

Mitigation, adaptation and scenario planning for the development of an 'anti-fragile' transport system

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BACKGROUND

In the context of the Covid-19 global pandemic, the 'new normal' has become a widespread term used to help frame the predictions on how our post-pandemic future would look like. We like to believe that we will be returning to a 'normal' or a 'status quo'. However, as [Flyvberg \(2020\)](#) argues, we might be facing an era in which the highly interconnected global system that we have created will make rare 'black swan' events our 'new normal'.

Although we might not be able to predict them all, we can anticipate a significant number of extreme events to be associated to climate change. There is scientific consensus that human action has influenced our current climate and that this, in turn, is affecting every inhabited region through an increase in frequency and intensity of extreme weather events ([IPCC, 2021](#)). Whilst assessing different future-emissions scenarios, the IPCC report suggests that even if we meet the most ambitious net zero targets, we can still expect global temperatures to continue increasing until 2050 as a result of past human-action. This shows that global interconnectedness has also strengthened between human and natural systems and that therefore, the strategy we take to address climate change must be an integrated one, which goes beyond narrow mono-angular approaches.

We must continue mitigating emissions and striving for net zero, but we must also adapt. We must

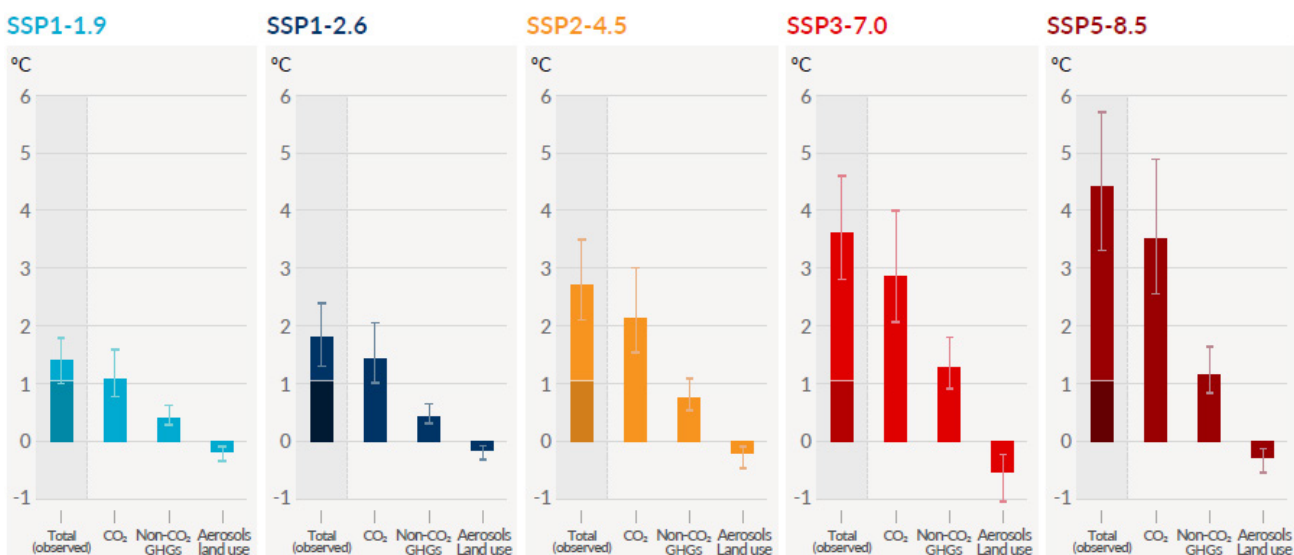
be able to coordinate our immediate responses to shocks with long-term strategizing for the achievement of wider societal goals.

This research aims to provide one way of breaking-down the complexity of the challenge by exploring a number of future scenarios and their implications for transport planners. The development of these scenarios has been informed by a review of governance systems and responses to disruptive events taken within the UK and Peru. These have been taken as contrasting case studies that can help illustrate lessons from a spectrum of approaches and lead to the development of more diverse scenarios. Ultimately, this is expected to challenge the strategies that transport planners could take as we pursue wider objectives within the context of a 'climate changing' world.

Although this paper seeks to explore contrasting scenarios and potential actions, it is by no means expected to provide an exhaustive investigation of all plausible futures. In recognition of the high complexity and uncertainty surrounding the future of transport, this aims to serve as one example of exploratory work focusing mainly on transport governance and responses to shocks. Further work considering other variables for scenario-planning is highly encouraged to help the profession develop the resilience needed to operate within a context of uncertainty.

Figure 1: Increase in global temperatures across scenarios as a result of past emissions. Source: IPCC (2021)

Change in global surface temperature in 2081-2100 relative to 1850-1900 (°C)



Total warming (observed warming to date in darker shade), warming from CO₂, warming from non-CO₂ GHGs and cooling from changes in aerosols and land use

METHODOLOGY

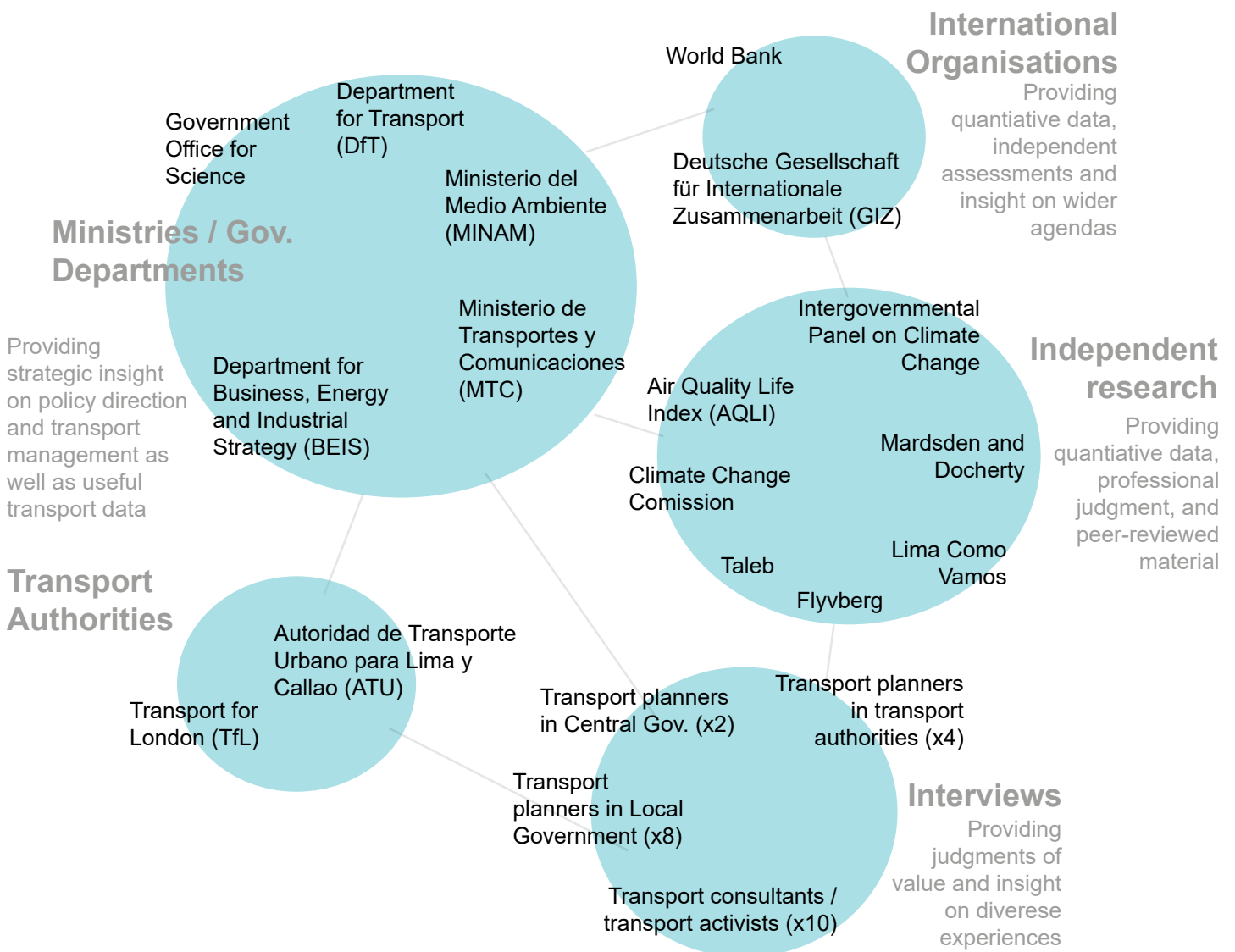
To build the scenarios and suggested actions, this research reviewed institutionalised forms of governance influencing transport systems in major and intermediate cities in the UK and Peru and their evolution throughout the pandemic. It must be stressed that the focus of this paper is purely on the factors and dynamics influencing urban responses, as these areas are most likely to experience challenges inherent to high system interconnectivity. Further investigation is needed and encouraged to understand implications for rural areas which will present a set of equally significant but different challenges.

The review sought to develop a robust analysis by using diverse data sources which could illustrate narratives and case studies at different levels. The list of resources used and the rationale for choosing

them can be seen at Figure 2. Overall, these included a mix of openly available transport data, official government reports and strategies, reports from independent organisations, research papers, and interviews conducted independently to cross-test the data and assumptions. More information on the approach for the interviews can be found at the [Appendix](#). The analysis was also complemented by concepts from risk management literature.

The review is presented thematically to help visualize how this has been used to inform the development and recommendations for the four future scenarios which share the baseline assumption of a 'climate-changing world' where extreme events are the new normal. More information on the steps taken for the development of the scenarios is included on [Section IV](#).

Figure 2: Ensuring a diversity of insight. Source ecosystem.



ANALYSIS

Governance approaches

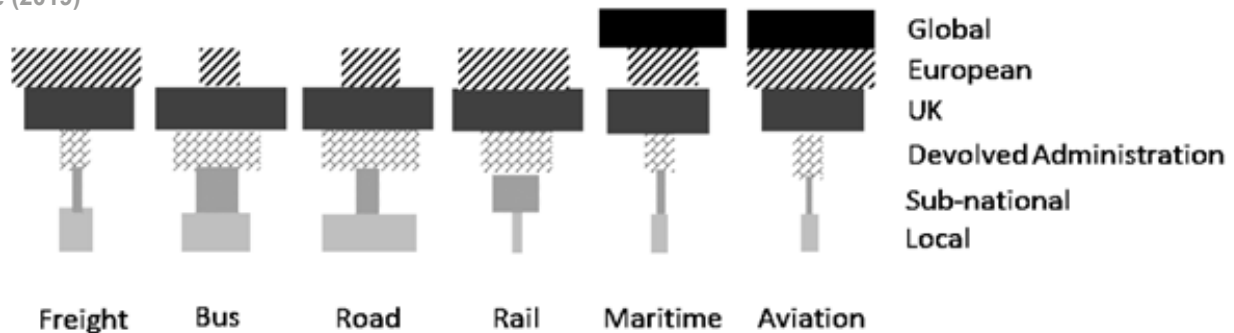
[The Governance of UK Transport Infrastructures \(2019\)](#) report explores the different governance networks underpinning transport operations in the UK, exposing its variations across modes and between devolved administrations. As Figure 3 suggests, this has become a complex multi-layered system which is mostly influenced by global and national tiers rather than the local.

When compared to the UK, transport governance and operations in Peru are much more devolved. This is the product of market reforms that occurred

in the 90s, as well as a historical lack of data, understanding and even recognition of evolving territorial dynamics, which have led to different actors stepping in to fill public sector gaps ([MTC, 2019](#)).

It must be noted that in both countries, the level of influence for managing their complex transport networks is in constant evolution as shaped by changing political agendas. For example, lately in the UK we are seeing higher interest in local devolution whilst in Peru there are efforts at conducting a transport reform which would see further integration under central strategies.

Figure 3: Relative Influence of Different Scales of Government Across Modes. Source: Government Office for Science (2019)



Responses to the pandemic

The real value of transport

COVID has had a huge influence in transport planning as practitioners and government sought to respond to evolving travel behaviours. A summary of actions taken by the UK government can be seen in Table 1, extracted from [Marsden and Docherty \(2021\)](#).

As shown, these included several rescue packages which were made available to transport providers to keep essential services running despite the fall in ridership and constrained ability to generate income ([DfT, 2020](#)).

Similar measures were taken in Peru after operators increased fares or filed for bankruptcy. In recognition of the key role that transport networks play during emergencies and to avoid

further consequences to vulnerable households, the Government started subsidies for transport providers upon the condition that they share their general vehicle information and data on routes, and schedules ([MTC, 2020](#)). For a system where there is free access to urban and interurban routes and where any natural or juridic person can provide a transport service with the only condition of not transporting people in trucks or two wheelers ([MTC, 2019](#)), this meant a step-change for mapping the different transport operations taking place across the country. Furthermore, it also meant that imagining alternative transport models and ways of working was possible.

“People were in awe. They couldn’t believe there was an alternative way to a transport system which run purely based on profitability”

Interviewee account (Transport consultant at transport authority)

Table 1: Timeline of key transport related policy changes March - December 2020. Source: Mardsen and Docherty (2020)

Date	Action	Source
18th March	Government announces first phase of social distancing: schools closed, avoid gatherings and non essential travel self isolate if ill or vulnerable	https://www.gov.uk/government/speeches/pm-statement-on-coronavirus-18-march-2020
23rd March	Government announces lock down-shelter in place, no gatherings, leave home only for basic necessities, medical care, solo exercise or to work if absolutely necessary	https://www.gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-23-march-2020
23rd March	Rail Emergency Management Arrangements put in place with all cost risk taken by Government. Train Operating Companies receive maximum 2% fee	https://www.gov.uk/government/speeches/rail-emergency-measures-during-the-covid-19-pandemic
3rd April	£167 m bus rescue package announced to fund running of 50% of all services on top of £200 m of payments that would have been due normally and £30 m top up funds for new essential services. Services to run with no net profit.	https://www.gov.uk/government/news/almost-400-million-to-keep-englands-buses-running
April to May	Transport Scotland confirms with operators the re-allocation of Bus Service Operators Grant and Concessionary Fares Support for operators with obligation to deliver 25-35% of services.	https://www.transport.gov.scot/public-transport/buses/covid-19-support-grant/
28th April	£10 m Spaces for People Fund announced for Scotland for accelerating walking, cycling and disabled access	https://www.sustrans.org.uk/our-blog/projects/2020/scotland/spaces-for-people-making-essential-travel-and-exercise-safer-during-coronavirus/
9th May	£2bn fund for walking and cycling over 5 years announced including £250 m to be spent on emergency active travel measures	https://www.gov.uk/government/news/extraordinary-funding-and-financing-agreement-on-coronavirus-covid-19-9-may-2020
14th May	Transport for London receives £1.6bn emergency funding, including a £500 m loan and a commitment to increase bus and underground fares 1% above inflation and limits to concessionary fare users	http://content.tfl.gov.uk/extraordinary-funding-and-financing-agreement-t-may-2020.pdf
26th May	A further £20 m announced for Scottish Spaces for People Fund	https://www.transport.gov.scot/coronavirus-covid-19/transport-transit-on-plan/adapting-our-transport-systems/
29th May	£254 m more bus funding announced for a further 12 weeks	https://www.gov.uk/government/news/almost-400-million-to-keep-englands-buses-running
29th May	Tranche 1 Emergency Active Travel Fund allocations announced for urgent schemes including pop up infrastructure (£42 m)	https://www.gov.uk/government/publications/emergency-active-travel-fund-local-transport-authority-allocations
15th June	Wearing of face masks on public transport compulsory with limited exemptions (e.g. young children)	https://www.bbc.co.uk/news/uk-53045386
19th June	COVID-19 Support Grant - Restart (CSG-R) launched in Scotland to support additional services with £191.3 m being announced in phases (June, August, October, December) through to March 2021	https://www.transport.gov.scot/public-transport/buses/covid-19-support-grant/
26th June	Review of 2 m social distancing guidance to allow spacing of 1 m minimum where 2 m is not practicable such as on public transport	https://www.gov.uk/government/news/pm-announces-easing-of-lockdown-restrictions-23-june-2020
30th June	Launch of e-scooter trial rules in England by Department for Transport	https://www.gov.uk/government/publications/e-scooter-trials-guidance-for-local-areas-and-rental-operators
7th July	£9 m in emergency funding for Glasgow Subway and Edinburgh Tram to end of September, extended in September and December to total £21 m through to March 2021	https://www.transport.gov.scot/news/emergency-support-for-glasgow-subway-and-edinburgh-trams/
27th July	Launch of Department for Transport Gear Change strategy	https://www.gov.uk/government/publications/cycling-and-walking-plan-for-england
8th August	Bus services outside London receive up to £218.4 million of support over eight weeks, with further rolling funding at up to £27.3 million per week afterwards. Tram services received up to £37.4 million over 12 weeks with funding to be reviewed at the end of the period.	https://www.gov.uk/government/news/government-extends-coronavirus-support-for-buses-and-trams-total-funding-tops-700-million
21st September	Emergency Recovery Measures Agreements (ERMAs) introduced for rail for up to 18 months. At the end of the agreements current franchises will expire. Management fees capped at 1.5%	https://www.gov.uk/government/speeches/rail-update-emergency-recovery-measures-agreements
31st October	Settlement agreed with Transport for London to 31 st March 2021 of £1bn, of which £95 m is loans. Conditions include fares increases, operational efficiencies, expansion of ULEZ, cancelling Crossrail 2 preparatory work, additional TfL board scrutiny from central government.	https://www.gov.uk/government/publications/transport-for-london-settlement-letter
13th November	Tranche 2 Emergency Active Travel Fund allocations announced for longer term schemes including pop up infrastructure (£175 m)	https://www.gov.uk/government/publications/emergency-active-travel-fund-local-transport-authority-allocations

ANALYSIS

The rationale behind schemes

Another similarity between both countries was the sudden availability of funds for rapid scheme implementation. However, this also meant that many of projects proposed had been devised pre-pandemic which inevitably brought a risk of lack of adaptation to the evolving conditions (see Table 2 of the data used to inform the 'Temporary Strategic Cycle Network' as an example). Furthermore, as maintaining operational resilience was one of the main priorities, not only were there little efforts at revaluating existing schemes, but there was also a pause at plans which sought to explore alternative options that could have better catered for evolving behaviours. For example, the bus rescue package saw £30 million which were originally earmarked for starting new services redirected to support local authorities maintain existing ones ([DfT, 2020](#)).

Nonetheless, it was highly beneficial for the realm of sustainable transport, that the decarbonisation agenda was already gaining further prominence in the years prior to the pandemic, as this helped fast-track support for active travel policy and schemes (e.g. [Gear Change, 2020](#)).

Something similar happened in Peru, where rapid scheme deployment was guided by plans that international organisations and cooperation funds had been developing in the years prior to the pandemic ([GIZ, 2020](#); [MTC, 2019](#); [World Bank, 2020](#)). Despite contrasting views on the efficacy of these plans at reflecting local realities, most interviewees agreed that they helped provide a clear sustainable transport narrative that later underpinned government support for new schemes. For example, as early as May 2nd 2020, the ATU was meeting with local authorities to coordinate the implementation of a network of 301km of connected cycle lanes across Lima ([ATU, 2020](#)). The plan was complemented by the launch of a prototype cycle model that could be of cheap distribution and of the right size for the average Peruvian. According to a study conducted by [Lima Como Vamos \(2021\)](#), the number of people that cycled in the capital increased from 3.7% to 6.2% during the pandemic.

Table 2: Data used for Temporary SCA and comparison with SCA. Source: [TfL \(2020\)](#)

	SCA (2017)	Temporary SCA for Street-space Plan (2020)
Current demand	Current cycle flows based on 2014 levels	Current cycle flows (based on 2016 levels)
Potential demand	Potentially cyclable trips from all modes of transport	Potentially cyclable trips from public transport as temporary network needs to provide clear alternative to public transport
Future growth	Estimated population and employment forecasts (2041)	Not used as temporary network needs to serve travel in the immediate term

“The consensus view from our interviewees was that the schemes tended to reward authorities such as the larger city councils with sufficient capacity to have an existing pipeline of active travel schemes that could be accelerated once additional funding was made available”

Mardsen and Docherty (2021)

“In many neighbourhoods in Lima, the ‘juntas vecinales’ (neighbours associations) are now prioritising cycle lanes within their participatory budgets and are asking us for more”

Interviewee account (Transport planner in Local Government)

“Even if not all the infrastructure deployed was up to standards, people were responding to it. Central government would always tell us there was no demand. But put the cycle lanes and cyclists will come, put more carriageways and you will have more cars...”

Interviewee account (Transport planner in Local Government)

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Articulating the vision

All projects across Peru did not share the same luck. In many places, active travel schemes ended up being heavily criticized and even taken off by the local communities. A few issues were identified by the interviewees including the disconnect between central planning and local realities, the lack of articulation between multi-layered political agendas, and a lack of technical support and capabilities at the local level. It must be noted that the areas in Lima where the new infrastructure is being best utilised are those boroughs that already had the best records and most experience implementing these schemes, and where attractors and key services are at close cyclable distances.

We saw similar experiences across the UK where it was tempting for local authorities to fast-track projects already in the pipeline without questioning their current relevance. A key challenge was how to coordinate and make the case for a wider place vision that reflected the new place and movement demands. By failing to communicate wider benefits other than improving the immediate place-quality, many of the active travel schemes gained opposition leading to their removal shortly after being implemented ([Heaton-Harris, C., 2020](#)). Even in places where authorities were initially bold enough to make changes to major links, they also struggled to keep the ambition and were quick to back-track based on status quo assumptions.

“We were very lucky that during the pandemic the Minister of Transport, the leader of the ATU and the Mayor of Lima all shared similar views on the importance of sustainable mobility. Having our political leadership aligned was key for the deployment of schemes in Lima compared to other cities”

Interviewee account (Transport consultant to various cities in Peru)

“Once funding was made available and the instruction to develop schemes given by central government, the local technical teams in other cities would try to rush schemes based on what they were handed, but there was a key planning step that was skipped. The Local Authorities would then struggle to make people and business owners understand how this would benefit them”

Interviewee account (Transport consultant to various cities in Peru)

“I do know that a few councils have removed, or are proposing to remove, cycle schemes installed under the fund, or to water them down... Schemes need time to be allowed to bed in; must be tested against more normal traffic conditions; and must be in place long enough for their benefits and disbenefits to be properly evaluated and understood”

[Letter from Minister State for Transport Chris Heaton-Harris \(2020\)](#)

ANALYSIS

New players

During the pandemic, we saw the UK embark in controlled trials, as in the case of the e-scooters. This shows that disruptive events have the potential to push systems that commonly show conservative tolerance to risks, to be more open towards experimentation within managed boundaries.

In Peru, e-scooters were already operating prior to the pandemic, but it was actually the health emergency and advise to stay at home that led to many companies to pause their operations. However, the high transport demand for essential trips remained. Alternative transport solutions emerged to fill the transport gaps from decreased public transport capacity, and lack of services catering for new routes. As part of a study on the impact of the health emergency on households in Lima, [Robert et al. \(2021\)](#) captured the experience of people who started using their cars to provide a transport service during the pandemic, as they noticed their neighbours were spending more time locally and that there were no routes taking them to key local attractors.

“In response to the COVID-19 pandemic we are delivering a green restart of local transport. To support this and to help mitigate reduced public transport capacity e-scooter trials will be brought forward.”

[DfT \(2020\)](#)

Lessons Learnt

Overall, considering responses to disruptive events, we saw similarities regarding an increased ability to rapidly implement projects when (i) there is political support, (ii) there are plans that could be taken ‘off-the-self’ and be rapidly deployed, and (iii) there are capabilities at the local/operational level to enable delivery. However, a missing step in many solutions was the ability to effectively adapt, expand and communicate them within an evolving context. As seen, over-reliance on historical assumptions meant many of these solutions lost relevance for the current context or were not bold or innovative enough to catalyse on the full extent of potential gains. This follows another similarity between nations which is that they have long operated following models of ‘predict and provide’ coupled with reactionary approaches. As such, they have struggled to actively influence desired behaviours that could ensure more sustainable futures in the long-term.

SCENARIOS

The baseline

This section aims to illustrate some of the key challenges around mitigation and adaptation that nations such as they UK and Peru will face in the coming years. This is to provide a context framework under which the scenarios will be developed.

[‘The Climate Change Act 2008 \(2050 Target Amendment\) Order 2019’](#) states that by law the UK must be net zero by 2050. In 2019, transport was the single largest contributor of greenhouse gas emissions in the UK, accounting to 27% of total domestic emissions, whilst being one of the sectors with the slowest decarbonisation trend ([BEIS, 2019](#)). According to the latest [Climate Change Commission \(2021\)](#) report, without considering the 2019-2020 period, the emissions from the transport sector are ‘widely-off track’ to meet the goals set as there has not been any structural change that could ensure a sustained reduction.

In the case of Peru, the country does not yet have legally binding transport-specific decarbonisation goals. Yet, it is estimated that in the country, 40% of GEI emissions come from transport ([GIZ, 2020](#)). In Lima and Callao, the automotive fleet contributes to over 50% of PM2.5 in the city’s air ([MINAM, 2018](#)) leading to levels of pollution which have reduced an estimated of 4.7 life expectancy years for people living in the capital ([AQLI, 2021](#)).

In addition to the clear urgency for the reduction of transport emissions, both countries also need to take significant steps to adapt to climate-change induced challenges.

The [CRA3 \(2021\)](#) report identifies 61 climate-related risks for the UK. Table 3 shows some of the key risks identified for the transport network, although it is important to note that the high system interconnectivity within the country means that risks and impacts are likely to be cross-sectoral. For example, flooding in one electricity substation might quickly disrupt IT and communication services necessary to support transport operations. Similarly, being able to rely on an efficient transport network is also key when a disaster hits and people need to reach emergency services.

Table 3: Key climate-related risks for transport networks in the UK

11	Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures
12	Risks to infrastructure services from river, surface water and groundwater flooding
13	Risks to infrastructure services from coastal flooding and erosion
14	Risks to transport networks from slope and embankment failure
15	Risks to bridges and pipelines from flooding and erosion
17	Risks to subterranean and surface infrastructure from subsidence
112	Risks to transport from high and low temperatures, high winds, lightning

Table 4 shows some of the key impacts identified for Peru by the [MTC \(2020\)](#). Again, these will ultimately impact transport networks as a result of shifting social, economic and environmental dynamics.

Table 4: Key climate-related risks for transport networks in Peru

Meteorological impacts	Such as the ‘El Nino’ phenomenon, which in 2017 destroyed 489 bridges and caused landslides affecting 4931km of highways, blocking key links across the country
Economic impacts	Impacting production in key sectors such as agriculture, fishing, commerce, tourism, and transport. A study by the BCR (2018) considers that to 2030, the economy will have a GDP 6.8% lower due to Climate Change
Health impacts	Increasing cases of malaria, dengue and zika in warmer areas of the country, and cases of asthma and pneumonia in the cooler areas
Social impacts	Increasing climate displacements due to the less favourable living conditions in more parts of the country

As seen, there is a variety of challenges that, despite not being transport-specific, are heavily influenced by the system’s operations. As such, any scenario-planning exercise should seek to consider the wider implications of increased interconnectedness across the physical, digital, social, economic and political systems.

SCENARIOS

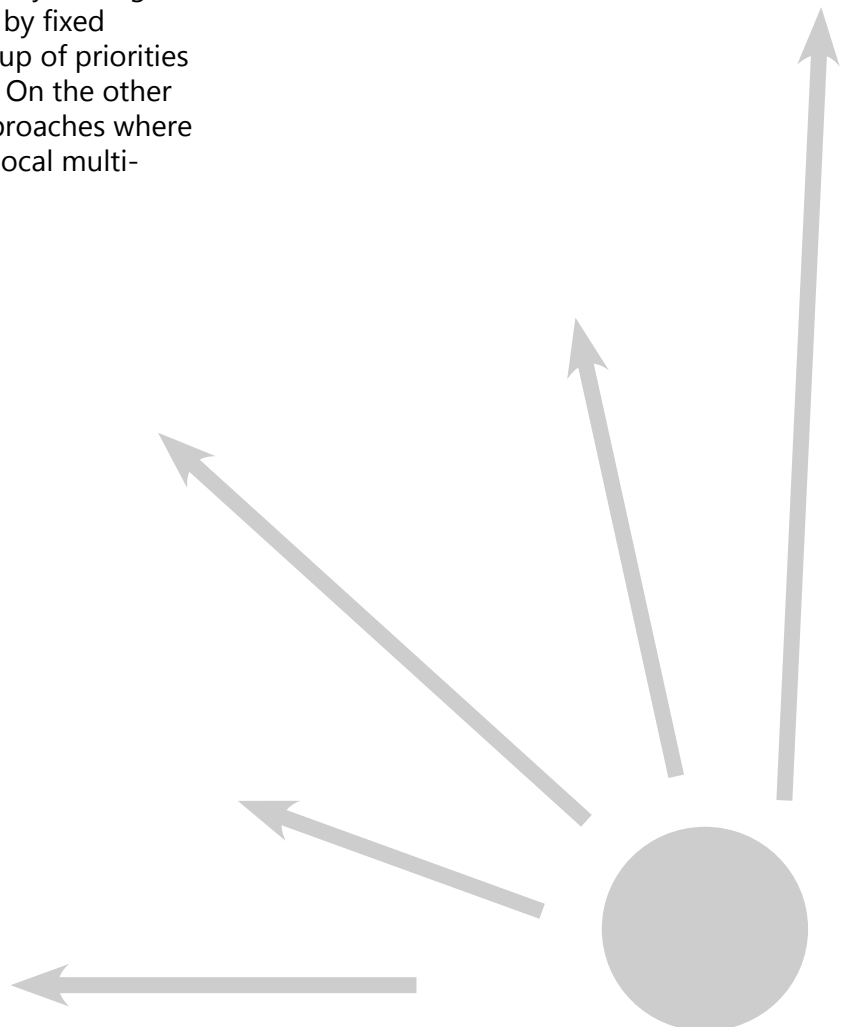
Scenario-planning

Scenario planning can help us test potential system behaviour against a number of plausible futures. This research takes climate change and extreme events as the default baseline condition. However, within this focused context, there are still significant uncertainties that can help inform the development of contrasting scenarios. The baseline review on governance models and responses to an extreme event has been used to inform the proposed axes of uncertainty:

Central Management vs Local Agency

This axis is inspired by the contrasting forms of governance in cities of the UK and Peru. The review of these approaches has provided valuable insight that helped illustrate a spectrum of devolution. On one end, we consider the more centrally-managed approaches, which are characterised by fixed structures and processes for the set-up of priorities as well as high influence on delivery. On the other end, we consider more devolved approaches where transport provision relies mostly on local multi-agency.

Although Peru and the UK both present contrasting governance approaches, this research does not position their cities at any end of the spectrum as the strategies taken have been in constant evolution. In the case of the UK, the nation has been historically good at setting strategies within solid institutional frameworks, but it is lately showing interest in pursuing more place-based approaches. Conversely, in Peru, where there has long been a higher degree of multi-agent devolution at the local level, the country is now showing further interest for influencing alignment under central strategies. In both cases, the pandemic has shown that there are improvements to be made to enable the desired outcomes from these reforms.



SCENARIOS

Fragility vs Anti-fragility

Risk management literature touches upon the concept of system fragility (Taleb, 2012), explaining that a system can be considered as fragile when it hates disorder and takes stability as the desired condition. Anti-fragile systems on the other hand, are those that incorporate volatility as part of their acceptable conditions. As such, these systems are constantly embracing convex exposure to risks, which relates to risks where there is an asymmetry between potential gains (large) and errors (small). Embracing controlled risks is not only useful to harvest potentially large benefits in the long-term but also to help build resilience following a logic of post-traumatic growth (Figure 5).

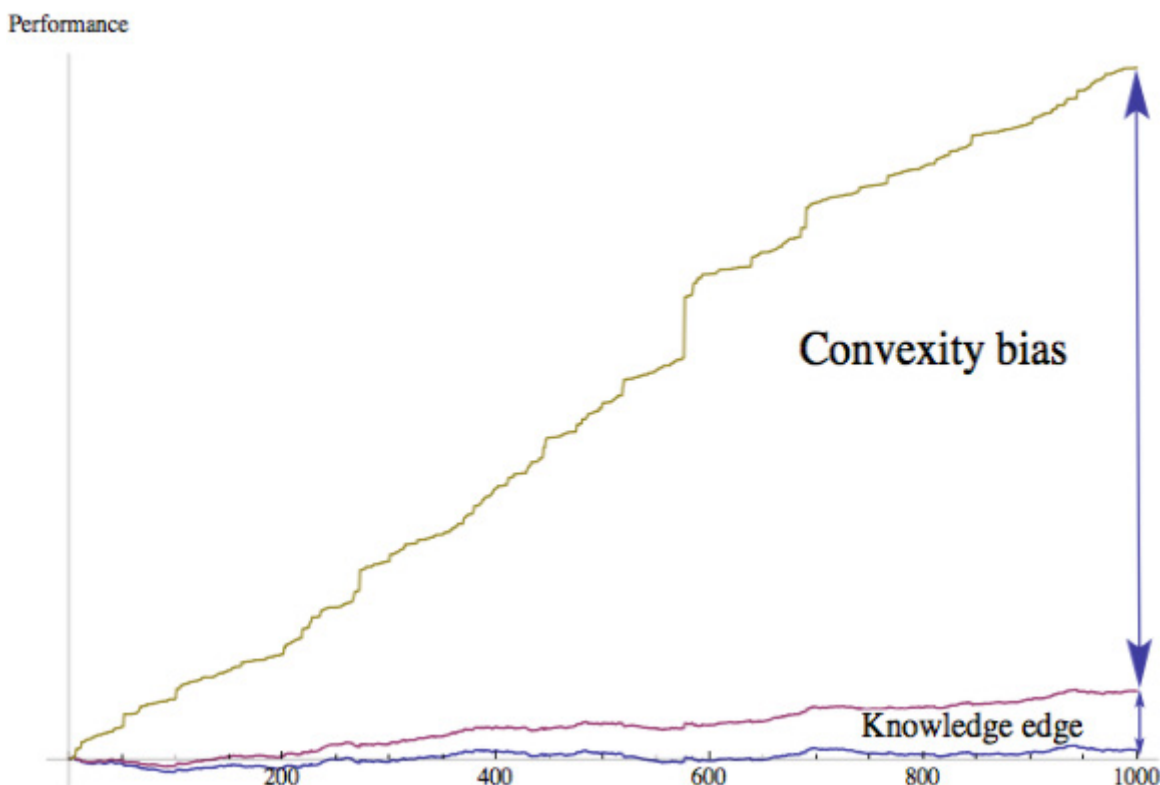
This axis has been informed by the responses observed during the pandemic. We can probably associate the UK's response to that inherent to a 'fragile system' where the aim was to return to stability. Although there was some engagement in trials, these were often devised following pre-pandemic logics and assumptions or presented such constrained margins for experimentation that would again make it resemble a fragile / knowledge-based system.

Contrary to the UK, transport provision in Peru has often been characterized by trial-and-error at the local scale, with transport solutions constantly entering and adapting or entering and exiting the transport ecosystem. However, this arrangement has historically lacked a clear strategic approach that would enable the pursue of wider societal goals or cumulative innovation in the sector. An experimental and shifting governance has also led to fragility within the system when exposed to shocks. For example, during the pandemic when central regulation had the potential to overrule local practices following the declaration of 'state of emergency'.

Considering a future where volatility will be 'the new normal', ensuring the anti-fragility of our transport systems and their governance will be key. The scenarios described below seek to provide some direction on what transport planners could focus on to influence resilience when faced with a number of contrasting futures. The suggested actions have been drawn from the lessons explored throughout the review on [Section III](#).

Figure 5 The Antifragility Edge (Convexity Bias). Source: Taleb (2012)

"A random simulation shows the difference between a) the process with convex trial and error (antifragile) b) a process of pure knowledge devoid of convex tinkering (knowledge based), c) the process of nonconvex trial and error; where errors are equal in harm and gains (pure chance). As we can see there are domains in which rational and convex tinkering dwarfs the effect of pure knowledge."



SCENARIOS

Figure 6: Scenario matrix

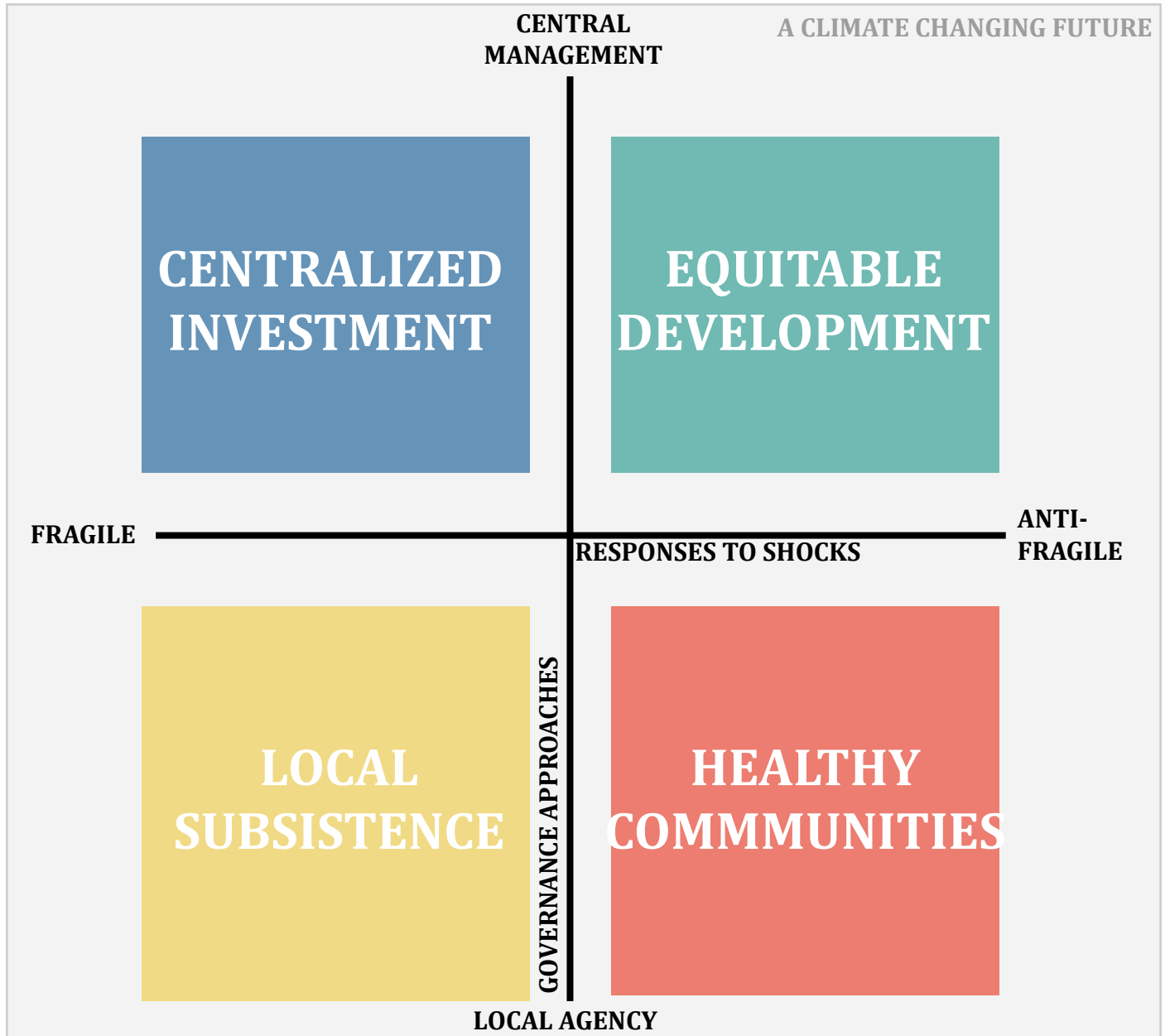
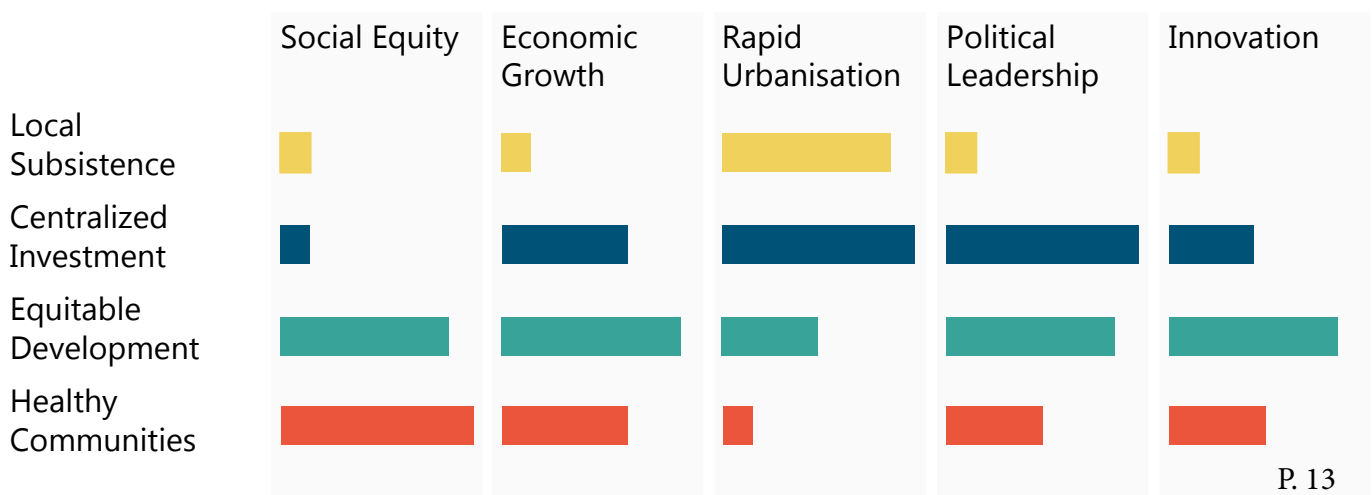


Figure 7: Level to which different characteristic associate to each scenario [indicative measures]



SCENARIOS

Local Subsistence

Key driver: Everyday adaptation to shocks

This scenario is characterized by high local devolution implemented in a disjointed manner. The lack of coordination between local actors enables them to rapidly adapt and tackle immediate issues but constrains their ability to pursue wider goals and cumulative innovation. Infrastructure investments are very small in scale and unable to unlock growth opportunities. As the frequency and intensity of extreme events increases, there is a constant opening of gaps which is seen as opportunities for entrepreneurship at the local level. However, the lack of a safety net constrains the likelihood of long-term success. Similarly, the lack of integration constrains the potential for dissemination of lessons learnt and cumulative growth. Collectively, this leads to an inability to curb emissions and accelerates the pace of climate change bringing further stresses to vulnerable areas.

Key challenges:

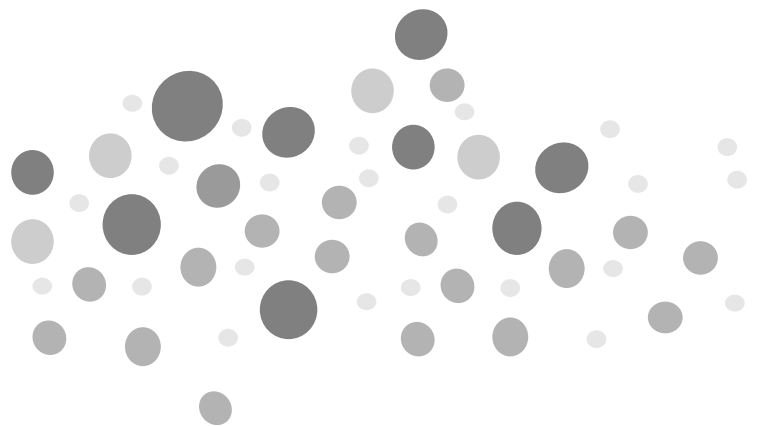
- Multi-agent coordination
- Long-term planning
- Cumulative innovation
- Achievement of wider societal goals

Key opportunities:

- Rapid adaptation
- High entrepreneurship
- Context-sensitive solutions

Key considerations for transport planners include:

- Developing more agile and innovative ways of mapping dispersed innovation as well as improving the ability to 'see the big picture' and draw potential connections between disjointed efforts.
- Ensuring schemes can be increasingly resilient to extreme weather events as the pace of climate change increases more rapidly than expected due to an overall inability to curb emissions. Also, ensuring that these schemes can be part of a wider place and movement vision rather than disjointed point-based interventions.
- Improving our ability to do quick strategic options appraisal, considering how we can deliver schemes that can be rapidly deployed, but which can also maximize the ability of communities to access wider opportunities outside their immediate surroundings.



	Social Equity	Economic Growth	Rapid Urbanisation	Political Leadership	Innovation
Local Subsistence	Low	Low	High	Low	Low
Centralized Investment	Low	Medium	High	High	Medium
Equitable Development	Medium	High	Low	Medium	High
Healthy Communities	High	Medium	Low	Low	Medium

SCENARIOS

Centralized Investment

Key driver: Economic growth and city competitiveness

In this scenario, central investment is actively targeted to a few cities with the aim of improving their 'competitiveness'. Rapid urbanisation is inherent to this setting as people seek to access the opportunities within these areas. As such, knowledge becomes heavily concentrated within hubs, leaving high inequalities not only at the national or regional but also city-level. Local innovation becomes highly constrained as there is not much room for deviation from central planning dynamics and as only a few hubs have the optimal conditions for innovative ideas to prosper and further develop.

Key challenges:

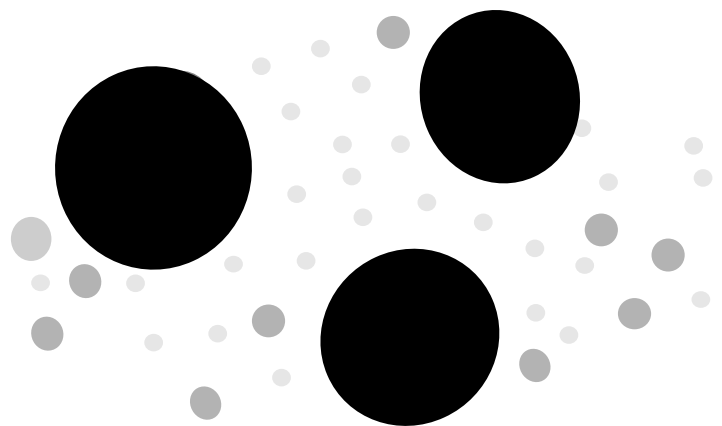
- Social, economic and environmental equity
- System resilience (relying on a few hubs)
- Local-based innovation
- Capacity for rapid adaptation

Key opportunities:

- Hyper-performing hubs
- Central investment and leadership to take schemes off the ground
- Major structural investments

Key considerations for transport planners include:

- Considering the wider place-based dynamics surrounding each scheme in order to maximize potential opportunities for unlocking new developments and activity hubs that could then relieve pressure from rapidly urbanising centres.
- Improving our ability to measure and communicate the benefits of decentralized investment. Ensuring we can develop strong business cases to leverage on central investment.
- Thinking strategically and avoid falling on 'wars of local competition'. Ensuring we can work collaboratively with other practitioners and local authorities to maximize the extent of social and economic benefits and their fairer distribution. Being able to form networks of collaboration and collective strategizing between small and intermediate cities and towns.



	Social Equity	Economic Growth	Rapid Urbanisation	Political Leadership	Innovation
Local Subsistence	Low	Low	High	Low	Low
Centralized Investment	Low	High	High	High	Low
Equitable Development	High	High	Low	High	High
Healthy Communities	High	Low	Low	Low	Low

SCENARIOS

Equitable Development

Key driver: Polycentric development

This scenario sees much central involvement for the active promotion of polycentric development. This takes the form of general framework-setting as well as targeted investment for strengthening local hubs. Infrastructural improvements in transport are mainly targeted to key transport hubs and their immediate surroundings as well as improving connectivity between 'secondary cities' to develop the polycentric network. There is high investment in education and capacity building as it is recognised that this is key for the long-term success of the developing hubs. Similarly, there is high central support for innovation through the provision of a support net for engaging in convex-risks trials and through the acceptance of managed failure. Once successes are identified, the high interconnectivity of the network ensures that knowledge can be disseminated to other centres.

Key challenges:

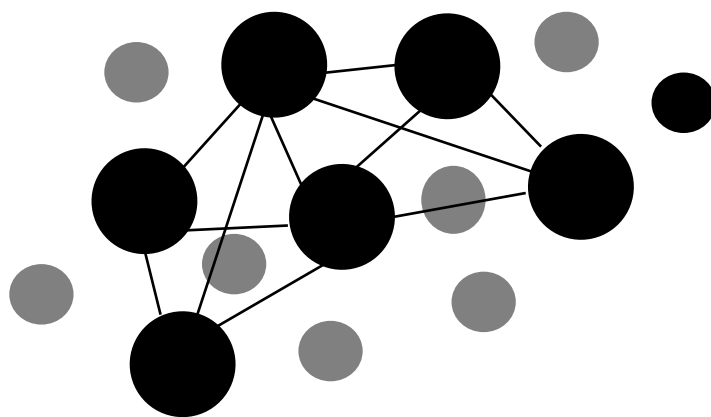
- Spreading benefits of investment beyond developing hubs
- Falling in 'one-size fits all' solutions
- Nurturing and disseminating hyper-local innovation

Key opportunities:

- Collaboration networks
- Development along 'opportunity corridors' (those connecting strategic hubs)
- System resilience from decentralized investment

Key considerations for transport planners include:

- Ensuring that the benefits and opportunities being nurtured at the developing centres can also be accessed by the communities outside of them. Also paying attention to inner-city connectivity and access to key services to ensure development is inclusive to all.
- Improving our ability to rapidly respond to shocks and to be able to adopt new strategies when the ones in place are not fit for the situation. This would require improving the way we monitor evolving conditions at the local level and would also require having agreed contingency plans in advance. Once a shock hits, then the most suitable option could be rapidly deployed, minimizing red tape.
- Ensuring innovation occurring at a hyper-local level can be effectively spotted and communicated in order to maximize the benefits of a connected network of knowledge-share. Embracing digital tools and alternative channels for sharing information can prove key to achieve this.



	Social Equity	Economic Growth	Rapid Urbanisation	Political Leadership	Innovation
Local Subsistence	Low	Low	High	Low	Low
Centralized Investment	Low	Medium	High	High	Medium
Equitable Development	High	High	Medium	High	High
Healthy Communities	High	Medium	Low	Medium	Medium

SCENARIOS

Healthy Communities

Key driver: People's health and wellbeing

In this scenario, coordinated bottom-up approaches take a pivotal role in the pursue of local objectives. Even though economic prosperity is key to ensure the viability of wider social objectives, growth is not the main goal. A localised approach is mostly prioritised through local participatory budgets and decentralised systems of consultation and decision-making. There is high investment in local infrastructure including connectivity to key local services and attractors but also in place-making and street liveability. This includes the propagation of measures such as low-traffic neighbourhoods, school streets, 'ciclodias', etc. which put people's health and well-being at the forefront.

Key challenges:

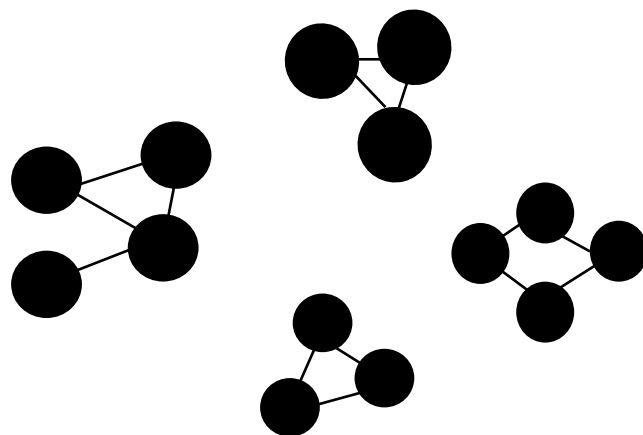
- Polycentric strategy alignment
- Translation and dissemination of hyper-local knowledge
- Securing support nets to embrace risks and innovation

Key opportunities:

- High social capital and local coordination
- Using inclusive development as a framework for polycentric coordination
- Sustainable transport as a proxy to achieve inclusive development

Key considerations for transport planners include:

- Ensuring local strategies are aligned with those from neighbouring communities in order to secure wider system resilience. This is in recognition of the interconnectedness of our systems and that resilience to climate change and extreme events cannot be achieved if approaches are not coordinated. This also involves improving our ability to see beyond immediate gains and to be able to communicate this to local communities.
- Setting up networks of knowledge-share to enable cumulative innovation from efforts taking place within different communities.
- Finding alternative support nets (alternative to central investment and assistance) that could help foster innovation at the local level. This can also be encouraged by being able to articulate the benefits of embracing convex-risks and developing a culture of acceptance to managed trials and errors.



	Social Equity	Economic Growth	Rapid Urbanisation	Political Leadership	Innovation
Local Subsistence	Low	Low	High	Low	Low
Centralized Investment	Low	High	High	High	Low
Equitable Development	High	High	Low	High	High
Healthy Communities	High	High	Low	High	Low

FINAL REMARKS

What now?

Scenario-planning is a useful tool to help prioritise actions when faced with uncertainty. Furthermore, it can help us take a proactive approach and actively influence our trajectory away from the least desirable futures.

As argued throughout this paper, there is a role for transport planners in helping create an 'anti-fragile' system. Following the lessons explored and the patterns of potential actions identified for the different scenarios, a compiled set of recommendations that we could consider **now** for the achievement of a robust system in the context of climate change are:

1. Having a clear strategic goal that goes beyond operational resilience: Including the pursue of decarbonisation and wider societal goals, and ensuring that this goal is constantly referred to when faced against extreme events.
2. Take a network approach: An over-focus on transport efficiency specially within networks that are run by various providers also risks falling into silo-approaches. As transport professionals we should look beyond mode-specific solutions to mobility challenges. Maybe it is not a new rail line that we need, but better integration between existing ones and bus services? Or reopening a new station and integrating with active modes? An integrated approach to transport should enable us to explore more creative solutions that could lead to cumulative innovation in the sector.
3. Plan in advance: Having a repertoire of projects in the shelf can provide a menu of options from which we can choose and adapt as we face a variety of increasingly unpredictable future challenges.
4. Adapt: When choosing the project that best fits the challenge, we must always test the relevance of detail against real-time data but also considering the desired behaviours that we want to encourage and not underestimating potential for change.
5. Build-in local capacity: Associated to the point above, this is about having a local team that is able to quickly adapt schemes and be able to communicate the benefits to the wider population.
6. Ensure there is strong political support: Providing the framework for experimentation and ensuring that the schemes are tested against a variety of scenarios as inherent to a continuously evolving mobility ecosystem.
7. Allow room for mistake: Provided all the above is in place, this should provide the base for a solid framework to enable controlled experimentation. Sporadic failure should be acceptable as this allows the system to become more resilient and enables a safe space to nurture creativity and innovation.

This is not aimed to be an exhaustive list. It is rather meant to serve as an attempt at recording some of the things that transport planners 'already know how to do and should be doing more of', and of areas where skills need to be developed more widely across the sector.

As climate change continues to interact with our existing systems, our challenges will evolve and so must we. Scenario-planning will continue to be a key tool to help us adapt in order to ensure we can be prepared for delivering the best outcomes as we approach these increasingly uncertain futures.

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APPENDIX

Interview method

24 one-to-one interviews were conducted between October - November 2021 to gather reflections on key challenges and opportunities for the achievement of a sustainable transport system* in Peru and the UK. The interviews were taken as a complementary source of information during the literature review stage of this research.

Overall, the interviews would last between 60 - 90 minutes. A semistructured format was chosen in order to encourage qualitative judgements and the sharing of personal experiences and reflections from transport practitioners working across a variety of sectors. The conversation was broadly focused around 3 main parts:

1. Past - Reflections on the key challenges and opportunities for the achievement of a sustainable transport system prior to the pandemic. Reflections on historic trends.
2. Present - Personal experience delivering transport schemes during the pandemic and whether significant changes have been perceived.
3. Future - Perception of key challenges and opportunities for the achievement of a sustainable transport system as we look forward. What should continue, what should change and perceived capacity for change in the system

For each of these parts, a set of questions would be prepared based on each individual's background and personal experience.

Each person would also be encouraged to comment on the interaction of their work with governance systems, and the interaction of their work with public engagement / community participation at the different stages (pre-pandemic, during the pandemic and thoughts for post-pandemic).

All interviewees were ensured anonymity for this work.

*sustainable transport system: The term would be left unspecified on purpose in order to assess what was the immediate understanding that the professionals would get. Some interviewees would provide their own definition at the beginning whilst some would explain their understanding throughout the interview.