



The carbon impact of the national roads programme

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transport for quality of life

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Headline findings

In terms of carbon emissions, transport is the worst-performing sector of the economy. Whereas emissions in all other sectors have fallen, emissions from transport are still going up.

The Department for Transport is developing a decarbonisation plan for the transport sector, and has stated that the forecast rate of carbon reduction from transport is much slower than is needed.

The Climate Change Act 2008 now commits the UK to reduce net carbon emissions to zero by 2050, and to five-yearly carbon budgets between now and then. The Committee on Climate Change (CCC) has already shown that transport is not even on track to comply with existing carbon budgets (set when the target was to reduce emissions by 80% by 2050), let alone net-zero ones.

However, in terms of impact on the climate, what matters is not so much the end date, as the total amount of CO₂ that is emitted between now and then. Under the Paris Climate Agreement, the UK is committed to restricting the increase in global average temperatures to well below 2°C and preferably below 1.5°C. For this, **cutting carbon emissions over the next decade will be crucial.**

The significance of the Strategic Road Network (SRN)

Total carbon emissions from the Strategic Road Network (SRN) and other roads over the next decade will depend on the rate of adoption of electric vehicles and the volume of traffic. Even using the DfT road traffic forecast (RTF) with the most optimistic assumptions about take-up of electric vehicles (RTF Scenario 7), we calculate that **total carbon emissions from the SRN between now and 2032 will be 381 MtCO₂.**

We believe that DfT should set a binding Paris-compliant carbon budget for all parts of the transport sector, including Highways England which is responsible for the SRN. By analogy with carbon budgets proposed for local authorities by the Tyndall Centre for Climate Change, we estimate that **a fair, Paris-compliant budget for the SRN between now and 2032 is about 214 MtCO₂.**

This would mean that total carbon emissions from the SRN over the next 12 years need to be cut by about 167 MtCO₂, or 44% of forecast levels, even assuming DfT's most optimistic forecast of how emissions will change with rapid uptake of electric vehicles.

This scale of reduction is extremely challenging. It will only be possible through a combination of a faster switch to electric vehicles (e.g. requiring all new cars/vans to be fully electric from 2030) *and* a significant reduction in vehicle mileage. Mileage reduction will require measures to restrict driving, such as road pricing, better and more affordable rail and coach services, improvements in conditions for active travel (since many journeys on the SRN could potentially be replaced by a combination of

cycling and rail travel), better planning to prevent car dependent development and universal roll-out of superfast broadband to support remote working. Further carbon could be saved by reducing the speed limit on the SRN to 60mph, with speed camera enforcement.

Two weeks before publishing its initial thinking about how to decarbonise the transport sector, DfT published the second Road Investment Strategy (RIS2). This commits expenditure of £27.4 billion over the next five years to the SRN. Just over half (£14.1 billion) is for “capital enhancements” – that is, new roads and increasing the capacity of existing roads.

This is a **very substantial increase in expenditure on road building**. It has been described by the Chancellor as the largest ever road investment package, and it represents a doubling in average expenditure.

DfT has not published any assessment of the cumulative carbon impact of RIS2.

The carbon impact of RIS2

This paper estimates the likely carbon impact of RIS2. To do this, it uses Highways England’s own figures from post-opening project evaluations of strategic road schemes built over the last 18 years, and every publicly-available Environmental Statement for a planned RIS road scheme.

A road scheme increases carbon emissions in several ways. There is significant embodied carbon in the steel, concrete, asphalt and other raw materials used to build it. If there is extensive land clearance and many mature trees are felled, a carbon ‘sink’ is lost. Once the road is opened, it may result in higher speeds, and this may lead to more carbon emissions: an increase in average speeds from 60mph to 70mph causes carbon emissions to go up by about 13%. And over time, increased road capacity generates more traffic, as it encourages driving and enables development of car-dependent housing estates, retail parks and business parks. This is known as ‘induced’ traffic.

Highways England measures some of these effects, in its appraisal and evaluation process for individual roads. However, failings in the way it evaluates road schemes (using a method categorised as ‘weaker / riskier’ in the government’s own evaluation ‘rulebook’, the Magenta Book) lead it to systematically underestimate the effect of induced traffic.

Our estimate of the likely carbon impact of RIS2 takes account of embodied carbon, carbon emissions from higher speeds, and carbon emissions from induced traffic. We estimate that these three factors have roughly equal effect, and that total additional emissions between now and 2032 as a result of RIS2 will be about 20 MtCO₂. Emissions

could be higher than this if planning policy becomes more permissive, allowing more out of town, car-dependent development.

RIS2 will make carbon emissions from the SRN go up, by about 20 MtCO₂, during a period when we need to make them go down, by about 167 MtCO₂. This increase in CO₂ from RIS2 will negate 80% of potential carbon savings from electric vehicles on the SRN between now and 2032.

This suggests that RIS2 is incompatible with our legal obligation to cut carbon emissions in line with the Paris Climate Agreement, the CCA budgets and the emerging principles for the DfT's decarbonisation plan. We therefore believe that it should be cancelled.

Re-purposing RIS2 funding to address the COVID-19 and climate emergencies

The COVID-19 pandemic has wrought enormous behaviour change, with both work and non-work journeys replaced by a variety of video conferencing solutions and greater use of local facilities. When rebuilding the economy, it is vital that investment supports behavioural shifts that will also help to achieve reductions in carbon emissions. Cancelling RIS2 would free up investment for this.

In the short term, funding could be used to develop thousands of local 'remote working' hubs. These would enable businesses to start to function again while maintaining social distancing, would reduce the difficulties many people face when working at home, and would avoid an increase in carbon and congestion as commuters shift from public transport to driving.

In the medium term, funding could enable universal superfast broadband, providing a more efficient and low-carbon way of meeting our everyday needs. It could also be used to improve active travel and public transport networks, thereby reducing congestion on the SRN in a more effective, sustainable and permanent way.

1. Introduction

The Department for Transport is currently developing a decarbonisation strategy for the transport sector. Its recent paper *Decarbonising transport: setting the challenge* states that current plans and policies will not achieve the reduction in emissions that is needed if transport is to play its part in contributing to our legal obligation to “net zero” carbon emissions by 2050¹.

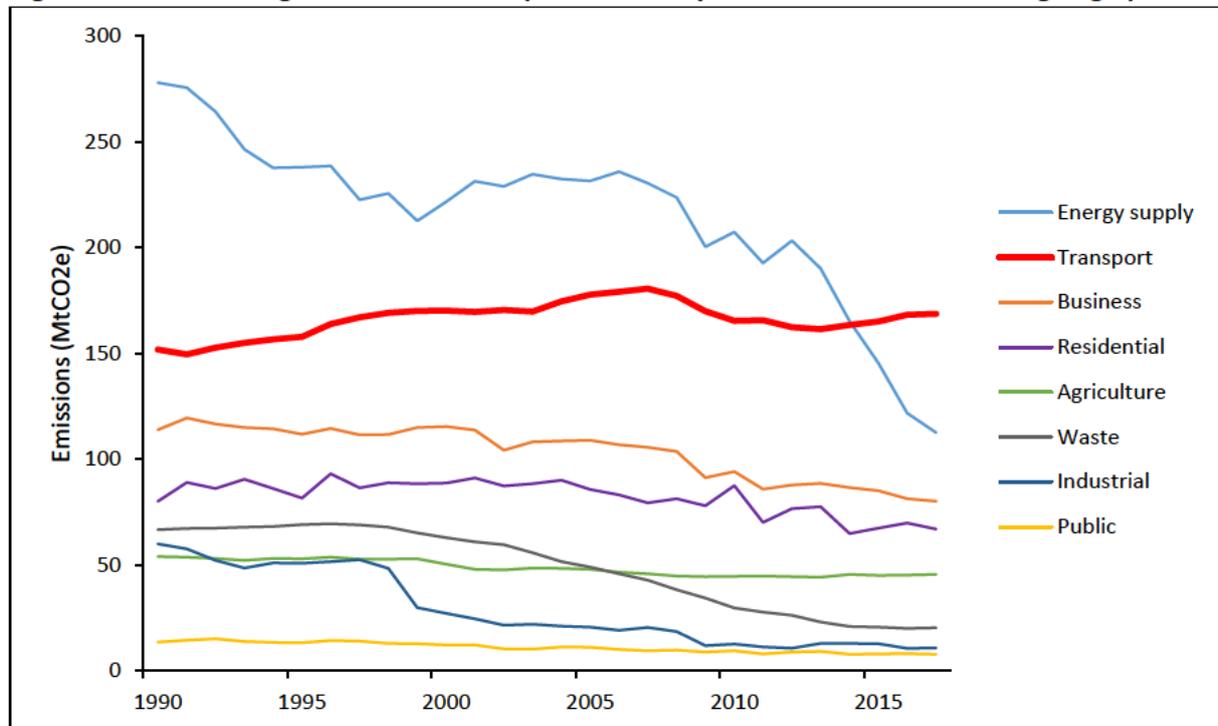
The need to take account of our legally binding climate commitments when making transport policy decisions has also been highlighted by the recent judgment by the courts in relation to expansion of Heathrow airport.

This raises the question of what other areas of transport policy may be problematic for the achievement of our climate commitments. One particular cause for concern is the large-scale road-building programme. This paper uses carbon data reported by Highways England to make, for the first time, a programme-level estimate of the likely carbon impact of the government’s second Road Investment Strategy, RIS2. It considers the potential impact due to construction (including embodied energy of construction materials), increases in vehicle speeds, and induced traffic, and compares the likely carbon impact of RIS2 with total emissions from the motorway and trunk road Strategic Road Network (SRN), and with a suggested carbon budget for the SRN.

2. Why carbon emissions from the SRN matter

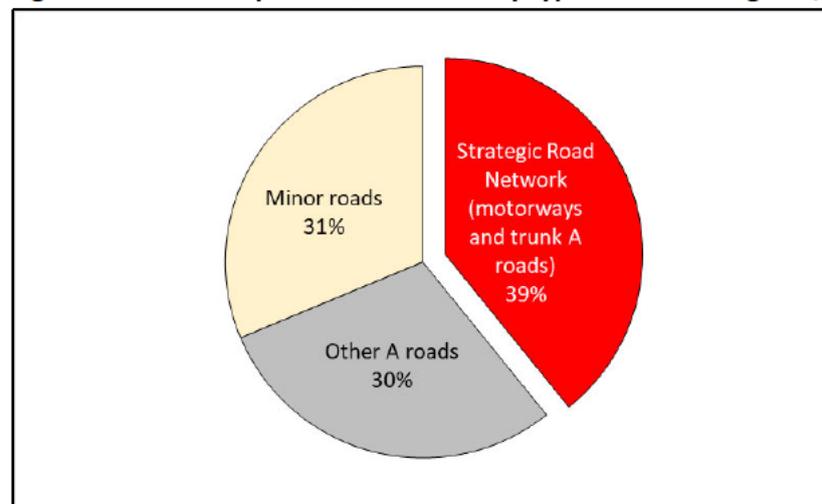
Transport is the UK's worst-performing sector for carbon reduction, and the only sector where greenhouse gas emissions are still going up, as shown in Figure 1. If emissions from international aviation and shipping are included, it is now responsible for over a third of UK greenhouse gas emissions.

Figure 1: Greenhouse gas emissions: transport is the only sector with emissions still going up²



Road transport accounts for the bulk (two-thirds) of total transport greenhouse gas emissions, or 91% of domestic transport emissions. Emissions from the SRN account for two-fifths of all CO₂ from road transport in England, as shown in Figure 2. This means the SRN in England accounts for roughly a third of the UK's domestic transport emissions³. If we are to get transport emissions down, the emissions from traffic on the SRN are a key target for action.

Figure 2: Road transport CO₂ emissions by type of road in England, 2015⁴



The Climate Change Act (CCA) 2008 was amended in 2019 so that it now commits the UK to reduce net carbon emissions to zero by 2050, as well as to five-year carbon budgets between now and then. The Committee on Climate Change (CCC) has already shown that transport is not even on track to comply with existing carbon budgets, and has called for all infrastructure decisions to be checked against their consistency with the UK's Net Zero target⁵. We estimate that by 2032 the policy gap for domestic transport will be around 60 MtCO_{2e} and even higher for total transport⁶.

It might be thought that even if RIS2 increases carbon emissions over the medium term, this does not matter because the shift from petrol and diesel to electric cars means that by 2050 the transport network will be decarbonised. However, because of the longevity of carbon emissions in the atmosphere, the catastrophic impacts of climate change can only be avoided by limiting our *total* emissions between now and 2050 to stay within a total atmospheric carbon budget. Climate models show a strong relationship between cumulative CO₂ emissions and temperature rise. What matters is the amount of CO₂ that is emitted in every year between now and 2050 (i.e. the CCA carbon budgets), not just the amount emitted in the final year. This is a key concept underpinning the IPCC's 1.5-degree report. This estimated the global carbon budgets and pathways to limit warming to 1.5°C above pre-industrial levels in line with the Paris Climate Agreement, and explains why they consider the next decade to be so important.

Because we have left it so late to act to reduce carbon emissions, we have very little carbon budget remaining. Research by the Tyndall Centre for Climate Research suggests that if a global carbon budget consistent with the Paris Climate Agreement is divided fairly between all countries and all sectors, the carbon budget for the UK car sector is equivalent to just 7-8 years of current carbon emissions⁷. Other researchers agree that remaining within a fair carbon budget for the period to 2050 requires deep and rapid cuts in carbon emissions over the next 10 years in the UK^{8 9}.

The government is currently consulting informally on bringing forward the end-date for sales of *new* petrol and diesel cars to 2035. If this happens, the majority (around 65%) of cars *on the road* in 2030 will still be petrol and diesel. In order to stay within a Paris-compliant fair carbon budget, we estimate we will need to make cuts in car traffic of around 40-50% by 2030 compared to current traffic levels. Under other scenarios for the rate of take-up of electric cars, the scale of traffic reduction that is needed by 2030 in order to stay within a Paris-compliant fair carbon budget ranges from 20% to 60%¹⁰. These findings are consistent with the conclusion of a recent report from the Centre for Research in Energy Demand Solutions (CREDS) that *"a reduction in CO₂ emissions from transport by technology, without changing demand, [does] not appear to be based on a realistic assessment of what is practically possible"*¹¹.

In this situation, any RIS2 investment that increases carbon emissions from the transport sector is impossible to justify. The challenge of achieving even a 20% cut in car mileage is so large that we cannot afford to make the problem worse. This message has been echoed by Chris Stark, CEO of the CCC, who has said: *"The government mustn't be investing in anything likely to increase carbon emissions... I would spend the roads budget on fibre. You would get a huge return to the economy with people having better connections."*¹²

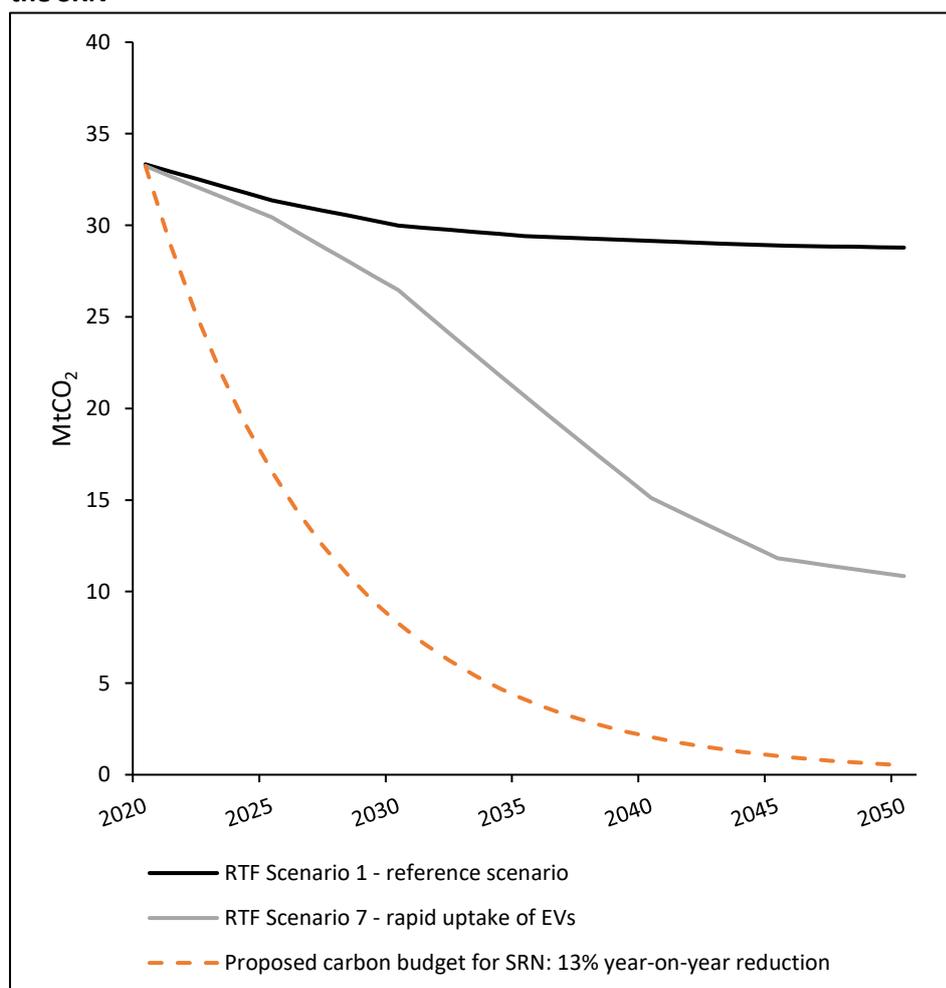
3. A suggested carbon budget for the SRN

Government departments and agencies such as Highways England have no carbon budget, or any plan to show how they will stay within their budget¹³. This means that there is nothing against which the carbon emissions from RIS2 can be judged.

However, the government's latest road traffic forecasts show that (even without RIS2) carbon emissions from the SRN will not fall fast enough to achieve "net zero" emissions by 2050 (Figure 3). In a reference scenario (RTF Scenario 1), emissions from the SRN only fall by 14% between 2020 and 2050. Even in the best performing scenario with rapid uptake of electric vehicles (RTF Scenario 7 which assumes all car and LGVs sold are zero exhaust emission by 2040), emissions only fall by two-thirds (67%) by 2050.

We suggest a binding carbon budget for the whole transport sector¹⁴, including the SRN, will need to be adopted soon, in order for the DfT Decarbonisation Strategy to be credible. To be consistent with the Paris Climate Agreement, it is likely to require a reduction in emissions similar to that calculated for local authorities by the Tyndall Centre for Climate Change, at around 10-16% year-on-year¹⁵. The change in annual emissions from the SRN using a 13% annual reduction (i.e. in the middle of this range) is shown in Figure 3. This provides a basis against which the potential effect of RIS2 can be compared.

Figure 3: Forecast CO₂ emissions from traffic on the SRN compared to proposed carbon budget for the SRN

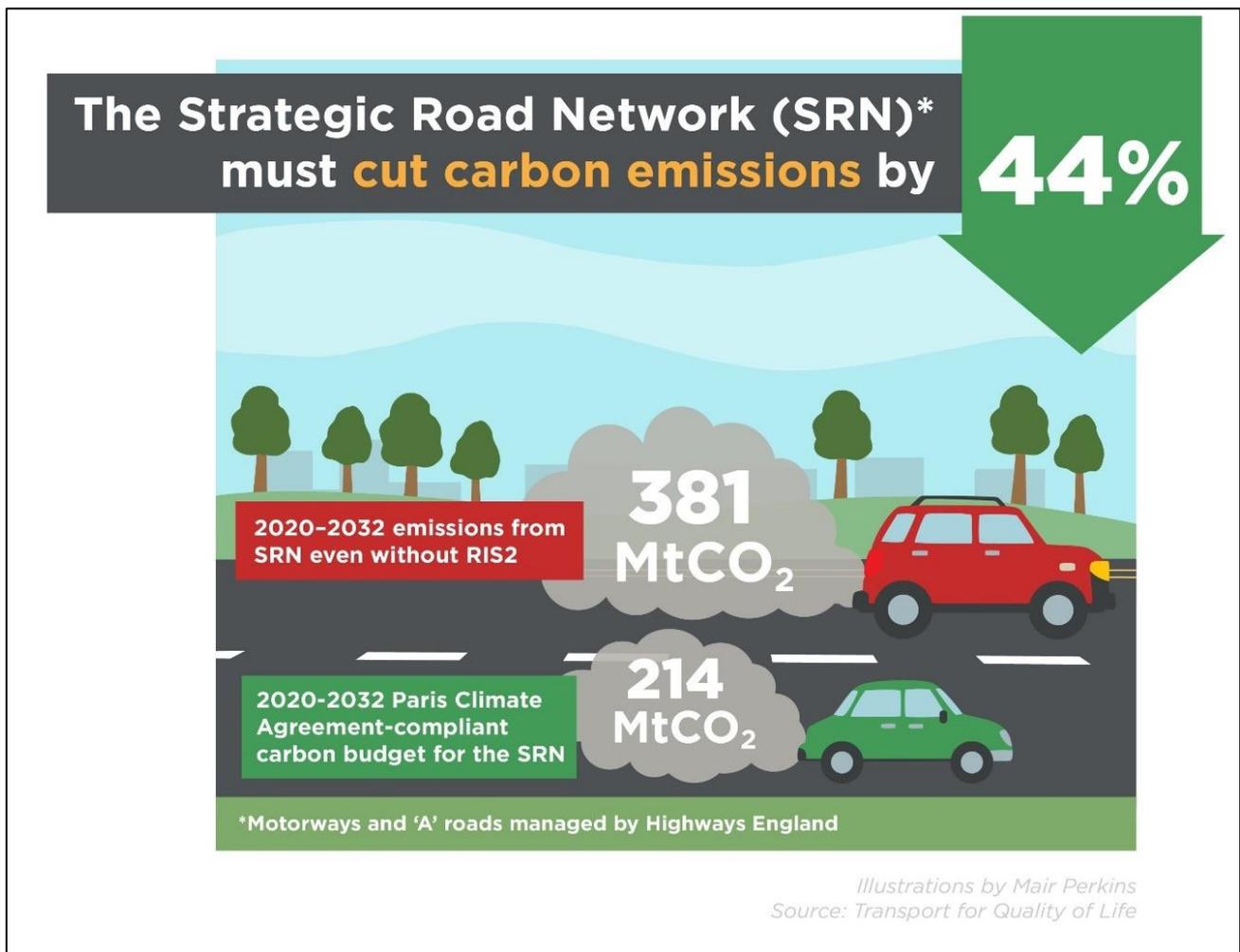


Source: Department for Transport (2018) Road Traffic Forecasts. Forecasts take account of all fully committed road schemes implemented as part of RIS1, but not the RIS2 schemes (or any further road building in RIS3).

Table 1 shows how our proposed carbon budget for the SRN compares with forecast emissions, for the crucial period up to the end of 2032. We have chosen this end date to align with the CCC’s 5-year carbon budget periods (running up to the end of their fifth carbon budget period). Using the DfT road traffic forecast with rapid take-up of electric vehicles (RTF Scenario 7), we calculate that total carbon emissions from the SRN between now and 2032 will be 381 MtCO₂. A fair, Paris-compliant carbon budget for the SRN would be about 214 MtCO₂. This means that we need to cut total carbon emissions from the SRN over the next 12 years by about 167 MtCO₂, or 44% of forecast levels, even compared to the most optimistic forecast of how emissions will change with rapid uptake of electric vehicles.ⁱ

Table 1: How a proposed Paris-compliant carbon budget for the SRN compares to forecast emissions

	Total emissions, MtCO ₂ 2020 - 2032
Forecast, assuming rapid uptake of EVs (RTF Scenario 7)	381
Paris-compliant carbon budget	214
Necessary reduction in emissions	167 (44%)



ⁱ Even if the ban on ICE cars/vans is brought forward from 2040 to 2035 the majority (ca. 65%) of vehicles on the road in 2030 will still be petrol/diesel fuelled. While an earlier ban will reduce forecast emissions from the SRN the main impacts of this policy will not be felt until after 2030, and by itself will not be sufficient to meet carbon budgets. In 2030 we estimate it will reduce UK car emissions by less than 5 MtCO₂e compared to a 2040 ban.

4. Current approach to assessing carbon impacts of road schemes

At present, the carbon impact of the roads programme is considered at the level of individual road schemes, but there is no assessment for the programme as a whole¹⁶. Carbon impacts of individual schemes are predicted as part of the appraisal of a scheme, and reported in the Environmental Statement. This figure is then monetised and added into calculations for a scheme's Benefit Cost Ratio. For schemes designed to alleviate severe congestion, it is possible that there could be carbon emission reductions (at least in the short-term). However, based on our assessment of reports and evaluations about schemes (see section 6), most schemes are expected to result in carbon emission increases.

We discuss below why we believe that these carbon increases are often under-estimated. Nevertheless, the estimates of additional CO₂ resulting from some RIS1 and proposed RIS2 schemes are very substantial, even according to Highways England's own figures. Some of the more egregious examples are the Lower Thames Crossing, which Highways England predicts will increase carbon emissions by 5.7 MtCO₂ over its 60-year life; A303 Stonehenge (+1.95 MtCO₂); A1 Cambridge to Huntingdon (+1.4 MtCO₂); and M42 Junction 6 (+0.6MtCO₂). The lifetime emissions from these five schemes alone are equivalent to the annual emissions from 4.4 million carsⁱⁱ.

As far as we are able to tell from the road schemes we have reviewed, the conclusion of the Environmental Statement is *always* that any change in emissions resulting from the scheme is small relative to the total carbon emissions of the economy, and therefore not relevant to the decision to grant consent for the scheme. Government policy in fact requires that the carbon impact of any individual road scheme should only be treated as a material factor in deciding whether the scheme should go ahead if *"the increase in carbon emissions resulting from the proposed scheme [is] so significant that it would have a material impact on the ability of government to meet its carbon reduction targets"*¹⁷.

This approach remains unchanged even after the net zero legislation, Heathrow judgement and DfT's consultation on decarbonisation¹⁸.

Some examples of conclusions in Environmental Statements are summarised in Table 2.

For example, a recent Environmental Statement for the A38 Derby Junctions scheme concludes that total emissions as a result of the scheme during the period 2023-2027 will be roughly 87 ktCO₂e, compared to a total carbon budget for the whole UK economy over the same period of 1,950 MtCO₂e. This is a proportion of 0.004%, and so the Environmental Statement concludes that the increased carbon emissions from the scheme do not have a material impact on UK carbon reduction targets¹⁹.

ⁱⁱ Based on the emissions of an average petrol car and average mileage per car in 2018.

Table 2: Typical findings from Environmental Statements about the carbon impact of road schemes

Road scheme	Region	Comment in Environmental Statement
A585 Windy Harbour to Skippool	NW	“This increase in emissions as a result of the Scheme would be negligible, and therefore, effects would be Not Significant.”
A1 Birtley to Coalhouse	NE	“Based on professional judgement, the magnitude of change in GHG emissions is considered to be negligible. The Scheme with the Allerdene embankment option is therefore expected to have a slight adverse effect (not significant) on climate.”
M42 Junction 6	WM	“The assessment has identified that the emissions arising as a result of the Scheme represent less than 0.006% of the total emissions in any five year UK carbon budget during which they would arise. Accordingly, the assessment has concluded that the GHG emissions impact of the Scheme would not have a material impact on the UK Government meeting its carbon reduction targets.”
M54 to M6 Link Rd	WM	“Indeed, emissions arising as a result of the Scheme represent less than 0.01% of total emissions in any five-year carbon budget during which they arise. In this context, it is concluded that the GHG impact of the Scheme would not have a material impact on carbon reduction targets as set by the UK government.”
A38 Derby	EM	“Indeed emissions arising as a result of the Scheme represent less than 0.01% of total emissions in any five year carbon budget during which they arise. In this context, it is concluded that the GHG impact of the Scheme would not have a material impact on carbon reduction targets as set by the UK government.”
A14 Cambridge to Huntingdon	E	“The additional operational emissions of the scheme represent only 0.0043% and 0.012% of the third and fourth national carbon budgets respectively. Those percentages are considered to be negligible and have no bearing on the likely achievement of the relevant policy objectives.”
A303 Stonehenge	SW	“Indeed emissions arising as a result of the Scheme represent less than 0.03% of total emissions in any five year carbon budget during which they arise. In this context it is concluded that the GHG impact of the Scheme would not have a material impact on the Government meeting its carbon reduction targets.”
A27 Arundel Bypass	SE	“..all Scheme options represent less than 0.004% of any of the current UK carbon budgets. All Scheme options represent between 0.07 and 0.14% of emissions from West Sussex in 2016, and less than 0.5% of emissions from West Sussex A roads in 2016.” [Tables 14-29 and 14-30 assesses significance as ranging from negligible adverse to moderate adverse]
Lower Thames Crossing	SE	“In the context of the total UK emissions from transport modes presented in Table 16.4, and the UK carbon budget, it is considered unlikely that the Project alone would have a significant adverse effect on climate change. However further calculations to determine carbon emissions during the operational phase of the Project, including cumulative effects, will be undertaken and reported within the ES.”

There are three flaws with the current approach to assessing the carbon impacts of individual road schemes. First, the denominator (i.e. the comparison with emissions across the whole economy) is inappropriate, since it is true of almost any single investment that its impact is small relative to the emissions of the economy as a whole. There should be a strategic assessment which looks at the carbon emissions from the whole programme in the context of a transport carbon budget. At the scheme level, a comparison with a Paris-compliant carbon budget for road transport emissions in the local authority area in which the scheme is proposed would be more relevant.

Second, the denominator used for this comparison is in any event out of date and too high, as it was set before the Paris Agreement and the government legislated for net zero emissions by 2050 and is based on out of date carbon budgets.

And finally, the method used to assess a scheme’s carbon impact does not take full account of likely increases in emissions over time due to induced traffic and car-based development, and so the carbon impact is systematically under-estimated. The failure of transport modelling to properly account for induced traffic is a longstanding concern, and we summarise in Table 3 the main issues as they relate to assessment of the carbon impact of road schemes. More detail on these points is given in section 6.3.

Table 3: How evaluation and appraisal underestimate carbon emissions from induced traffic

Post-opening project evaluation (POPE) is not robust	When Highways England evaluates whether a new road scheme has caused induced traffic, it compares actual traffic volumes after construction to a prediction of what would have happened to traffic “without” the scheme. However, the prediction of what would have happened without the scheme is based on inaccurate forecasts which systematically overstate the general rate of traffic growth. The evaluation thus understates the amount of induced traffic, i.e. the difference between traffic volumes “without” and “with” the scheme.
Modelling is more of an art than a science	When a road scheme is proposed, the effect of it on specific behavioural responses is modelled. Models always allow for route changes, and generally consider changes in mode and destination. But models are weaker in taking account of more complex changes – for example, changes in car occupancy, consequential land use, and effects on trip rates. These are exactly the features which may lead to induced traffic. There is a lot of discretion for promoters to judge qualitatively which features are important and should be modelled.
Long-term effects are not considered	Post-opening project evaluation (POPE) only collects and analyses traffic flow data for one and five years after a road scheme opens; and models are particularly poor at taking account of longer term effects (such as changes in land-use facilitated by changes in travel opportunities). This means that long-run induced traffic effects are under-recorded and under-predicted.

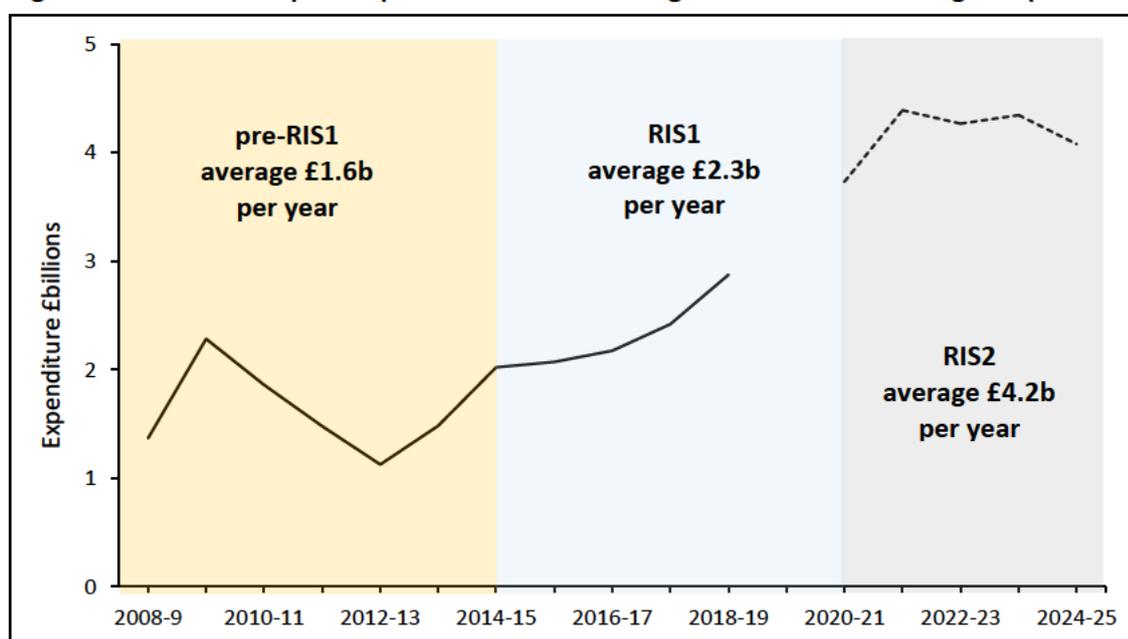
5. Scale of the roads programme

Carbon emissions as a result of RIS2 are of growing concern because the programme itself is now bigger than it has ever been, as shown in Figure 4.

In the six years to 2013, capital expenditure on the SRN averaged £1.6 billion per year (2018-19 prices)²⁰.

In 2013, the Treasury signalled the government’s intention to “commit to the biggest programme of investment in roads since the 1970s”²¹. DfT subsequently allocated more than £15 billion to Highways England for the first Road Investment Strategy, RIS1, covering the period between 2015 and 2020²². This budget covered both capital expenditure and operational costs. From 2014-15 to 2018-19, outturn capital expenditure averaged £2.3 billion per year (in 2018-19 prices).

Figure 4: Real-terms capital expenditure on the Strategic Road Network in England (£billions)



Data from 2008-09 to 2018-19 is for national roads in England funded by central government, from Country and Regional Analysis Interactive Tables adjusted to 2018-19 prices. Data for 2020-21 to 2024-25 from RIS2 Statement of Funds Available.

In the autumn 2018 budget, the Chancellor went further, announcing that the government would deliver “the *largest ever* strategic roads investment package from 2020-2025”²³ [our italics]. Income from Vehicle Excise Duty was ring-fenced to form a National Roads Fund to pay for this. Budget 2020 confirmed that RIS2 would cost £27.4 billion over five years (see Table 4). Total capital expenditure would average £4.2 billion per year. Of this, £14.2 billion (average £2.8 billion per year) was allocated to be for capital enhancements i.e. road schemes.

Highways England’s draft Strategic Business Plan presumes that funding will continue at the high level set by RIS2 until at least 2034/35. The Office for Rail and Road’s Efficiency Review of RIS2²⁴ shows that Highways England is working to create a pipeline of road schemes which will lead to expenditure of over £28 billion in RIS3 (2025/26 – 2029/30) and over £31 billion in RIS4 (2030/31 – 2034/35).

Table 4: RIS2 Statement of Funds Available

Item (£000s)		2020/21	2021/22	2022/23	2023/24	2024/25	Total
Operations, maintenance, renewals and business costs	Resource	1,201	1,160	1,199	1,221	1,293	6,074
	Capital	1,098	1,145	1,113	1,276	1,193	5,825
Capital enhancements		2,475	3,076	2,980	2,885	2,702	14,118
Designated funds		159	169	174	184	184	870
Preparing for RIS3		39	59	107	142	124	472
RIS2 Total		4,973	5,609	5,572	5,708	5,496	27,358

Source: DfT (2020) Road Investment Strategy 2: 2020-2025. Funding for road schemes is highlighted in grey.

The National Roads Fund (announced in 2014 but still not legislated) is also intended to provide £3.5 billion for road schemes on local authority roads, through a Major Road Network programme and a Large Local Majors programme²⁵. This funding will be provided over the same period as RIS2 (2020-2025), but has not yet been allocated between years. It is in addition to an extra £2.5 billion for local road maintenance, announced in the Spring 2020 Budget²⁶.

Other government funding streams are also being used for road-building. For example, we estimate that the Housing Infrastructure Fund may provide additional funding for road schemes of about £1.8 billion between 2018-19 and 2023-24²⁷. There is also significant government funding for road schemes via the Local Enterprise Partnerships (LEPS)²⁸.

This increase in spending on roads represents a huge opportunity cost in terms of foregone investment in active and sustainable travel, at a time when we need to rapidly reduce carbon and other impacts of road traffic.

Road schemes **increase carbon** in multiple ways



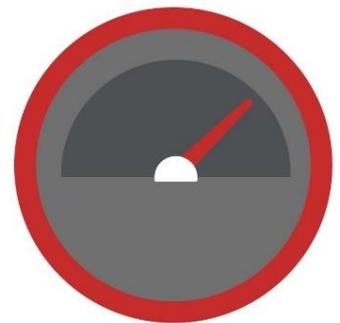
Land clearance - many trees are felled and carbon 'sinks' are lost.



Embodied carbon in steel, concrete and asphalt used to build roads.



Higher speeds - an increase in average speeds from 60mph to 70mph causes carbon emissions to go up by about 13%.



Induced traffic - Increased road capacity generates more traffic and more car-dependent housing estates, retail parks and business parks



*Illustrations by Mair Perkins
Source: Transport for Quality of Life*

6. How RIS2 schemes will affect carbon emissions

RIS2 road schemes will increase carbon emissions in several ways. Some impacts are one-off; some are ongoing at about the same level; and some are both ongoing and increase over time. Table 5 summarises the main factors, and indicates which of these are probably already accounted for in Highways England’s estimates, and which are likely to be underestimated.

Table 5: How RIS2 road schemes will affect carbon emissions

Factor	Accounted for in HE estimates	Description
Land clearance	Y	If there is extensive land clearance and many mature trees are felled, a carbon ‘sink’ will be removed. Over the medium term (e.g. between now and 2030), it is not possible to offset this by replacement planting of saplings, which will take many years to mature and capture significant amounts of carbon.
Construction materials	Y	One-off impact of embodied carbon in the steel, concrete, asphalt and other raw materials used to build the road.
Construction activity	Y	There are emissions associated with fuel, electricity and water used to clear the site and build the road, as well as fuel used to transport workers, materials and waste to and from the site.
Vehicle speed	Y	Once a road is completed, it may increase vehicle speeds. Carbon emissions for petrol / diesel vehicles are lowest at speeds of about 40mph. An increase in average speed from 60mph to 70mph causes carbon emissions to rise by about 13% ²⁹ . This is an ongoing impact ⁱⁱⁱ . In congested locations with average speeds <i>below</i> 40mph, a road scheme that increases speeds to around 40mph could temporarily reduce speed-related emissions – at least, until induced traffic causes average speeds to fall back to the original level.
Induced traffic	N (may be partially taken into account for some schemes)	Over the medium- to long-term, roads which increase the capacity of the network are likely to result in increases in traffic volume, relative to what would have happened if the road had not been built. This is due to a combination of factors: mode change, destination change, trip frequency change, and changes in land use as the road opens up land for car-dependent development such as housing estates, retail parks and business parks. The carbon impact of this induced traffic is ongoing and increases over time.
Large-scale regional effects	N	At a regional level, the combined effect of all new road schemes on traffic volumes, and therefore carbon emissions, may be substantially greater than the sum of the effects of each individual scheme. For example, dualling individual sections of a single-carriageway A-road may have a fairly modest impact on traffic volumes until such time as the road is dualled from end to end, at which point it may quite quickly attract large amounts of extra traffic.

ⁱⁱⁱ It also has an effect on casualty rates, as highlighted in a recent [REDACTED] issue, which argued for a reduction in speed limits on main roads to 50mph in order to free up health service capacity for COVID-19 work.

This was seen in the case of the Newbury bypass, which was the final ‘upgrade’ on a N-S corridor: traffic volumes on the new road and the existing road jumped by almost 30% within a year of scheme completion³⁰.

Cumulatively these carbon impacts across the RIS2 programme are significant but are currently not assessed and effectively ignored. We used two sources of official information to estimate the overall effect of these factors for the whole of the RIS2 programme:

- Publicly-available **Environmental Statements** for RIS road schemes, downloaded from the website of the Planning Inspectorate³¹. These are available for a relatively small number of schemes (15 with suitable data for our analysis). Most include an assessment of carbon emissions from construction. They also include modelled change in carbon emissions due to use (reflecting modelling assumptions about changes in vehicle speeds, but, as noted above, probably significantly underestimating induced traffic and not taking account of large-scale regional effects). Estimated changes in emissions in use are typically reported for the scheme opening year and the “design year” 15 years later, though sometimes a total over 60 years of the lifetime of the scheme is reported as well or instead of these annual figures.
- **Post-opening project evaluation (POPE)** reports for all Highways England road schemes. These are available for 87 road schemes built over the last two decades. The “One Year After” and subsequent “Five Year After” POPEs estimate the outturn change in carbon emissions in the scheme opening year (relative to what would have happened “without” the scheme). This takes account of changes in vehicle speeds (and also link length and traffic composition), but since it is for the scheme opening year, cannot take account of medium- or long-run induced traffic or large-scale regional effects (and probably also underestimates short-run induced traffic). Total carbon emissions in the scheme opening year are also reported, and we make use of these figures to estimate plausible emissions from medium-to-long run induced traffic.

We made the assumption that the road schemes that will form RIS2 are likely to be broadly similar to the schemes built by Highways England in the recent past, and that the main differences are the increased scale of funding for the programme, and the improvement in average vehicle efficiencies.

6.1 Carbon emissions from construction

Most Environmental Statements for planned road schemes include an assessment of the one-off increase in carbon emissions from construction.

The construction impacts of road building arise from land use changes (e.g. site clearance and loss of trees, disturbance of soil); embodied emissions associated with the materials (e.g. steel, concrete, asphalt); fuel, electricity and water associated with plant and equipment used in clearance and construction; travel of construction workers to the site; and transport of construction materials and waste. These emissions are generally estimated using the Highways England Carbon Tool³² (published in 2015 and updated in 2019) and guidance set out in a British Standards Institute specification³³.

Relevant chapters of all publicly available Environmental Statements for Highways England road schemes were downloaded from the Planning Inspectorate website^{iv}. Of these, 11 (with a combined

^{iv} Most of the publicly available Environmental Statements for road schemes on the SRN form part of the RIS2 programme. A few are formally “RIS1 schemes” in terms of their funding, but are now programmed for construction during the RIS2 time period.

cost of £5.3 billion) reported CO₂ emissions from construction. Embodied emissions accounted for 31% - 97% of the total greenhouse gas emissions from construction of the road schemes, with an average of around 70%. Construction carbon ranged from 60-730 tCO₂e per £1 million expenditure, with an average of 456 tCO₂e per £1 million.

If we assume that these 11 schemes are representative of the likely construction impact of RIS2 schemes, the £14,118 million expenditure on RIS2 road schemes will generate around 6.4 MtCO₂e from construction.

6.2 Carbon emissions from changes in vehicle speeds

Eighty out of the 87 schemes for which a POPE was available included an assessment of the change in carbon emissions in the scheme opening year due to the scheme. Reported changes in carbon emissions increased for 72 schemes and went down for 8 schemes.

For most schemes, the method used to estimate changes in emissions is a simple spreadsheet model³⁴. It takes account of changes in average speeds “with” versus “without” the scheme, and also of any changes in road length and traffic composition. While it is reported that the method also takes account of changes in traffic flows (“with” versus “without” the scheme), medium- to long-term induced traffic effects cannot be included, since the calculation is for the scheme opening year. It is also unlikely that the method takes full account of short-term induced traffic effects, for reasons noted in Table 3 above and discussed further in section 6.3. Emissions due to scheme construction are not included. Essentially, this means that we can treat the reported change in emissions in the scheme opening year as being largely the result of changes in average vehicle speeds.

For each scheme, we factored the reported change in opening year carbon emissions downwards, to reflect current (2018) average vehicle efficiencies. For example, emissions from schemes completed in 2003 were factored downwards by 0.88; emissions from schemes completed in 2010 were factored downwards by 0.94. These factors were calculated using UK CO₂ emissions from all road travel, and road traffic vehicle kilometres for all vehicles, for each year from 2002 to 2018³⁵.

Added together, the scheme opening year change in emissions from all 80 schemes, adjusted to reflect current vehicle efficiencies, totalled 389 ktCO₂. Expenditure on these schemes was £7.9 billion (in 2020 prices). These figures give an increase in scheme opening year emissions of 49 tCO₂ for each £1 million expenditure (in 2020 prices).

This increase in emissions is ongoing i.e. it will occur not just in the scheme opening year but also in subsequent years. However, emissions in subsequent years will fall due to improvements in vehicle efficiency. We used the DfT Road Traffic Forecasts (RTF) to estimate by how much the annual change in emissions would fall in each year between 2020 and 2032 (i.e. the period for which we propose a Highways England carbon budget). Using RTF Scenario 1 (the “reference scenario”), average emissions would fall by 21% between 2020 and 2032. Using RTF Scenario 7 (with the most rapid growth in use of electric vehicles), emissions would fall by 41%.

Cumulative emissions between 2020 and 2032 were calculated, for each £1 million capital enhancement expenditure in each year of RIS2, on the assumption that the carbon effect of changes in speed, link length and traffic composition is ongoing, but diminishes over time due to improving average vehicle efficiency. The results are shown in Table 6. Expenditure early in the RIS2 period has a larger cumulative effect in the period of interest (2020 to 2032) than expenditure later on. The additional emissions between 2020 and 2032 are calculated as 6.6 MtCO₂ using vehicle efficiency factors based on RTF Scenario 1, or 5.9 MtCO₂ using vehicle efficiency factors based on RTF Scenario 7.

Table 6: RIS2 expenditure, and cumulative CO₂ emissions between 2020 and 2032 due to changes in vehicle speed, link length and traffic composition from schemes built in each year of RIS2

Year of scheme construction		2020	2021	2022	2023	2024	TOTAL
RIS2 capital enhancement expenditure £m		2,475	3,076	2,980	2,885	2,702	14,118
Cumulative emissions (Mt CO₂)	RTF Scenario 1	1.39	1.58	1.38	1.21	1.00	6.56
	RTF Scenario 7	1.28	1.44	1.25	1.08	0.89	5.95

We cross-checked this estimate from completed road schemes against modelled predictions from RIS road scheme Environmental Statements.

A total of 12 publicly available Environmental Statements included predicted CO₂ emissions from operation in the scheme opening year and the “design” year (15 years later). These 12 schemes overlapped with, but were not identical to, the ones for which construction emissions were reported (see section 6.1) and had a combined cost of £5.2 billion.

The modelled changes in CO₂ emissions (“with” versus “without” the scheme) in the scheme opening year and “design” year enabled us to estimate the change in emissions for intervening years by interpolation. The modelling appears to take account of changes in average speed, link length and traffic composition. Given the extended time period that is being modelled, it is possible that some element of induced traffic has been taken into account. However, the change in annual emissions over this period is very small for most schemes, suggesting that, in most cases, (with the single exception of the A303 Stonehenge scheme), little or no induced traffic has been allowed for. Cumulative emissions were calculated for each scheme over 13 years (equivalent to the 13 years from 2020-2032 inclusive for which emissions were estimated using POPE data from completed road schemes). Cumulative emissions over this period ranged from -35 to +1754 tCO₂e per £1 million, with an average of 410 tCO₂e per £1 million. If this average is applied to the £14,118 million RIS2 road schemes, it suggests cumulative emissions from operation of 5.8 MtCO₂e over 13 years, which is similar to the estimates in Table 6 (although note that it is not exactly equivalent because the calculations shown in Table 6 are based on staggered expenditure over a five year period). This cross-check suggests that our earlier estimate is plausible.

6.3 Carbon emissions from induced traffic

As noted earlier, changes in carbon emissions in the scheme opening year reported in POPEs are likely to underestimate any short-term induced traffic effects, and take no account of medium- to long-term induced traffic.

The method used in the POPEs to estimate traffic flows “with” the scheme versus those “without” relies on national road traffic forecasts to predict what traffic flows would have been expected if the scheme had not been built. This is a form of evaluation which is categorised by the government’s Magenta Book guidance on evaluation as “weaker / riskier”³⁶, because there is no comparison with changes in traffic flows at similar locations where no road building has occurred. Since national road traffic forecasts have repeatedly over-estimated traffic growth, using a “do-nothing” forecast as the counterfactual is highly unreliable, and is likely to substantially understate the amount of induced traffic. This is the main reason why Highways England argue that their POPEs show relatively little evidence of induced traffic. For example, a recent “meta-insights” paper by Highways England

examined the POPEs for a sample of 71 schemes, and (using this “weaker / riskier” research design) concluded that evidence of induced traffic was observed in only a quarter (24%) of schemes³⁷.

A further weakness of the Highways England POPE methodology is that no evaluation of longer-term induced traffic effects, over periods of more than five years, is undertaken. Since large-scale regional induced traffic effects may occur over much longer time periods of a decade or more, the POPE meta-insights finding that only a minority of schemes show evidence of induced traffic is more likely “absence of a search for evidence” rather than “evidence of absence”.

In an earlier study, we evaluated changes in traffic flows from road schemes by comparing with regional and county-level traffic trends³⁸. In a sample of nine schemes across England, plus four longer-term case study schemes, use of this method found evidence of induced traffic (defined as traffic growing in the scheme corridor at a higher rate than in the relevant region and county) for all 13 schemes. The rate of traffic growth in excess of background regional / county trends was fairly modest in the short-term (averaging about 7% over periods of 3-7 years) but much larger in the longer-term (averaging about 40% over periods of up to 20 years). The combined data from these 13 schemes suggests induced traffic might on average increase at around 2% per year, although it would be expected that some schemes might show higher rates, and some lower. However, it should be noted that the time period on which this estimate is based includes the 2008 economic downturn, following which there was a hiatus in new development. It may therefore be an underestimate of the amount of induced traffic in periods of normal economic activity.

These findings are consistent with analysis in 1994 by the Standing Advisory Committee on Trunk Road Assessment (SACTRA) on trunk roads and the generation of traffic³⁹. SACTRA reported 11 before-and-after studies in which traffic levels were compared with background general traffic growth, or with growth on specific control (unimproved) roads in the same area. In every case, the growth rate in the corridor of the scheme was substantially greater than that on the roads used as controls, and greater than background growth rates, with an unweighted average of “unexplained” growth of 25%, and a range from 7% to 66%. The unweighted average of the growth rates over less than a year was 9.5%, increasing to 33% after 5 years.

More recently, a 2018 evidence review on induced traffic, commissioned by DfT to inform the development of RIS2, supports the findings of the SACTRA report on induced traffic⁴⁰. It also notes the inaccuracy of “do-nothing” scheme forecasts, citing a statistical analysis of 20 road projects in the UK and 15 in Denmark, for which the “do-nothing” case could be empirically established (for example, schemes for which “do-nothing” forecasts were made, the scheme was cancelled, and “do-nothing” outcomes could then be observed). A systematic bias was found towards overstating the forecast of “do-nothing” demand.

In order to estimate the possible effect of induced traffic on carbon emissions at the programme level for RIS2, we checked the POPEs for all 87 road schemes for the *total* carbon emissions in the scheme opening year. POPEs for 63 schemes reported this figure (a subset of the 80 schemes for which the change in carbon emissions was reported).

For each scheme, we factored total carbon emissions in the opening year downwards to reflect current average vehicle efficiencies, in the same way as described in section 6.2. Opening year total emissions from all 63 schemes, adjusted to reflect current vehicle efficiencies, were 4.2 MtCO₂, and expenditure on these schemes was £6.9 billion (in 2020 prices). These figures give an opening year figure of 613 tonnes CO₂ for each £1 million expenditure (in 2020 prices).

We made the assumption that induced traffic would be zero in the year the scheme was completed; 2% of opening year traffic in the year after the scheme was completed; and rising by 2% per year to

24% of opening year traffic 12 years after scheme completion. We then used the same assumptions from RTF Scenarios 1 and 7 described in section 6.2 to estimate cumulative emissions due to induced traffic for the period between 2020 and 2032, for each £1 million expenditure in each year of RIS2, assuming, as before, that the carbon effect of each extra kilometre of induced traffic would diminish over time due to improvements in vehicle efficiency. The results are shown in Table 7. As before, expenditure early in the RIS2 period has a larger cumulative effect in the period of interest (2020 to 2032) than expenditure later on. The additional emissions between 2020 and 2032 are 8.0 MtCO₂ using vehicle efficiency factors based on RTF Scenario 1 or 6.9 MtCO₂ using vehicle efficiency factors based on RTF Scenario 7.

These figures are sensitive to the assumed rate of increase of induced traffic. If induced traffic increases at only 1% per year, additional emissions are 3.4 - 4.0 MtCO₂, and if induced traffic increases at 3% per year, additional emissions are 10.3 - 12.0 MtCO₂. Induced traffic is likely to be higher if land use planning policy is more permissive (i.e. allowing more out-of-town car-dependent development). The shift towards more permissive planning policy by the current government means that it is plausible that cumulative emissions from RIS2 could be in the higher range of 10 – 12 MtCO₂.

Table 7: RIS2 expenditure, and cumulative CO₂ emissions between 2020 and 2032 due to induced traffic, from schemes built in each year of RIS2

Year of scheme construction		2020	2021	2022	2023	2024	TOTAL
RIS2 capital enhancement expenditure £m		2,475	3,076	2,980	2,885	2,702	14,118
Cumulative emissions (Mt CO₂)	RTF Scenario 1	1.98	2.07	1.66	1.31	0.97	7.99
	RTF Scenario 7	1.74	1.80	1.43	1.11	0.82	6.89

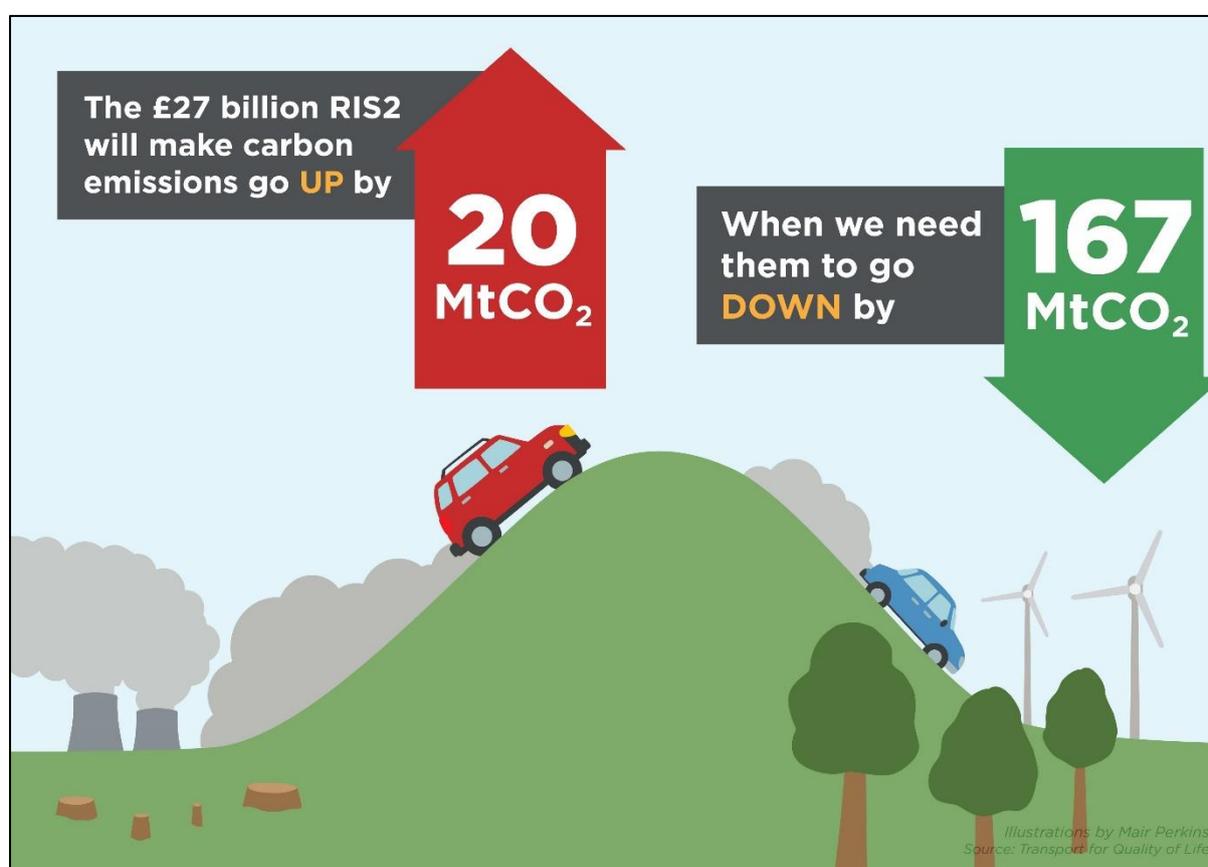
7. Discussion and conclusions

Table 8 summarises our findings on the potential increase in carbon emissions due to RIS2 schemes.

RIS2 schemes could increase cumulative emissions from the SRN between 2020 and 2032 by around 19 – 21 MtCO_{2e}, as a result of emissions from construction, higher speeds and induced traffic^v.

This compares with our suggested Paris-compliant carbon budget for the SRN over the same period of 214 MtCO₂. The additional carbon emitted as a result of RIS2 could therefore use up around 10% of the proposed carbon budget for the SRN over the crucial period when we most need to reduce our carbon emissions.

Another way of putting this is that RIS2 will make carbon emissions from the SRN *go up*, by about 20 MtCO₂, during a period when we need them to *go down*, by about 167 MtCO₂.



Comparing forecast emissions from the SRN in RTF Scenarios 1 (the reference scenario) and 7 (the high electric vehicle scenario) suggests that the estimated increase in CO₂ from RIS2 will negate 80% of the potential carbon savings from electric vehicles on the SRN (which is 25 MtCO₂, i.e. 406 minus 381 MtCO₂, between now and 2032). The roads programme will thus negate almost all of the effort that will go into reducing SRN emissions by stimulating take-up of electric vehicles.

^v Note that estimates of increased emissions from higher speeds and induced traffic are for CO₂, but a small part of the estimated emissions from construction is from other (non- CO₂) greenhouse gases, and hence reported as CO_{2e}.

This suggests that RIS2 is incompatible with our legal obligation to cut carbon emissions in line with the CCA carbon budgets, the Paris Climate Agreement and the emerging principles for the DfT’s decarbonisation plan. We therefore believe that RIS2 should be cancelled.

Highways England’s high expenditure on road schemes during RIS2 is set to continue, at a similar rate, for at least a decade after the end of RIS2. This will lead to further increases in carbon emissions.

Table 8: Estimated carbon emissions from RIS2 compared with proposed carbon budget for the SRN over the period 2020-2032

	Cumulative carbon emissions 2020-2032 (Mt CO₂)
Forecast emissions from SRN (Scenarios 1, 7), 2020 - 2032	381 - 406
Proposed carbon budget for SRN 2020-2032	214
Emissions from RIS2 construction	6.4
Emissions from higher speeds on RIS2 roads	6.0 – 6.6
Emissions from induced traffic on RIS2 roads	6.9 – 8.0
Total increase in emissions from RIS2	19.3 – 21.0
Proportion of proposed SRN carbon budget 2020-2032 consumed by RIS2	9 – 10%

But it would be an illusion to think that merely cancelling the roads programme funding will of itself mean we keep carbon emissions from the SRN within a Paris-compliant carbon budget. The scale of emissions cuts that is required on the SRN in response to the climate emergency is extremely challenging. We believe that it will only be possible through a combination of a faster switch to zero exhaust emission vehicles than is currently being considered (e.g. requiring all new cars and vans to be fully electric from 2030) *and* a significant reduction in vehicle mileage on the SRN. Further carbon could be saved by reducing the speed limit on the SRN to 60mph, with camera enforcement.

Mileage reduction will require measures to restrict driving, such as road pricing⁴¹, better and more affordable rail and coach services, improvements in conditions for active travel (since many journeys on the SRN could be replaced by a combination of cycling and rail travel), better planning to prevent car dependent development and universal roll-out of superfast broadband to support remote working.

The reduction in traffic that would result from these policies would reduce the perceived need for road building to alleviate congestion. At present, the roads programme only gets a (weak, disputed) cost-benefit ‘justification’ due to the presumption that it will cater for traffic demand growth that will happen anyway. If there are carbon-related (or congestion or health-related) reasons for policies that reduce the growth in demand, the benefit-cost ratios for road schemes will drop, and much of the roads programme will not be justified even on its own criteria. In other words, once the policy imperative to reduce traffic mileage is accepted, cost-benefit analysis is unlikely to show RIS2 schemes are value for money.

The COVID-19 pandemic has wrought enormous behaviour change, with both work and non-work journeys replaced by a variety of video conferencing solutions and greater use of local facilities. In the process, it has generated new debates – for example, about the time ‘wasted’ by commuting or travelling to business meetings by those who have the flexibility to work remotely; about the benefit

of families all being home in the early evening to eat meals together; about the potential to involve more colleagues in work meetings, or people in different parts of the country in social events; about the opportunity for more regular interactions with elderly relatives where a reliable teleconference link is possible; about the role for local delivery services (both commercial and community-based) to ensure vulnerable residents can access what they need; about the advantages/disadvantages of people's immediate local environments for taking daily exercise etc.. Whilst the lifting of lockdown is likely to be welcomed, it is unlikely that things will revert to how they were before the pandemic. Improved understanding of technology; experience of new ways of working and socialising; and a greater appreciation of local environments will all affect future travel habits.

When rebuilding the economy, it is vital that investment helps to support behavioural shifts that people may wish to maintain in the future for a wide variety of reasons, that can also help to achieve reductions in carbon emissions.

In this new context, RIS2 is anachronistic. Instead, money saved by cancellation of RIS2 funding would free up substantial investment for a variety of more efficient and low carbon ways of meeting our everyday needs. In the short term, funding could be used to develop thousands of local 'remote working' hubs. These would enable businesses to start to function again while maintaining social distancing, would reduce the difficulties many people face when working at home, and would avoid an increase in carbon emissions and congestion as commuters shift from public transport to car.

In the medium term, funding could enable universal superfast broadband, providing a more efficient and low-carbon way of meeting our everyday needs. Even the President of the AA has recently been quoted as supporting a shift in funding from road infrastructure to broadband services⁴². Funding could also be used to improve active travel and public transport networks, thereby reducing congestion on the SRN in a more effective, sustainable and permanent way.

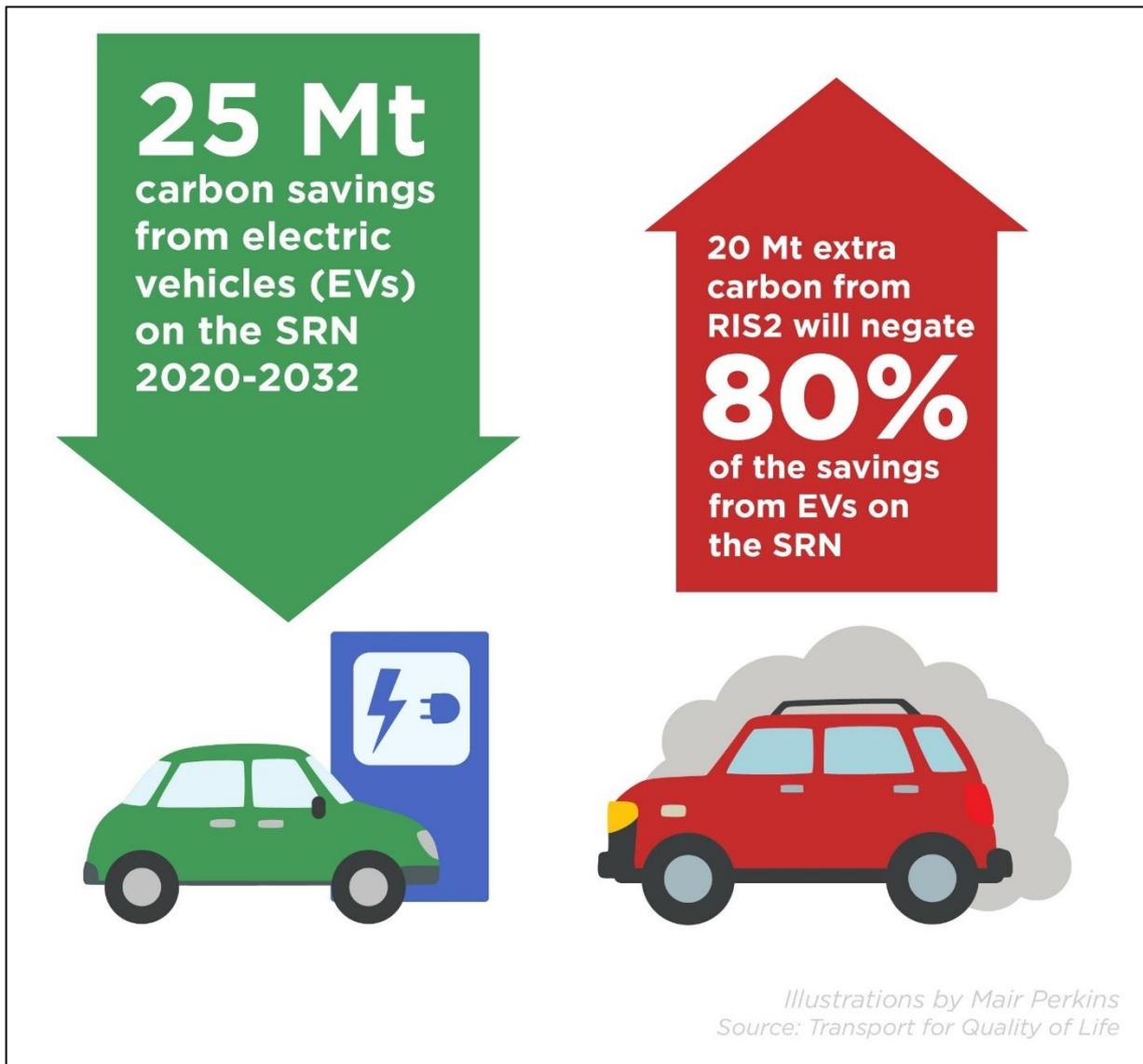
One of the contributors to this paper has argued elsewhere that a complete rethink of the way the road programme is appraised is now required, in order to take full account of carbon emissions⁴³. This should include appraisal of the programme as a whole; a new approach to appraisal of individual schemes; and comparison of each scheme (and of the whole programme) with its alternatives. It requires all of the following:

Strategic

- Setting of a binding carbon budget for the SRN, and assessment of the cumulative impact of RIS2 road investment against this carbon budget.
- Recognising that legally-binding constraints on carbon emissions should take precedence over economic trade-offs e.g. between more carbon and shorter journey times.

Appraisal and evaluation

- Better evaluation of the short, medium and long-term impact of road schemes on induced traffic, using a robust methodology to estimate the counterfactual, and incorporation into scheme appraisal of realistic assumptions (derived from new evaluation evidence) about the likely level of induced traffic from proposed schemes.



- Abandoning the practice of using shadow prices based on marginal abatement costs, for the non-marginal impact of higher carbon emissions.
- Systematic definition and consideration of alternative ways of solving transport problems, at both scheme level and programme level.

Scheme level

- Assessment of individual schemes against a local carbon budget for road transport in the local authority areas where they are proposed.
- Assessment of individual schemes against a future in which other policy instruments have reduced traffic volumes to a level consistent with the SRN carbon budget (in which future, traffic congestion would also be much less).

In this context, we argue that the roads programme is having a material impact on the ability of government to meet its carbon reduction targets, that better policy options are available, and that this means that RIS2 as it is currently conceived should be halted now. Instead, future investment should focus on schemes designed to reduce carbon emissions, given the need to ensure that the UK is prepared for, and resilient to, the challenge of climate change.

¹ Department for Transport (2020)

² Figures for transport include international aviation and shipping, which are often omitted from transport carbon budgets. This is different to Figure 2 in the DfT's report which shows domestic transport only. If emissions from international aviation and shipping are included, transport was responsible for over a third (34%) of UK greenhouse gas emissions in 2018, whereas if international aviation and shipping are excluded domestic transport was responsible for 28% of UK emissions in 2018 .

³ There are no up to date figures showing emissions on the SRN or type of road making comparison with overall UK figures difficult. However, the government's include data for CO₂ by type of road in 2015 (in practice 99% of road transport greenhouse gas emissions are CO₂). This estimates that emissions from the SRN in England in 2015 were 35.6 MtCO₂, equivalent to around 29% of the (122.2 MtCO₂) in 2015.

⁴ Department for Transport (2018) Road Traffic Forecasts: figures for England, 2015

⁵ Committee on Climate Change (2020) June 2020.

⁶ The DfT's report shows a 16 MtCO_{2e} gap in 2032 between emission levels set out in the Clean Growth Strategy (83 MtCO_{2e}) and DfT's current policy projections (assume 99 MtCO_{2e}). The Committee on Climate Change's (CCC) has already shown that there is a further gap of 21 MtCO_{2e} in 2032 between the emission levels under the Clean Growth Strategy and target transport emissions under the fifth carbon budget (62 MtCO_{2e}). The CCC's contains an indicative net zero reduction pathway equivalent to a 68% reduction in emissions by 2032 compared to 1990 levels. This means that a net zero target for domestic transport would be around 41 MtCO_{2e} in 2030 (while a net zero target for total transport would be around 49 MtCO_{2e}). In other words **there is a gap of 58 MtCO_{2e} in 2032** between DfT's current policy projections and what is required under a net zero budget. This gap should widen further due to the addition of International Aviation and Shipping into budgets, as recommended by the CCC, unless their emissions are cut by 68% over the same period.

⁷ Anderson K. (2019)

⁸ Pye S, Li F, Price J and Fais B (2017)

Nature Energy, 2, 17024

⁹ Jackson T (2019)

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¹⁰ Hopkinson L and Sloman L (2019)

¹¹ Anable J and Goodwin P (2019) Chapter 4, Transport and Mobility, in

Report by Centre for Research in Energy Demand Solutions, CREDS

¹² Stark C. (2020) Interview with the BBC, 21 April 2020.

¹³ Hopkinson L. and Sloman L. (2019)

¹⁴ To take account of rising emissions from the energy and industry sectors due to the rising use of electric and hydrogen vehicles, this carbon budget should be based on both source and end user emissions. The latter attributes emissions in accordance with where the activity occurs so that the emissions from electricity used to power electric vehicles will be attributed to transport rather than energy. While electric vehicles have considerably lower lifetime greenhouse gas emissions than conventional vehicles, as they become a larger percentage of the fleet they will account for a greater proportion of emissions associated with energy production. In 2016 road transport greenhouse gas emissions were 114 MtCO_{2e} by source and 126 MtCO₂ by end user. This gap will grow with increasing electrification of the fleet and use of hydrogen for fuel.

¹⁵ The presents climate change targets for UK local authority areas that are based on the commitments in the United Nations Paris Climate Agreement, informed by the latest science on climate change and defined by science-based carbon budget-setting. These are the budgets that most local authorities are working towards. The budgets apply to CO₂ only rather than other greenhouse gases but road transport climate impacts are driven largely by CO₂ emissions.

¹⁶ Apart from the

(2014) which considered this at a high level, combining predicted benefits from rail electrification and Electric Vehicles with impacts from road building and stated that 'the expected positive impacts [on greenhouse gas emissions] outweigh the predicted negative impacts'.

¹⁷ Department for Transport (2014) paragraph 5.18.

¹⁸ The A585 Windy Harbour to Skippool RIS2 scheme was on 9 April 2020.

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- ¹⁹ Highways England (2019) A38 Derby Junctions TR010022 Volume 6 6.1 Environmental Statement Chapter 14 – Climate, section 14.10.
- ²⁰ HM Treasury [REDACTED] for 2013, 2016 and 2019.
- ²¹ HM Treasury (2013) [REDACTED]
- ²² Department for Transport (2015) [REDACTED]
- ²³ HM Treasury (2018) [REDACTED]
- ²⁴ Office of Rail and Road (2019) [REDACTED]
- ²⁵ Department for Transport (2018) [REDACTED]
- ²⁶ Transport Network [REDACTED] 11 March 2020
- ²⁷ Sloman L and Hopkinson L (2019) [REDACTED]
- ²⁸ LEPs manage the bulk of the capital funding for local transport projects. Since 2015-16 they have received £9.1 billion in local growth funding. In 2018-19 the majority (42%) of LEP funds was spent on transport. NAO (2019) [REDACTED] However there is very little transparency and accountability on how LEP funds are spent and previous analysis suggests much of their funding is spent on roads or car-dependent infrastructure.
- ²⁹ Personal communication from Jillian Anable and Christian Brand.
- ³⁰ Sloman L, Hopkinson L and Taylor I (2017) [REDACTED] section 7.2
- ³¹ [REDACTED]
- ³² Highways England (2019) [REDACTED]
- ³³ British Standards Institution (2011) PAS 2080:2016 Carbon Management in Infrastructure
- ³⁴ Carbon emissions for most schemes were assessed using the DMRB Screening Method (Design Manual for Roads and Bridges Volume 11 Section 3 Part 1 HA207/07)
- ³⁵ BEIS (2020) [REDACTED] and Department for Transport (2019) [REDACTED]
- ³⁶ HM Treasury (2012) [REDACTED]
- ³⁷ Highways England (2019) [REDACTED]
- ³⁸ Sloman L, Hopkinson L and Taylor I (2017) [REDACTED]
- ³⁹ Cited in Goodwin P and Noland R (2003) [REDACTED] Applied Economics 35, 2003, issue 13
- ⁴⁰ WSP and Rand Europe (2018) [REDACTED] Report for Department for Transport
- ⁴¹ Sloman L and Hopkinson L (2019) [REDACTED]
- ⁴² BBC (2020) [REDACTED] News article, 3 April 2020
- ⁴³ Goodwin P (2020) [REDACTED] Local Transport Today, 3 April 2020