Capturing the value of urban transport investments

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Introduction

Cost benefit analysis is used to assist in deciding between infrastructure projects in the public sector. It makes diverse projects comparable to inform difficult an complex spending decisions. For some transport projects the benefit cost ratio of an appraisal can have a big impact on whether the project is funded. The types of analysis carried out, and the nature of the project objectives, has changed over time. This has led to criticism of the application of cost benefit analysis [1] and the outcome of decisions.

The Commission has engaged with a range of experts and interested stakeholders to better understand the limitations of existing methods and assess where improvements could be made. It would welcome suggestions for further development of this approach. Please send any comments to NICdiscussionpapers@nic.gov.uk.

For urban transport in particular, two key challenges have been identified with existing methods:

1. Appraisal methods may distort the choice of scheme. Some stakeholders argue that this can bias projects towards the most easily appraised outcomes, such as faster journeys, rather than focusing on harder-to-identify objectives such as integrating housing, jobs and transport.[2]

2. The initial development of schemes by local authorities and others is highly speculative, but requires substantial amounts of money to be spent on modelling and scheme design before central government funding can be applied for. Too often the process starts with an overly complex analysis of an overly narrow list of options. Simpler appraisal techniques at the early stages would make it easier for a wider range of options to be considered.

Devolution of funding makes this problem less acute but, as identified in the National Infrastructure Assessment, will never be viable for the largest projects. For these, better methods are needed of identifying the most beneficial types of investment, and the locations to prioritise.

This paper suggests a new approach which could be used to compare the value of the economic benefits of urban transport projects, prior to detailed scheme-specific approaches by directly measuring economic benefits rather than transport outcomes. This experimental method could be used as a supplement or potential alternative to conventional appraisal, and be applied earlier in the process of developing a proposal.

A new process of strategic assessment would enable more effective prioritisation of projects, allowing time and resources to be focused on those which are likely to have the most significant impacts.

The Commission believes the approach set out in this paper could potentially be part of this, producing a high-level range of estimates of a scheme's impact and reserving detailed and granular models for later decisions and more certain projects.

There are many criteria that could be used for such assessment. This paper considers only the overall economic impact of schemes: a key objective of many transport investments. This analysis could be combined with evidence on other factors, such as safety improvements or public health impacts, as is already the case in project assessments.

The proposed approach

Traditionally transport appraisal is designed to consider marginal changes to the existing network. These changes affect the generalised cost of travelling. For most infrastructure schemes this means time savings; new connections or wider roads enable a journey to be made faster, and this can be appraised based on the value travellers place on each minute of time saved. This has the advantage of being a fairly easy to understand measure and one which, particularly for business travel, can be validated by comparison to hourly wages.

Even if people choose to take advantage of faster journeys by moving further away from their destination, the assumption is that journey time savings are a reasonable proxy for the value of these new opportunities. Before the new connections, people could still have chosen to live elsewhere and paid a cost in time for a longer journey. Therefore, it is assumed that the value from other changes triggered by faster journeys should match the value of the time saving as measured by survey techniques.

This approach also recognises that transport has other impacts which don't directly accrue to the traveller and therefore aren't captured in the value of time: these externalities include pollution and congestion. They can also include benefits from increasing urban density ('agglomeration'), as increasing the population of a city has been shown to improve the productivity of all workers, not just the new ones. Generally, journey time changes are used to estimate how the volume of different journeys made will change, and the additional benefit are calculated based on those volumes.

However, this approach has been challenged on the grounds that, in urban areas in particular, transport investments do not always make journeys faster.[3] Observed average commuting times tend to stay constant at around an hour a day (known as 'Marchetti's constant').[4] If travel gets faster, commuters appear to take advantage of this by travelling further in order to live somewhere which better meets their other preferences.

This suggests that responses to changes in journey times aren't linear – the response will differ based on the status quo. If this is the case, journey time savings will not be a good measure of the benefits of the scheme, particularly when they are being used as a basis to estimate the scale of other benefits. Furthermore, changes may be 'lumpy' so that the relationship between new provision and its benefits may be complex and non-linear.

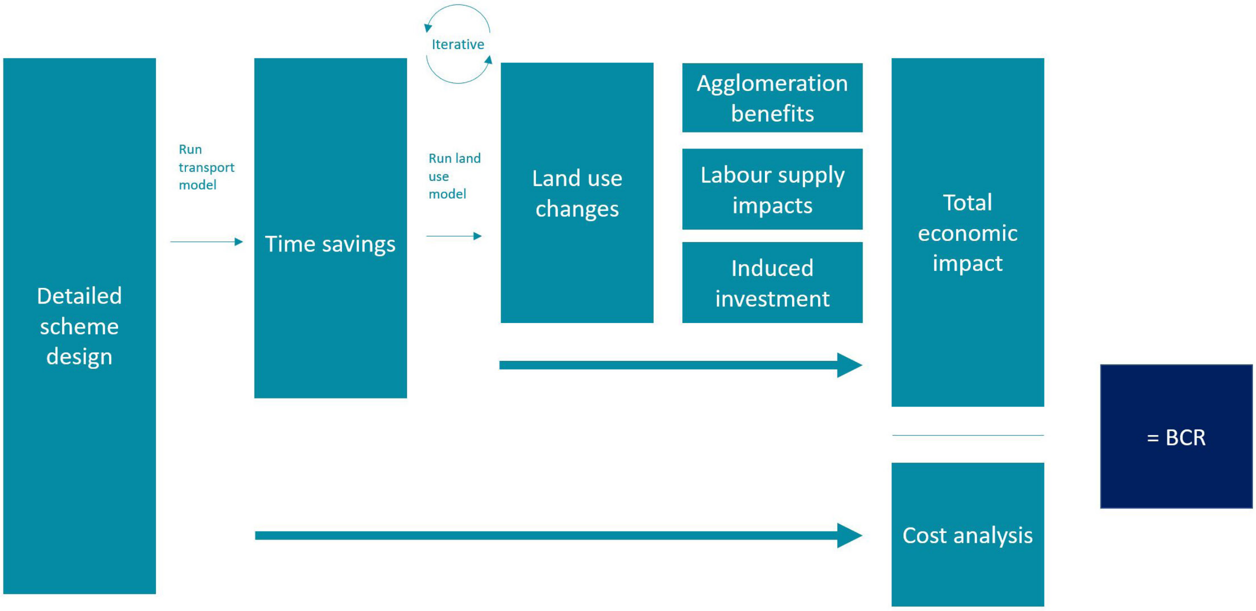

Figure 1 – Transport appraisal process (simplified)

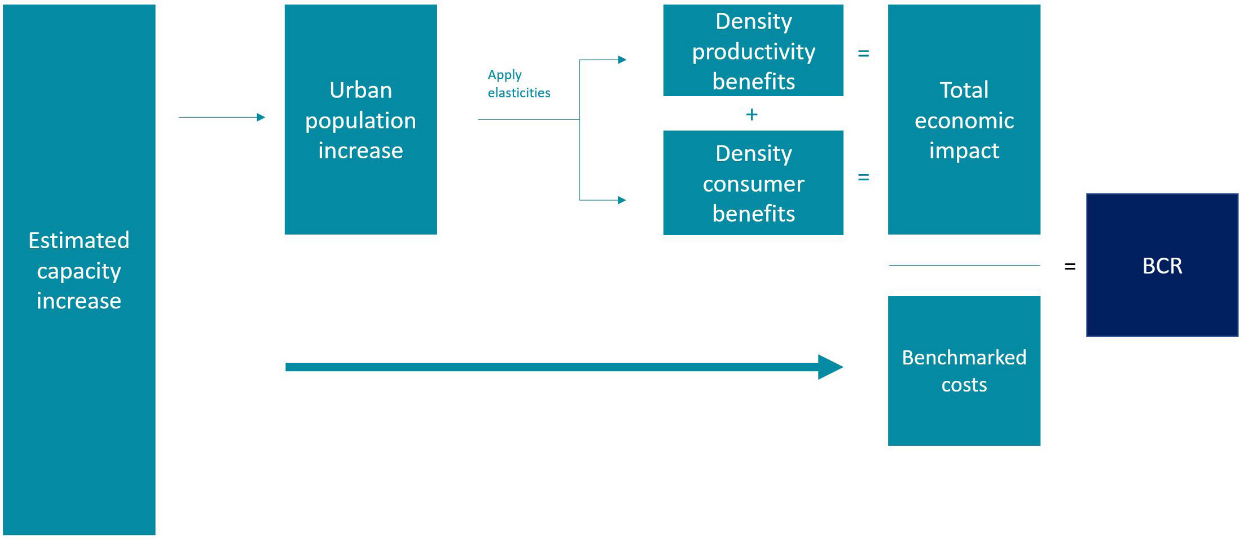

Figure 2 – Suggested strategic analysis

The Commission has therefore developed an approach which tries to avoid these problems. This approach starts from an assumption that enough latent demand exists that any additional capacity added in urban areas will be used – average speeds will remain the same but more journeys will occur. There is empirical evidence to support this assumption in urban areas[5]. Where this is the case, there are effectively no traditional time saving ben ts. Instead, the value of the capacity is the value of the relocation that better connectivity enables.

A key aspect of this is the ability for larger numbers of people to work in city centres, where current transport capacity constrains it – these extra workers create higher productivity ('agglomeration'). Increasing the density of employment within the city centre will increase productivity even if the total number of people living in or employed in the city doesn't change.

By compiling data on a range of variables for different cities over time, statistical techniques can be used to estimate the relationship ('elasticity') between economic output (GVA) and city density. When people and firms are close together this has been show [6] to have a range of benefits, which go some way towards explaining why cities are successful and productive places.

Not all the benefits of denser cities are captured through more productive jobs. Denser places also offer a wider selection of services and amenities, which people value. One way of measuring this is to look at the difference in housing costs in dense cities relative to other places, controlling for wage differences. This analysis has been carried out in other countries, particularly the USA,[7] and the Commission believes it could be applied in the UK. Estimating both the productivity gained through agglomeration and the social value gained from thriving and densifying cities can help to address the challenge from some stakeholders that urban projects are undervalued in conventional appraisals, as they do not primarily deliver time savings[8]. Nevertheless, this should theoretically produce results consistent in scale with conventional appraisal results across the sector, and this appears to be the case.

In addition to these effects, transport investment should reduce housing costs in a city by increasing the effective supply of land within reasonable commuting distance (all other things being equal).[9] That would tend to increase real wages, since the cost of living within commuting distance of the city centre falls.

However, the impacts are challenging to isolate. At least part of the productivity and amenity benefits from density set out above will be capitalised into higher property prices, offsettin the effects from increasing the effective supply of land. Some proportion of the net impac will be captured within the estimate of consumption benefits, but there is no obvious way to estimate a counterfactual to isolate the impact. The Commission would welcome suggestions on how to narrow down the range of impacts, reducing the level of uncertainty.

A key advantage of this approach would be the transparency of the process. It will not capture all of the economic benefits of a project, but neither can existing appraisals: long term dynamic impacts are extremely difficult to isolate from other economic changes. Partial but consisten analysis can play a useful role in decision making, in combination with other sources of evidence.

It is important however to recognise the limitations of this approach. Starting from the position that it is extra journeys that create value, rather than travel time savings, introduces new assumptions.

In particular, it assumes:

- that the density of city centre employment is currently constrained by a lack of transport infrastructure – which would not be true for example in cities where spare capacity exists in transport infrastructure (for example if population has fallen)
- that new infrastructure capacity is used – that 'if you build it, they will come'.

It also relies on relationships between density and productivity or amenity value derived from national data, which may not be valid for any particular city. However, this is also true of traditional methods.

1. Methodology

The methodology proceeds in six steps:

1. Firstly, an estimate is made of the existing maximum capacity of the transport infrastructure serving the centre of each city. This creates a theoretical upper bound to city centre employment growth, and hence employment density, in the absence of new investment.
2. Projections are created for the locations of population and employment growth both for a constrained world, where there is no new investment, and an unconstrained world, where transport infrastructure is no longer a limiting factor. Both projections are required to have the same overall population and employment levels at a national scale.
3. The difference between these two projections provides an estimate of the maximum impact transport can have on population or employment density in each area.
4. Differences in employment density can be converted into impacts on output (Gross Value Added) by multiplying the change in employment density through by the elasticity of GVA with regard to employment density. This needs to be done for all areas, both where transport investment enables people to move to, and where they move from, to get the net effect
5. Differences in population density can be converted into amenity benefits b multiplying through the change in population density by the elasticity of amenity benefits with regard to population density. Because of the way this elasticity is measured, amenity benefits and G A benefits can be added together without double counting.
6. Finally, the cost of delivering the capacity needed to bring city centre employment up to the unconstrained forecast, using a reasonable mix of modes, is estimated in order to estimate the cost benefit ratio of investment.

Further details are set out below. Annex A contains further information on data and assumptions. Underpinning analysis is published on the Commission’s website:

- Gibbons and Graham (2018) Urban Capacity and Economic Output Report for the National Infrastructure Commission
- Lomax and Smith (2018) Effect of capacity constraints on population and employment distribution
- Steer Davies Gleave (2018) Urban Transport Analysis: Capacity and Cost.

Capacity

There is no perfect way to determine a single value that represents capacity across an entire urban network. Steer Davies Gleave (2018), on behalf of the Commission, developed an Urban Transport Capacity Metric, capturing inbound capacity into city centres in the morning peak hour (0800 - 0900).

Capacity was measured across bespoke cordons defined around the city centres of 20 case study cities. Cordon definitions considered both census workplace population (employment) data and natural/man-made barriers to movement. In most cases, the cordons were defined tightly around the central business districts of case-study cities.

Public transport capacity was based on timetabled services. Private transport was measured as the capacity of inbound road lanes. Walking and cycling were assumed not to be constrained by infrastructure capacity. Instead, they were limited by social preferences. The costs of enhancing capacity take these different constraints into account (eg modest increases in public transport capacity can be achieved by increasing timetabled frequency).

Using the physical capacity of a city to accommodate traffic as the constraint sets a relativel conservative limit on how much growth is attributed to transport projects. This measure was adjusted to account for the reality that demand is not evenly distributed, so even in peak hours it is very unlikely that 100 per cent of capacity would be in use. Journeys are 'crowded out' before capacity is fully utilised, particularly on public transport.

Two scenarios were therefore developed to define when cities are 'full', based on the current level of modelled capacity utilisation in Bristol, a heavily congested city (68 per cent of theoretical capacity), and Newcastle, a busy but less congested city (49 per cent of theoretical capacity). The results set out below are based on the assumption that further investment is needed once congestion reaches the level of Newcastle.

This is a somewhat simplistic approach – it may be possible in future work to develop a more nuanced understanding of how increasing usage of capacity constrains future employment and population growth.

Productivity

The modelling reflects the constraints on growth which happen when transport is the limiting factor in the number of people who can move in and out of the city centre. The analysis started from ONS subnational population projections, which were taken as a benchmark for the unconstrained population distribution. Census data on commuting patterns was used to convert these estimates from residential growth to employment figures (Lomax and Smith, 2018).

The bespoke cordons set out above were used to define city centres for each of the UK's primary urban areas (Steer Davies Gleave, 2018). These were then used to sub-divide employment growth into two for each city area. This enables the estimation of separate impacts on city growth and densi cation. In the constrained employment distribution, additional growth was redistributed where total city centre employment was projected to exceed the estimated capacity of the transport system.

This process used census data on commuting patterns to understand the other likely locations for employment of people working in those areas, assessing the proportion who would work elsewhere in the local authority or in other locations. Where these commuters are redistributed to another city with constrained growth, they go to the next place on the list. The constrained and unconstrained projections of employment are consistent at a national level, with only the distribution changing rather than the overall totals.

By comparing growth in the city centre and wider city populations between the constrained and unconstrained projections and then applying agglomeration elasticities to the difference (with a range of sensitivities) the benefits of increasing capacity on G A can be estimated.

Separate estimates were made of the effect of overall city size and employment density on GVA (Gibbons and Graham, 2018). Most existing agglomeration elasticities do not make this distinction, so in order to isolate the impacts of densification they were both estimated from scratch. This analysis produced a range for each of the two elasticities (density and size) between 0.01 and 0.05, with a central case of 0.03. The analysis has used a measure of agglomeration derived from wages; analysis using private or commercial rents sometimes produces larger effects [10] but high-quality data which can be used for this is less readily available.

The use of agglomeration elasticities to capture some of the wider economic benefits of transport schemes is now common in appraisal. While it is only part of these impacts, agglomeration is a source of wider benefits which can be empirically observed and where the drivers are relatively well understood.[11]

However, measuring these on top of a transport appraisal requires care to ensure that benefits are not double counted – eg business time savings will overlap substantially with total productivity benefits. In the high-level analysis proposed, this problem is avoided as the traditional transport benefits are not used, enabling the use of simpler methods to estimate the improvement in productivity.

These elasticities may not capture some of the more intangible potential impacts of agglomeration such as innovation, the benefits of which may be spread widely throughout the economy. The estimation may also overcontrol for characteristics of cities (such as higher skill levels) which may not be wholly independent from agglomeration. These have not been measured, as the defensibility of the empirically derived estimates is considered a key benefit of this approach, but further work in this area would be valuable.

Consumption

In a standard appraisal, the benefits of travelling for consumers are assumed to be captured within the demand response to journey improvements. This is an imperfect method for valuing the kind of journeys urban transportation enables,[12] which often involve complex trip chains: travel to the city centre may serve a variety of social and economic needs within one return journey. These benefits will increase with agglomeration, as denser places sustain a greater variety of services and other facilities.

Historically, city growth has been a trade-off between the higher wages available in the city and the higher social and economic costs of living there – longer and more expensive commutes, higher living costs and more crime and pollution.[13]

The development of faster and lower cost transport, alongside improvements to sanitation and other infrastructure, has enabled cities to expand further over time by reducing these costs. There will still be some disbenefits to increased density, but by looking at revealed preference data the net effect is estimated.

There is clearly a social value to urban transport beyond commuting, as it enables a wider range of economic and leisure activity. But this is challenging to capture in appraisal as evidence suggests the value of time for leisure travel is relatively low,[14] and the longer term and systematic benefits cannot be robustly forecast. Housing costs in cities are often higher than in lower density areas, even accounting for higher wages in those areas, but many people are willing to pay this premium.

By empirically estimating the value consumers place on larger and more amenity rich cities, controlling for wages, it is possible to estimate the size of this effect. Analysis carried out internationally has shown that this effect is large in many cities [15] [16] accounting for a substantial proportion of the housing cost premium over other areas. Using Glaeser's US values estimated in 1990, the elasticity for this premium with respect to population size was 0.143. This implies that the benefits could be substantially larger than those of agglomeration, and some other recent analysis produces even larger results.[17]

Unfortunately, no recent analysis of this kind has been carried out in the UK. There are also no direct comparisons based on increasing density rather than total city size. The trend towards increased population growth is relatively recent in many UK cities, so these benefits may well be increasing.

Costs

To use this approach as a rounded analytical tool, estimates are required of how much it costs to deliver the forecast capacity. Because of the generic, rather than scheme-specific, approach taken, the starting point is to estimate standard unit costs for different levels of capacity uplift.

Scenarios were developed for the Commission by Steer Davies Gleave (2018) of generic capacity enhancing investments in small, medium and large cities, and for different levels of uplift, as well as different modal shares. Investments included relatively modest interventions, such as more frequent bus services of junction improvements, as well as more substantial interventions, such as light rail, where larger capacity uplifts were modelled.

Unit rates were then applied to these scenarios to produce cost benchmarks for different percentage capacity uplifts in each city. Modelling then extrapolated between these scenarios in order to scale costs to the actual capacity required in each city. These were compared to the costs and uplifts provided by existing UK schemes in order to provide greater confidence in the estimates. Costs include optimism bias and a 10 per cent uplift for planning and design costs. Full details are set out in Annex G of Steer Davies Gleave (2018).

This also gives some understanding of what level of capacity upgrade might be cost effective, although this is limited by the need to estimate generic costs across all cities. They may not reflect the actual costs of delivering capacity as they do not take into account any particular constraints which may limit the use of specific modes – eg particularly hilly cities may fin expanding rail and active travel difficult, and local land costs will vary significantly. Howeve the cost assumptions are conservative, and in practise these are likely to be an overestimate of the necessary capacity.

Initial Results

The Commission has conducted a high-level appraisal of the potential benefits of investments in urban transport across England's fast-growing cities, excluding London, as a test of this approach. London was excluded, largely because of its far greater size and distinct characteristics compared to other UK cities. There is no reason why this analysis could not be applied to London.

A high-level benefit cost ratio has been estimated for a programme of major urban investments. This reflects a scenario with high future urbanisation of employment and relatively low existing transport capacity:

	Low agglomeration benefits – (size and density elasticities of 0.01)	Medium agglomeration benefits – (size and density elasticities of 0.03)	High agglomeration benefits – (size and density elasticities of 0.05)
Benefits			
Productivity	£6.8bn	£26.1bn	£52.7bn
Consumption	£3.4-6.8bn	£13bn-26.1bn	£26.3bn-52.7bn
Marginal External Costs*	£3.2bn	£3.2bn	£3.2bn
Costs	£25.9bn	£25.9bn	£25.9bn
Benefit cost ratio range	0.5-0.65	1.6-2.1	3.2-4.2

Present Values (2018 prices) over 60-year appraisal period. Costs are total whole life cost including both capital and revenue expenditure.

*Benefits of mode shift to public transpor [18]

International evidence suggests that consumption benefits could be substantially larger than the productivity benefits [19] For illustrative purposes a range between half and equal to the productivity benefits is presented – the high end of this range is loosely based on Glaeser's results in the US. The medium benefits scenario would then have a BCR of 2.1, categorised as high value for money. Benefits only half as large as the productivity impacts would give a BCR of 1.6, enough for medium value for money.

The effect of increased effective housing supply has not been monetised independentl because the impacts are challenging to isolate.

2. Next steps

Major cities in the UK continue to grow, with high productivity jobs and increasing numbers of residents located in city centres. Decision making needs to reflect this in order to meet the demands this creates and proactively support this growth.

In the context of the Commission's recommendations on urban major projects,[20] the approach set out in this paper could become a useful tool to help allocating development funding to cities.

With further development and calibration, it could also provide an additional independent source of strategic evidence at later stages of development. By design, the modelling used for these schemes is highly individual and often bespoke: this is necessary for planning purposes, but makes comparing between schemes increasingly difficult.

The Commission intends to procure additional research to develop this work and further test its approach, and would be keen to engage with the Department for Transport, sub-national transport bodies and others to understand how this methodology could be developed and practically applied.

This analysis provides useful insights into the strategic impacts of transport, but the ability of schemes to deliver these benefits in reality will be dependent on effective transport planning This approach is not intended to replace transport modelling in project development and financial approvals, where a detailed understanding of the impacts of the scheme is necessary and highly valuable.

A future use of this method could be in evaluating different cities as candidates for enhancements. Taking outline funding decisions on the basis of high-level analysis, rather than after substantial project development has already happened, leaves more resources for option development and analysis meeting the specific needs of the project.

Annex A: Data and assumptions

This section outlines key information about the sources used for this analysis and some of the key caveats and constraints. Each of these sources is covered in more detail in the standalone papers cited in the bibliography and available on the Commission website.

Employment projections

Lomax and Smith (2018) produced for the Commission projections of the future distribution of employment, using as their basis ONS sub-national population projections. Census data on commuting patterns was used to convert these estimates from residential growth to employment figures.

These estimates were produced for a number of scenarios, both unconstrained and incorporating the estimated constraints on transport capacity. A scenario was considered which estimated the impact of housing constraints, but this had minimal impact. It is likely that, since short term housing constraints are incorporated into the data which is used to estimate the original projections, this captures most of the impact, although there is some evidence that this underestimates the impact of limited housing on growth[21] and further research may be valuable.

These projections are estimated relatively simply based on recent trends and are not forecasts. However, for the purposes of this analysis, they provide a useful indication of the growth that could be possible in cities if these trends continue. They also implicitly incorporate some of the existing constraints on city growth such as planning regulations or greenbelt. The ONS projections are used extensively for planning purposes by local authorities and central government.[22] There is arguably value in maintaining consistency and comparability with them, even setting aside the difficulties of creating independent population forecasts

In the constrained projections where commuters are crowded out of the city centre, they are reallocated to other destinations in proportion to the census data for their local authority. This may underestimate the impact of transport schemes on city size, as in practice many of these individuals will end up elsewhere within the wider city area. A more complex approach to this redistribution would require more detailed labour market inputs to understand employment patterns. This should be possible but has not been incorporated into the analysis at this time.

Urban capacity

Steer Davies Gleave (2018) created city centre cordons for 20 case studies, encompassing a range of different sizes of city. These were designed to capture the areas of highest employment density, but also take into account natural barriers and the existing infrastructure – they are generally defined within inner ringroads. They then assessed the city's existing tra and theoretical capacity for the crossings from the rest of the city into the centre.

This analysis is extended to other cities by extrapolating from the case study cities with similar characteristics, using population and employment data for scale. This approach is fairly standard in transport analysis and, given the range of outcomes for this analysis is unlikely to be significant.

Most places are not even close to using their total modelled capacity. This is not surprising; a city in which 100 per cent of road space is occupied at peak times would mean the system had no resilience to even minor delays. In order to understand where additional capacity is needed two scenarios have been developed to define when cities are 'full', represented by usage over 49 per cent and 68 per cent of total capacity. These thresholds were developed with reference to the existing evidence on how severe city congestion problems are, considering time series data of employment growth and growth in road traffic: 68 per cent is the current level o capacity utilisation in Bristol, which has a heavily congested city centre.

This is a simple approach based on assumptions. While there is good evidence that congestion prevents and discourages additional journeys, the modelling does not explicitly link rising congestion to specific impacts in constraining the growth of the city. There is some evidence of congestion's impact on location decisions,[23] but further econometric work could establish a better understanding of the relationship between capacity constraints and growth. This could permit a more sophisticated approach to the analysis which avoids such a binary cut-off, as well as making it more robust.

Agglomeration benefits

Gibbons and Graham (2018) estimated the benefits of alternative city growth scenarios on G A for the Commission. This was estimated using both size and density agglomeration elasticities. A range was tested for each to capture uncertainty over the possible scale of these elasticities given the range present in the literature, and the absence of previous work focused on density which can be used for comparison. The relative simplicity of this method for estimating benefits makes the point values less crucial, as it is possible to easily calculate a range of scenarios. The central case is those which use an elasticity of 0.03 for city size and 0.03 for city centre density, as these are most comparable to the more commonly used aggregate elasticity.

By focusing on densification rather than increased city size, displacement becomes less of a concern. Where this happens within the city, it is easier to capture and share some of the benefits of higher productivity. There are likely to be some additional positive impacts on suburban areas as employment moves to the centre, such as reduced congestion. Steer Davies Gleave (2018) have estimated the scale of this benefit, although it is not included in the central analysis as it is unclear whether other employment would instead move into the suburbs. The net impact of this is unclear, and the evidence is limited.

Costs

Steer Davies Gleave (2018) assessed the cost of delivering increased capacity in 20 case study cities. This assessed the costs of the schemes deemed most plausible, focusing on road improvements, bus priority schemes and frequency upgrades for public transport. Some larger tram or rail schemes were included in the scenarios requiring the highest increases in capacity.

Costs were modelled over the whole life of the projects, covering total public expenditure. Most spending was on capital, with some additional bus subsidies and active travel funding. Ongoing operational costs and maintenance expenditure is presented net of estimated fare revenue for the new services and increased patronage.

The Commission proportionately scaled these costs to the actual demand uplifts required in each city according to the capacity modelling. In practice cities may tend towards interventions which deliver capacity above this, or which incur higher costs in order to enable future expansion – new transport infrastructure will have a lifespan beyond the length of these employment projections, and enhancing capacity later on can be challenging. For example, planning for substantial capacity upgrades on London's Docklands Light Railway started before it had even opened.[24]

Endnotes

1 Transport Select Committee report into Rail Infrastructure Investment https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/582/582.pdf
2 National Infrastructure Commission (2018) Congestion, Capacity, Carbon: Priorities for National Infrastructure; Report on Consultation Responses https://www.nic.org.uk/wp-content/uploads/Interim-NIA-Consultation-Response-Analysis.pdf
3 See, for example, Metz (2016) Travel fast or smart?
4 Marchetti (1994) Anthropological Invariants in Travel Behaviour
5 Duranton and Turner (2011) The Fundamental Law of Road Congestion, American Economic Review
6 Glaeser (2010) Agglomeration Economics https://www.nber.org/chapters/c7977.pdf
7 Glaeser, Kolko, Saiz (2000) Consumer City
8 National Infrastructure Commission (2018) Congestion, Capacity, Carbon: Priorities for National Infrastructure; Report on Consultation Responses
9 Coombes, Duranton and Overman (2005) Agglomeration and the adjustment of the spatial economy, CEP discussion paper No 689
10 Gibbons & Graham (2018) Urban Capacity and Economic Output Report for the National Infrastructure Commission
11 Duranton and Puga (2003) Micro-foundations for Urban Agglomeration Economies https://www.nber.org/papers/w9931.pdf
12 Krizek (2003) Residential Relocation and Changes in Urban Travel http://kevinjkrizek.org/wp-content/uploads/2012/04/Residential-relocation.pdf
13 Crafts and Leunig (2005) The Historical Significance of ransport for Economic Growth and Productivity
14 webTAG Unit 3.5.6
15 Glaeser, Kolko, Saiz (2000) Consumer City
16 Dalmazzo & de Blasio (2010) Amenities and skill-based agglomeration effects: Some results on Italian citie https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1435-5957.2010.00327.x
17 Dalmazzo & De Blasio (2009) Skill-Biased Agglomeration Effects and Amenities: Theory with an Application to Italian Cities
18 webTAG Unit A5.4
19 Dalmazzo & de Blasio (2009) ibid
20 National Infrastructure Commission (2018) National Infrastructure Assessment
21 ONS (2018) Household projections for England, comparisons with other sources: 2001 to 2018 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/articles/householdprojectionsforenglandcomparisonswithothersources/2001to2018#why-do-the-trends-diverge
22 ONS (2018) Subnational population projections QML report https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/methodologies/subnationalpopulationprojectionsqmi
23 Gottlieb (1995) Residential Amenities, Firm Location and Economic Development
24 https://tfl.gov.uk/corporate/about-tfl/culture-and-heritage/londons-transport-a-history/d