UK DEPARTMENT FOR TRANSPORT COMMON ANALYTICAL SCENARIOS PAPER

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1. INTRODUCTION

'Uncertainty is the only certainty there is' (Paulos, 2003). This has only been reinforced in recent times (the Covid-19 pandemic, the war in Ukraine for instance) and will continue to hold in the future. Decarbonisation policy, regional imbalances, technological developments: all are areas of uncertainty that could significantly impact the transport sector.

In 2019, the UK Department for Transport (DfT) released the Appraisal and Modelling Strategy (Department for Transport, 2019), which included reflecting uncertainty over the future of travel as key theme. The importance of considering uncertainty in greater detail was reinforced by the Transport Analysis Guidance (TAG) Route Map (Department for Transport, 2020) and Route Map update (Department for Transport, 2021). Alongside the Route Map update, the DfT released an Uncertainty Toolkit (Department for Transport, 2021), which was a significant step forward in the application of uncertainty and scenario analysis. The Toolkit detailed types of uncertainty, how to conduct uncertainty analysis and present it effectively, as well as being the first introduction of the Common Analytical Scenarios (CAS).

Since the Toolkit's publication, the Department has worked to create a set of scenarios, for standard application in transport business cases. These provide 'consistent, off-the-shelf, cross-modal' comparators for schemes, which explore 'national level uncertainties' in the transport sector (Department for Transport, 2021). The development of a common set of appraisal scenarios was driven by the desire to see a more robust and consistent treatment of uncertainty in the appraisal of major schemes coming to investment committees. While scenario analysis has become more prevalent, the lack of consistency in the assumptions has made it challenging to compare how different uncertainties impact across schemes and consider the resilience of the DfT portfolio as a whole.

In the original publication of the Toolkit, six scenarios were listed, considering high and low trajectories for economic and demographic growth, regional imbalances, behavioural and technological change and decarbonisation. This has been expanded to seven scenarios, with two decarbonisation futures pictured, which alongside the core capture the key uncertainties that face the transport sector in the coming decades.

This paper will consider the creation of the scenarios, with focus on three scenarios: the Behavioural Change scenario and the two Decarbonisation scenarios. The CAS will be available by the time this is publicised for use by scheme promoters and transport modellers to consider in appraisal. The paper will also explain how to proportionately apply the CAS (which will be reiterated in TAG), as well as finally considering how to motivate a stronger focus on uncertainty in government decision making.

2. THE COMMON ANALYTICAL SCENARIOS

This section outlines the scenarios, including the inputs used in transport models to create them. More detail on the Behavioural Change and Decarbonisation scenarios is found in sections 3 and 4 of the paper. Please note that the Common Analytical Scenarios are not a statement of government policy, rather a reflection of the multiple directions in which travel patterns could evolve in the UK's future.

2.1 High and Low Economy scenarios

The High and Low Economy scenarios capture two opposite futures for demographic and economic change in the UK. In the High Economy scenario, productivity growth returns to its post-war trend, people become richer than is expected in central forecasts, and migration remains at high levels. Fertility and life expectancy increase in the population. On the other hand, in the Low Economy scenario, productivity growth fails to return to historic levels, and inward migration is subdued. These factors, combined with falling fertility and life expectancy, lead to a declining population and output trajectory.

The axes that are altered to create the scenarios are: Gross Domestic Product (GDP), Population and Employment. These are all standard inputs into transport models.

The High Economy scenario uses the ONS 2018-based High Population variant (Office for National Statistics, 2019)[1], which includes high fertility, life expectancy and migration assumptions[2]. A high variant of employment is calculated by scaling the core employment projection with the High Population variant projection. For GDP, a core GDP per capita growth rate is calculated, then 0.5 percentage points are added to each year's growth. This is then scaled back up to GDP level using the High Population variant.

For the Low Economy scenario, the ONS 2018-based Low Population variant (Office for National Statistics, 2019)[3] is used. Akin to the High Economy scenario, this is used to scale a core employment projection, to create a low variant. Core GDP per capita is again calculated, but this time 0.5 percentage points are taken away from each year's growth, and the values are scaled back up using the Low Population variant.

The High and Low Economy scenarios use standard prediction methods. They produce a fan of uncertainty similar to previous DfT scenario work, which now lies between the core and the upper and lower bounds of the uncertainty fan. They are the most common, comprehensible, and implementable scenarios in the CAS.

2.2 Regional scenario

The Regional scenario considers of future of "levelling up" (Department for Levelling Up, Housing and Communities, 2022). In this scenario, people leave London, the South East and East of England (henceforth the Wider South East) in search of more affordable housing. As a result, regions outside the Wider South East increase their relative competitiveness. This translates to lower employment and population growth in the Wider South East relative to the rest of the country.

To create this scenario, regional population projections were recalibrated so that:

- If a region outside of the Wider South East is growing slower than the average for Great Britain, the region appropriates the growth rate of Great Britain.
- If a region outside of the Wider South East is growing at or above the average for Great Britain, the region maintains its existing growth rate.
- If a region is in the Wider South East, its growth rate is adjusted down, so that the average growth rate for Great Britain is maintained.

This formula is used to calculate regional redistribution factors, which are applied to population, employment and household projections. When applying this methodology, it was found that several regions (for example those in the Midlands) were already growing faster than the average for Great Britain. This implies there is already some “levelling up” predicted in the Core scenario.

The Regional scenario maintains the same growth rate as the Core at the national level, so few changes can be seen when considering the scenario nationally. However, the scenario is expected to have more of an effect where regions see the greatest boost to growth (e.g. the North East), or where there is heavy reliance on growth in the Wider South East (e.g. a rail scheme in London).

2.3 Behavioural Change scenario

The Behavioural Change scenario is the only scenario to explicitly incorporate the Covid-19 pandemic. It supposes a world in which people embrace new ways of working, shopping and travelling. Trends, such as flexible and remote working, and online shopping, that emerged in the past decades, are accelerated by the pandemic. As a result, people travel less and for different reasons. To create the scenario, trip rates, driving license holding and Light Goods Vehicle (LGV, vans) trips are adjusted.

More detail on the Behavioural Change scenario can be found in section 3.

2.4 Technology scenario

The Technology scenario is one of the most challenging scenarios to model and appraise. It creates a future wherein technological progress leads to a rapidly electrified and autonomous road vehicle fleet. Car travel becomes more attractive than other modes, and the ability to work or relax whilst travelling makes travellers more amenable to traffic and longer journeys. At the same time, the vehicle fleet decarbonises, making road travel emissions less of an issue.

Trip rates, driving license holding, mileage splits, fuel efficiencies, values of time and vehicle occupancy are all adjusted to create this scenario. The trip rates of the elderly are increased towards that of an equivalent non-working and non-student person by purpose. Driving license holding universally increases towards 100% (in line with the uptake of Connected and Autonomous Vehicles), to simulate increased ability to use road vehicles. Values of time for Connected and Autonomous vehicles is decreased, along with vehicle occupancy, simulating a fleet of private, highly automated vehicles. Finally, the vehicle fleet (including lorries, vans and public sector vehicles) decarbonises in line with the Transport Decarbonisation Plan (TDP) High scenario.

This scenario is difficult to appraise, as it requires adjustments in both models and appraisal software, due to the assumptions around values of time, vehicle occupancy and fuel efficiencies. However, it creates an interesting and stretching future, where we decarbonise but focus on road travel, and actually become more accepting of traffic and longer journeys. It is the upper bound of traffic demand at the cross-modal, national level.

2.5 Vehicle-led and Mode-balanced Decarbonisation scenarios

The Vehicle-led and Mode-Balanced Decarbonisation scenarios explore the extremes of electric vehicle costs, alongside a decarbonising fleet. In the Vehicle-led Decarbonisation scenario, there is a high and fast uptake of electric vehicles, but the current cost advantage compared to petrol and diesel vehicles is maintained. This results in the demand for road travel increasing, so that the modal share of road travel is increased relative to the other modes. Meanwhile, the Mode-balanced Decarbonisation scenario also considers a future of high and fast uptake of electric vehicles, but with their costs equalised to the average of petrol and diesel. This removes the cost advantage, resulting in decarbonisation with a lower car mode share than in the Core and Vehicle-led Decarbonisation scenario.

More detail on the two Decarbonisation scenarios can be found in section 4.

3. BEHAVIOURAL CHANGE

The Behavioural Change scenario explores the impact of the pandemic alongside trends in trip-making and driving license holding in the previous decades. The trends are accelerated by the pandemic, allowing people to travel less and for different reasons. To create the scenario, trip rates, driving license holding and Light Goods Vehicle (LGV, vans) trips are adjusted.

Trip rates were severely impacted by the pandemic. In 2020, we assume trips are 71% of 2019 levels, and in 2021 they are 75%. These values were calculated as the pandemic was ongoing. Live mobile telecoms data from March 2020 to July 2021 was used to determine the severity of the drop in trip making due to pandemic restrictions and the persistence of the reduced level of trip making once restrictions lifted. The time series was adjusted for seasonality using data from the National Travel Survey[4]. In 2020, allowance was made for the broadly undisrupted trips in January and February, and in 2021, allowance was made for a recovery in trip making in its later months. To calculate the 'hysteresis' or permanent effect on trip making for 2022, the latest available data point was used (July 2021 at the time). A best estimate of 10% was chosen, meaning 10% of trips never return due to the influence of the pandemic.

From 2023 until 2041, trip rate trends by purpose from the 2010s are extrapolated. The annual average change on home-based trips per person can be seen in Table 1. Note that while rates for some trip purposes, such as holiday and day trips, do see increases, the majority decline.

Trip Purpose	Annual average change in trip rate
HB Work	-2.27%
HB Employer's Business (EB)	0.02%
HB Education	-1.56%
HB Shopping	-1.77%
HB Personal Business (PB)	-1.14%
HB Recreation / Social	-0.46%
HB Visiting friends & relatives	-1.81%
HB Holiday / Day trip	0.48%

Table 1 Behavioural Change Trip-Rate Adjustments

The extrapolation continues until 2041, from which trip rates are held constant. The resulting levels of trip rates can be seen in Table 2. Note that Employers Business trips, despite recovering from the impact of the pandemic, never fully reach their pre-crisis levels. This implies a narrative that there are more *home-based* employer's business trips, as people are working from home rather than travelling from work, but some of these trips remain online even after pandemic restrictions are lifted.

Trip Purpose	Trip rate in 2041 as a % of the Core
HB Work	61%
HB Employer's Business (EB)	92%
HB Education	60%
HB Shopping	70%
HB Personal Business (PB)	59%
HB Recreation / Social	80%
HB Visiting friends & relatives	45%
HB Holiday / Day trip	119%

Table 2 Behavioural Change Trip-Rates in 2041-2061 as a percentage of the Core trip rate used throughout

The impact of these changes to trip-rates are severe, with trip making pre-2041 being considerably lower than in the Core. When trip rates stabilise in 2041, the profile of trips begins to follow the trend seen in the Core, but at a much lower level.

In addition to trip rates, declining take-up of driving licenses in younger cohorts is also extrapolated forward. Internal modelling suggested an average yearly decline in driving license uptake for 17-20 year olds of 0.39%, and 0.52% for 21-29 year olds. To align with National Trip End Model (NTEM), which is used to generate trip ends, five-year period declines of 1.95% and 2.61% respectively are used to calculate the percentage of population by age group with a driving license until 2061. This is done using the existing rates in each area type in the model, pivoting off the Core. As the younger cohorts age, the effect permeates through the age distribution, eventually affecting those in their 60s by 2061 (the final NTEM forecast year). The cumulative impact for 21-29 year olds is a 21% reduction in license holding between 2016 and 2061, whereas the impact on those aged over 45 remains below 5%. These inputs impact forecasts of car ownership in the scenario.

The last adjustment in the Behavioural Change scenario is to LGV trips. These are adjusted upward, to account for online shopping trips replacing high-street shopping and creating a more active market for deliveries. The 2018 Committee on Climate Change Report to Parliament considered three factors that led to increased van demand between 2000 and 2016: online shopping deliveries, growth and self-employment in sectors associated with van use and switching from lorries (Climate Change Committee, 2018). They considered 6 billion vehicle kilometres of the 27 billion vehicle kilometre increase in van travel to be attributable to 'online retail parcel deliveries'. This represents 22% of the increase in van kilometres since 2000. This was considered alongside data from the National Travel Survey (Department for Transport, 2021), which showed a fall of 0.8 shopping trips per person per week between 2002 and 2019. This allowed for an assumption that a fall in tours of 0.40 per person per week between 2002 and 2019 was associated with an increase in LGV traffic of 8.18 billion vehicle kilometres. Using the extrapolated trip rate for shopping trips in Table 1, a factor was used to increase LGV travel growth from 2023 to 2060.

The Behavioural Change scenario is stretching, providing a lower bound for traffic demand at the national level, within the CAS fan of uncertainty. Note however, that Gross Domestic Product (GDP) and population assumptions are the same as in the Core. If combined with the Low Economy scenario, which assumes low population and migration and low GDP growth, very low levels of travel demand could be achieved.

4. DECARBONISATION

The Vehicle-led and Mode-Balanced Decarbonisation scenarios consider two opposing futures: one in which decarbonisation leads to increased road travel, and one in which decarbonisation leads to increased public transport use. Given the uncertainty on the future of motoring taxation, no specific assumption on taxation is made. Instead a future where current tax regimes are continued is accounted for in the Vehicle-led Decarbonisation scenario, and a future where an unspecified implementation results in electric vehicles being cost equivalent to petrol and diesel is considered in the Mode-balanced Decarbonisation scenario.

Mileage splits and fuel efficiencies are adjusted in both scenarios, in line with rate of decarbonisation from the Transport Decarbonisation Plan (TDP) High scenario. This assumes cars, vans, lorries and public sector vehicles decarbonise at rapid rates, resulting in 99% of cars, 95% of vans, between 96% and 99% of lorries and 98% of public service vehicles (i.e. buses and coaches) being electric (or have emissions equivalent to electric vehicles) by 2050. Fuel efficiencies for petrol, diesel and electric vehicles are adjusted, reflecting policies beyond those currently firm and funded. Regulations on carbon emissions increase fuel efficiencies for all vehicles relative to the Core.

In the Vehicle-led Decarbonisation scenario, no other adjustments are made. As electric vehicles under current conditions are cheaper than petrol of diesel, modal switch is encouraged. There is even a shift from other vehicle types (for instance, public transport) towards electric vehicles because of the cost advantage. Therefore, traffic demand at the national level in the Vehicle-led Decarbonisation scenario ends up close to that in the High Economy scenario (which assumes high population, migration and GDP growth).

By contrast, in the Mode-balanced Decarbonisation scenario, perceived costs are adjusted to create the alternative mode-balanced future. They are adjusted so that running an electric vehicle is considered the same as the weighted average by mileage split of petrol and diesel. In a transport model, as vehicles are not modelled differently by fuel type, effectively no electric vehicles are modelled, but instead a decarbonised fleet of petrol and diesel. Interestingly, as there are already cheap electric vehicles in the Core scenario (as we have currently), the Mode-balanced Decarbonisation scenario has weaker traffic growth than in the Core, and a higher uptake of public transport.

Both of these scenarios require adjustments to inputs in the appraisal software, due to the assumptions around mileage splits, fuel efficiencies and electric vehicle costs. However, they are relatively easy to model and consider two opposing futures of decarbonisation.

5. PROPORTIONALITY

Given that there are now seven scenarios (plus the Core) for scheme promoters and transport modellers to consider in business cases, there is a strong need for a proportionality framework advising how to decide which scenarios to run. This is provided in the updated version of the Uncertainty Toolkit, which recognises that the impact of uncertainty and level of uncertainty should be reflected in the analysis conducted. More weight should be placed on understanding uncertainty for schemes with higher impacts, greater revenue risk and more uncertain impacts.

The Toolkit notes several factors that can increase the *impact of the uncertainty*:

- The financial cost of a proposal and the cost to the public purse;
- If the decision maker takes revenue risk;
- Whether there is corporate risk (which considers how novel, contentious or repercussive the intervention is);
- The degree of interdependency between the proposal and other policies and investments;
- The marginality of the value for money case (i.e. whether the value for money rating is close to a changing category).

The *level of the uncertainty* is noted to be influenced by factors such as:

- The stage of project development;
- The lifetime of the project influencing the extent of uncertainty (i.e. the longer the lifetime the greater the uncertainty);
- National level uncertainties to which the project is sensitive;
- Specific local uncertainties that are applicable.

Notably, practitioners will need to use their *judgement* to determine what impact level a scheme may be. However, indicative factors ranking schemes as low, medium or high impact are given in Table 3.

	Indicative Impact		
	Low	**Medium**	**High**
Impact on public finances through budget cost or revenue risk	Tier 3 e.g. < £50m	Tier 2 e.g. £50 - 500m	Tier 1 e.g. > £500m
Corporate risk	Limited / risk of minor embarrassment	Risk of minor loss in confidence	Risk of major loss in confidence
Value for Money	Solidly within a value for money category	Close to a value for money category boundary	Bordering two value for money categories
Level of uncertainty	Input assumptions low range of uncertainty. Short lifetime e.g. <5 years	Input assumptions medium range of uncertainty. Medium lifetimes 5 – 50 years	Input assumptions high range of uncertainty. Long lifetimes e.g. > 50 years

Table 3 Indicative impacts for schemes based on uncertainty factors *(Department for Transport, 2021)*

The guidance in the updated Uncertainty Toolkit advises a qualitative discussion of how options could be impacted by the different CAS. This is true for all scheme impact levels, as it is likely, regardless of impact, the modelling capacity at early stages of scheme development will be more limited. As schemes develop more uncertainty analysis should be conducted. For low impact schemes, this may be limited to running the TAG Unit M4 High and Low growth scenarios or the envelope of the CAS. For higher impact schemes, critical CAS are to be identified and run, alongside relevant local scenarios at later stages. For high impact schemes, justification needs to be provided as to why a scenario is not being run. For example, it could have been considered at an earlier stage or discounted as unlikely to impact the scheme, evidenced by some level of quantitative analysis.

6. UNCERTAINTY IN DECISION MAKING AND CONCLUSION

The publication of the CAS will instigate a step-change in how uncertainty is considered in transport business cases. For the first time, there will be a real opportunity for schemes of all sizes and stages to consider national level uncertainties, that could significantly broaden or undermine their case for change.

However, simply providing decision makers with a list of benefit-cost ratios will not result in a more in-depth consideration of uncertainty. Instead, the illustration of uncertainty analysis will be key in communicating the need for this analysis to decision makers. Scheme promoters will need to consider how best to present the uncertainty analysis, using ranges and graphs to communicate the impact of the CAS on their scheme.

Embedding uncertainty into discussions will also be important. Upskilling scheme promoters and decision makers on how to describe uncertainty, risk and scenarios is part of the ongoing workstream by the DfT to allow decision making to be robust against multiple futures. Engagement, internally and externally, has already occurred and is planned for the future.

There is a wider movement across government aiming to enable the consideration of uncertainty more widely. The cross-government Uncertainty Toolkit (Home Office, 2021), which sits alongside the DfT Uncertainty Toolkit, is evidence of this. Now, as the UK exits a period of great uncertainty and change, it is even more important to build robustly against a range of futures. While predicting the future is impossible, it is possible to consider what might happen, and create a project or scheme that is useful and efficient in as many futures as possible.

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ANNEX

A.1 Pilot of the Common Analytical Scenarios

Over the course of 2018-2019 the Common Analytical Scenarios (CAS) were piloted. This was used to understand the extent to which scenarios are effective in testing uncertainties in scheme appraisal and in providing information in a more consistent way. The pilot was also used as a way of understanding the practical issues and costs associated with undertaking scenario analysis and testing whether the scenarios captured the right uncertainties.

Initially, five strategic schemes across different modes (road and rail) were chosen to test the scenarios on. The objective was to illustrate how using a consistent set of scenarios for different schemes would allow us to draw out messages about the resilience of the portfolio to divergent futures. The five schemes were Crossrail 2, Lower Thames Crossing, Trans-Pennine Tunnel, Northern Powerhouse Rail and East West Rail – Central Section.

Key learnings from the pilot were as follows:

- Where scheme promoters used scenarios in business cases, it added considerably to the quality of the cases.
- There was limited success in getting pilot schemes to do the full range of scenario analysis due to the significant cost and time implications of doing the additional work and the decision to try and incorporate within existing budgets and timelines.
- There is a need to account for concerns around proportionality, available resource and budget to produce the additional analysis.
- The pilot showed that the high and low do not represent the extremes of demand so the current names are misleading. The regional scenario is likely to have greatest value in accessing how the portfolio as a whole performs against different assumptions on spatial distribution. There were issues estimating the impact of the behavioural change scenario on rail demand due to the rail forecasting framework not using trip rates as an input.

Following the Pilot the recommendation to the investment committee was:

‘*All Tier 1 schemes should use scenario analysis to test resilience of the scheme to future uncertainty. This would include using the common analytical scenarios and any additional scheme specific scenarios*’.

This received support from the committee in December 2019, who requested that the specific uncertainties to be included were further confirmed in a follow up workshop. The committee specifically requested that greater consideration be given to environmental uncertainties. However, due to the developing Covid-19 crisis, specific Covid-19 scenario work was prioritized over holding a workshop.

A.2 Covid-19 Scenarios

The Covid-19 scenarios (developed May – August 2020) have helped inform the update of the five common analytical scenarios. The Covid-19 scenarios explored two principal axes of uncertainty: the economic response and impact of the pandemic on travel behaviour. Four scenarios were created to capture possible futures following the pandemic. These are laid out below, as well as input assumptions for key variables:

- **Word Reverts –** In this scenario, there is a short, sharp, V-shaped recession in 2020, but travel patterns return to their pre-crisis levels.
- **Digital Demand –** In this scenario, there is a large recession with a heavy scarring effect. All aspects of life become increasingly digitalised and people continue to work from home, shop and socialise online.
- **Individual Travel –** In this scenario, there is a large recession with scarring effects. Whilst trips do return to their pre-crisis levels, there is a long-term nervousness about public transport use.
- **Green World –** In this scenario, there is a large recession with scarring effect, however there are positive environmental outcomes from the pandemic, which lead to a long-term shift to pro-environmental behaviour: the increase in active modes seen during the crisis is sustained and increases; car use falls and when people do drive, they use electric vehicles; there is an increase in public transport use.

Broadly the Covid-19 scenario workstream provided learning about both the assumptions themselves regarding the economic and impacts on behaviour; and on modelling and the practical considerations in defining scenarios.

Regarding assumptions, the key economic levers explored were GDP and employment, although employment is not modelled directly. Instead due to time constraints changes to employment were principally modelled through trip rate changes. For the updated CAS, it was recommended that employment uncertainties are fully modelled in the National Trip End Model. GDP, despite having significant absolute changes, had a weak impact on road demand but instead a significant impact on modal choices.

Within the behavioural impacts, both trip rates and modal switching through cost functions were explored. Trip rates changes accounted for the bulk of the range in traffic demand. Splitting the trip rate impacts into short term due to the Covid-19 crisis, the permanent change in behaviour following social distancing, the medium-term trend and longer-term cap produced an evidence-based profile that could be borrowed for the CAS.

Modal switching through cost functions enabled the generation of a scenario where public trust in public transport remained low (Individual Travel) and a scenario where trust returned (Green World). Using the cost functions proved to be challenging due to the multi-dimensional nature of the different modal substitutions e.g. bus and cycle being interchangeable but road and bus less so.

Regarding the learning about modelling and defining of assumptions; the Covid-19 scenarios that were developed considered narratives that flexed the economic and behavioural axes simultaneously. These produced ‘richer’ scenarios with uncertainties likely to be correlated such as a longer economic downturn correlated with a greater long-term behaviour change. However, with the greater richness came less clarity of the impacts of specific changes. Additionally, there were modelling challenges associated with the multi-dimensional nature of modal substitutions. A distinction between counterfactual type scenarios, which mainly considered exogenous demand impacts (e.g. Digital Demand,) and those of a heavy policy nature, that were endogenous to policy interventions (Green World), was identified. These policy type scenarios had more of a visionary nature and could be used to test or develop policy rather than test against robustness to exogenous uncertainty.

NOTES

[1] Please note that the ONS released 2020-based Population projections without variants. Therefore, the 2018-based High and Low Population variants are the latest available.
[2] Note that the population projection used in the Core is the 0% Future EU Migration variant, as is consistent with the Office for Budget Responsibility and the Department for Transport's Transport Analysis Guidance.
[3] As in footnotes 1 and 2.
[4] Time series data can often contain a seasonal component – a cycle that repeats over time (such as monthly or yearly). In the case of trips, seasonal factors could include depressed trip rates over the summer in school holidays (when portions of the country might be abroad) which then pick up again into September and October. These repeating cycles can obscure any conclusions we wish to infer from the data – in this case, how much of the trips reduction across the period can we attribute to seasonal factors instead of Covid-19 impacts.