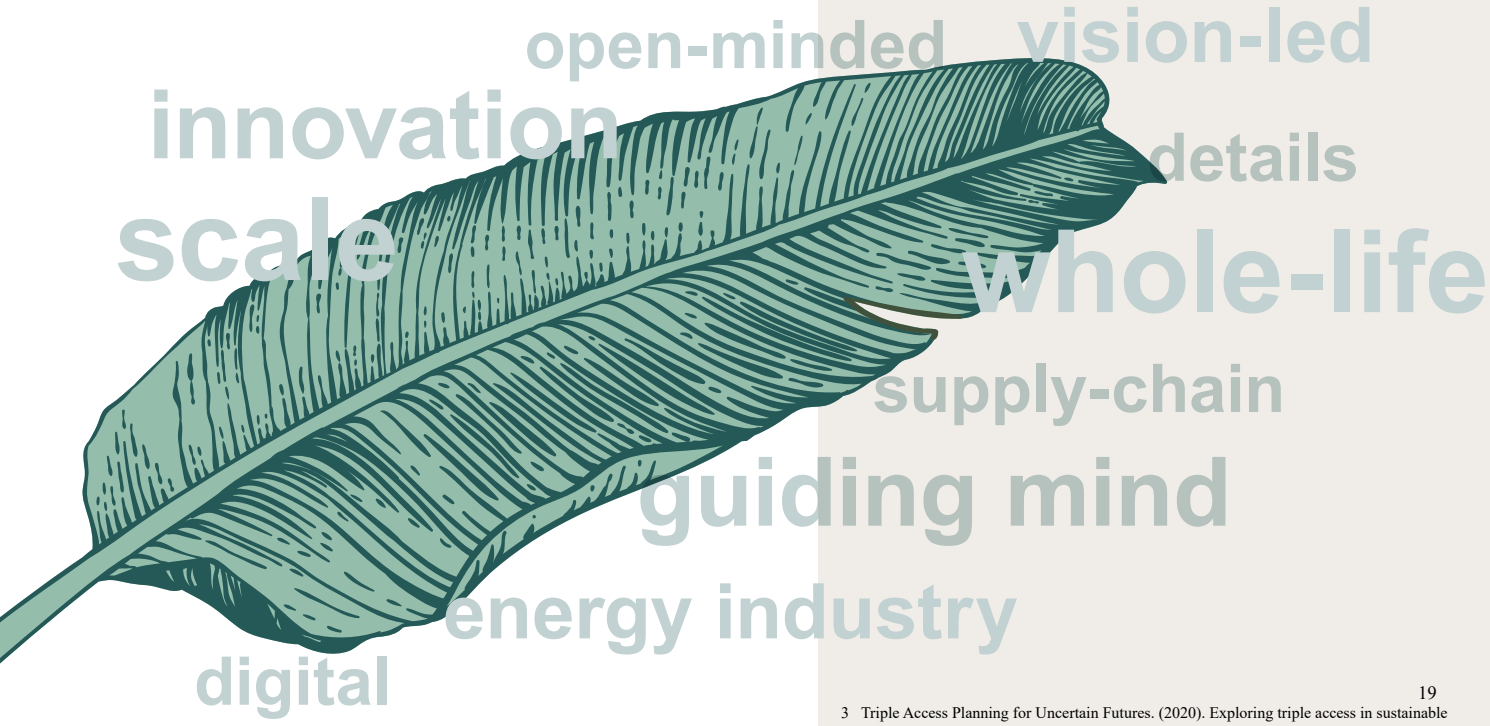
These ten actions can be taken now and will accelerate society's shift along the maturity curve toward system-wide decarbonisation.

1. Envision the mobility future we want

What do we want the future of mobility to be? This question helps us see the potential for transport to improve quality of life for all. Deciding first what future we want encourages out-of-the-box thinking to provide the policy, technology and infrastructure to deliver it. At every stage of a project, we can be guided by this vision.

2. Collaborate

The transport solutions of the future need to leverage synergies across disciplines from energy and technology, to industrial reform and education. Cross-disciplinary teams and partnerships can break down the traditional barriers to adopting new solutions. Standardisation of clean vehicle technology, is a key area of opportunity. Integrated planning that yields solutions to provide access, while considering mobility, proximity, and technology, and reducing the embodied and enabled carbond associated with traditonal transport systems[3].



3 Triple Access Planning for Uncertain Futures. (2020). Exploring triple access in sustainable urban mobility planning. Retrieved from Triple Access Planning for Uncertain Futures: https://www.tapforuncertainty.eu/

3. Design for people

Projects that are engagement and behaviour-led can bring about the most effective solutions because they are designed with and for their prospective users. It is also important to find ways to develop empathy with diverse potential users and impacted parties. Doing so can help build the social license for unfamiliar solutions.

4. Redefine 'good'

The benefits of sustainability in transport go beyond traditional metrics of transport system performance. It is important to account for the health, liveability, sustainability, safety and equity benefits of all transport proposals. Carbon assessments should be a routine consideration in the appraisal of alternatives, to give realistic information about the climate change impact of embodied and enabled carbon. Strategic options should be evaluated based on these holistic benefits (or costs).

5. Explore new financing arrangements

Public, private and community partnerships should be leveraged to innovate new solutions that deliver returns to the community they are designed for. Trialling and integrating solutions based on such partnerships is a great way to gather data and tailor solutions for maximum benefit. Green and social impact bonds are increasingly being used to finance transport infrastructure, the benefits of which go beyond traditional cost-benefit measures of value.

6. Deploy cleaner technologies

Many of the solutions needed to decarbonise transport are already available and ready to deploy immediately. Alternative powertrains and fuels (electricity and hydrogen), and their associated infrastructure, are available for deployment. Transitioning government and operational fleets can bring down the cost of such technologies and accelerate widespread adoption. Providing incentives and subsidy for cleaner technologies can also assist in accelerating their adoption.

7. Reevaluate supply chains

Buyers and manufacturers of transport vehicles and infrastructure can assess the embodied energy of their supply chain. Lower embodied carbon alternatives, including recycled or more local content, may be ready to deploy. Setting targets for sustainable content can create the incentives needed to drive research and innovation in new, low-carbon inputs.

8. Manage demand

Facilitate the most efficient use of existing transport network capacity. This includes shifting people to space-efficient modes of transport and reducing the need to travel. Modeshift to active and public transport can be encouraged in diverse ways by different actors, including implementing policy incentives, service innovation by operators and road-space reallocation in the design and operation of transport networks.

9. Embrace digital connectivity

Digital technology can be leveraged to reduce the impact of transport in many ways. Delivery services and online working can replace certain trips. Integrated payment and journey planning applications can provide seamless access to shared mobility options that reduce the need for the operation of privately owned automobiles. When used appropriately, the information collected from these applications can be used to prioritise investment in sustainable transport, and improve the experience for users in a virtuous cycle that encourages adoption.

10. Reduce embodied carbon

Reduce material inputs and waste and maximise the useful life of transport infrastructure. Governments can work with academics and suppliers to explore circular design options that facilitate ease of repair and replacement, disassembly, modular design. For existing assets, explore ways to recover, reuse and repurpose materials such as batteries.

By being open-minded and working in a truly integrated way, transport leaders can rapidly reduce emissions and catalyse decarbonisation in a wider arena, including energy and urban systems.

Towards a net zero land transport system

The decarbonisation challenge can sometimes seem overwhelming, but it represents opportunities for transformational change across the transport industry. Whether an organisation is leading in this space or just starting on the journey, everyone has a role to play. By understanding transport's different spheres of influence, and actions we can take at each stage in the transport lifecycle, we can effect change.

Learning from the experience of others within and outside the transport industry is key. By focusing on scaling up what we already have, demanding further innovation, and deepening collaboration, we can have a tremendous impact on emissions. Transport can and will be a leading light in our global target for net zero.

Credits:
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Arup and sustainable transport

What if nature could veto transport planning decisions?

Delivering net zero emissions transport – climate change

Our pathway through net zero | Reduce, restore, remove: a call to action

Three steps for accelerating decarbonisation of road transport

Designing the fifteen minute neighbourhood

Getting rail ready for a net zero world

Arup Future – Ideas for a sustainable world

The electric vehicle revolution: why it's already time to invest in the grid

What are nature-based solutions?

What is green finance?

What is a just transition?

What is climate resilience?

What is the circular economy?

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