Accommodating Growth on Urban Networks

Courtney Groundwater (presenter)
BE(Hons), MSc (Eng) CMEngNZ, CPEngNZ
Principal Transportation Engineer, Abley
Courtney.Groundwater@abley.com

Jake Cartmell
BSc Economics
Associate, Steer
Jake.Cartmell@steergroup.com

Neil Chadwick
BA(Hons), MSc Transport, MA Public Administration and Policy
Director, Steer
Neil.Chadwick@steergroup.com

ABSTRACT

With 'economic density' widely recognised as a key driver for productivity, facilitating and accommodating growth in our city and town centres is a core objective of many policies. This paper considers the challenges associated with providing additional transport capacity to serve commercial growth in urban centres. It looks at a range of capacity uplift scenarios, to understand at what point capacity can no longer be accommodated through increments to the existing transport system and transformational change is required.

Defining how capacity uplifts could be delivered is based on current contemporary themes in delivering transport infrastructure. Contemporary themes consider how local authorities and other bodies are currently approaching the challenge of building transport capacity into urban/built-up environments and include things such as the current focus on reducing private vehicle trips (with the goal of improving air quality and health), and the concomitant of encouraging use of more sustainable travel modes through, for example, implementation of light rail networks in large cities. Four core modes are the focus of the scenario building (bus, rail, light rail and private vehicle). The starting point of the study is a baseline of inbound transport capacity by mode, developed for twenty case-study towns and cities. Capacity uplifts are considered relative to this baseline.

This study is set in the context of a range of UK towns and cities, providing the opportunity to consider how lessons learned from abroad may be relevant in the New Zealand context. The study was developed to inform the UK National Infrastructure Assessment (July 2018) and underpins a recommendation that £43 billion of additional investment in urban transport by 2040 is required to unlock growth in regional cities.

INTRODUCTION

Study Context
The purpose of this study, reviewing urban transport capacity and considering options for increasing that capacity, is set in the context of a public policy goal to deliver economic growth in the United Kingdom. Transport networks play an important role in supporting the economy and facilitating economic growth. As well as reducing time and money costs incurred by transport users, improved transport connectivity can support and facilitate economic growth through[1]:

- increasing productivity of existing economic assets (land, capital etc.);
- improving the efficiency of the labour market;
- supporting sustainable housing and employment growth; and
- enhancing the attractiveness of places as locations for investment.

The original study (Groundwater, C., Cartmell, J., and Chadwick, N., 2018) forms part of a suite of three parallel studies, which taken together seek to understand the cost of increasing transport capacity into city centres and the potential economic benefits of doing so. The study was developed to inform the UK National Infrastructure Assessment (National Infrastructure Commission, 2018) and underpins a recommendation that £43 billion of additional investment in urban transport by 2040 is required to unlock growth in regional English cities.

Transport capacity in this study is considered in the context of providing access into city centres only. All analysis is based on inbound trips during the morning peak hour (0800 - 0900). The peak was chosen because this is when demand is greatest and capacity constraints are most severe. Analysis of twenty case-study cities underpins the results presented in this study. Case study cities and key metrics are set out in Appendix A.

Study Overview and Interpretation
This study provides an order of magnitude estimate of peak hour transport network capacity into the centre of large towns and cities in England. Across a number of scenarios, the study also considers a range of interventions and estimates order of magnitude costs for increasing capacity.

Ultimately the results of this study are structured around answering the following questions:

1. What is the current capacity of urban transport networks?
2. What could a 5%/10%/20% uplift in transport capacity ‘look like’? (how could this be accommodated on the network); and
3. How much would it cost to achieve this?

In producing the results of this study, it has been necessary to make a large number of assumptions. As far as possible, we have drawn upon relevant, publicly available datasets and evidence sources to inform and support the assumptions applied, nonetheless an element of professional judgement has also been necessary. As a consequence, the results of this study are appropriate for application in the context for which they have been developed, which was for the National Infrastructure Commission to get an understanding of the scale of investment that may be required and for that to become part of the public discourse on the nature and direction of future transport investment. However, it is important to understand the limitations of the results and how these results should be interpreted. The remainder of this section includes commentary regarding appropriate use and application of the study outputs. More detailed commentary related to these assumptions are included in the original study (Groundwater, C., Cartmell, J., and Chadwick, N., 2018).

[1] Noting that improvements in transport connectivity in and of themselves do not guarantee economic growth.

Cost Estimates
Cost estimates for the capacity uplift scenarios in this study are intended to be used in aggregate across multiple cities, as opposed to on a city-by-city basis. Assumptions associated with the transport interventions within each scenario are made on the basis that investment in some cities may be overstated, and understated in others.

Peak Spreading
This study assumes that the key trips of interest occur during the morning peak hour (0800-0900) and will continue to occur at this time. In reality, some cities have a propensity for 'peak spreading', where trips that would ideally be undertaken during the peak hour are undertaken during the hours either side of the peak (peak shoulders). This simplification may mean capacity requirements are overstated in this study.

Delivery timing
The scope of this project considers transport interventions which could be delivered to 2050. Transport technology is constantly developing, it is recognised that the intervention options available to transport authorities at the time of planning and delivery may be different to those available at the time of writing. Therefore, the implicit assumption is that a similar uplift in capacity could be achieved with a similar level of investment, albeit the actual interventions delivered may be different.

Connected and Autonomous Vehicles
Connected and Autonomous Vehicle (CAV) technology, and frameworks for its widespread adoption, are developing over time. By 2050 it is plausible that there will be a significant uptake in Level 4/5 (autonomous driving capability) CAV use, however the impact of CAVs on capacity is uncertain and is included here as a sensitivity test only. There is a lot of variability in forecast rates of uptake for CAVs. For example, Litman (2018) predicts that by the 2040s, approximately 40% of vehicle travel could be autonomous, assuming fully automated vehicles become commercially available in the 2020s. Furthermore, there is uncertainty whether CAVs would result in a greater or lessor intensity of transport infrastructure.

Travel Patterns
In addition to technology affecting the range of modes available, it also has an impact on how we travel. Technology enables more remote working and influences trip timing, mode choice and route choice. This, combined with ongoing changes in societal preferences, means travel patterns are changing over time. This study uses data for current travel patterns and does not extend to consider how these may change in future.

Applicability to New Zealand
This study is set in the context of a public policy goal to deliver regional economic growth in the United Kingdom. This is consistent with the New Zealand Policy context;

- the Transport Outcomes Framework (Ministry of Transport, 2018) identifies economic prosperity is one of five outcomes.
- the 2018 Government Policy Statement on Land Transport (New Zealand Government, 2018) refers to access to social and economic opportunities including development that supports thriving regions as part of its strategic prioritisation of 'access'.

The focus in this study, on alternatives to private vehicles, is also aligned with the direction set by the Government Policy Statement. High growth regions in New Zealand are currently planning how growth can be accommodated within the transport system. This study will be of interest to form part of the conversation around mode options and what may be the most cost effective and appropriate way to invest in transport infrastructure going forward.

Structure of Paper
The remainder of this paper is structured in the following sections:

- **What is the current capacity of urban transport networks?**

   - Provides an overview of our approach and the results of our capacity assessment.
- **What could a capacity uplift look like?**
   - Sets out our approach to considering the types of interventions that could be appropriate relative to city size, and the balance of capacity that could be contributed by various modes.
- **How much will it cost?**
   - Provides order of magnitude estimates for implementing the capacity uplift scenarios
- **Discussion and conclusions**
   - Considers applicability to the New Zealand context

WHAT IS THE CURRENT CAPACITY OF URBAN TRANSPORT NETWORKS?

There is no perfect way to determine a single value that represents capacity across an entire urban network. While each individual element of a transport network has a definable capacity, for a system formed of a combination of those elements it is much more difficult to determine a single numeric value of capacity. The way in which the system is used on any given day can change. This, in turn, affects the overall capacity available to an individual accessing the city centre. For example, a single seat on a bus can provide capacity for multiple people as different passengers board and alight along the route. Moreover, it should be noted that services and links crossing each city centre cordon do not exist in isolation; rather, they form part of wider networks. Consequently, constraints away from city centres could, in fact, be the key determinants of capacity in the peak periods.

Our simplified approach to determining order of magnitude urban transport capacity across modes is centred on defining city centre cordons (for each case-study city in Appendix A) and measuring inbound capacity across these. Capacity is measured by mode, based upon nationally available datasets and information including: Census journey to work data (2011), public transport timetables, National Travel Survey (a household travel diary), traffic counts (where available) and aerial photography. All capacity measurements are at the defined cordons. In particular, this study focuses on inbound capacity into city centres in the morning peak hour (0800 - 0900). The measurement of capacity of urban transport networks in this study is intended as an order of magnitude estimate only. Results are used as a baseline to understand the scale of uplift required to accommodate growth.

Additionally, the measurement of a single value for capacity by city and mode does not provide insight into how the availability of a given mode is distributed across the city. For example, Birmingham, at the time of analysis, has a single, radial, light rail (Midland Metro) line, meaning only city centre-bound trips on a single corridor are served. The capacity that light rail offers is therefore only available to a small sub-set of people who travel into Birmingham city centre from the north-west. This is an important point to note when considering how capacity is distributed across modes and the potential for available capacity, as reported, to provide for the growth of a city dependant on the dispersion of that growth. Further detail of our methodology is available in the original study report (Groundwater, C., Cartmell, J., and Chadwick, N., 2018).

Capacity results by city are shown in Figure 1, note that these results are somewhat theoretical in nature and should be adjusted (or normalised) to better represent the reasonably useable capacity in each city and for each mode. Normalisation is necessary to account for:

- The difference between theoretical capacity and actual capacity;
- Gaps in geographic coverage and level of service; and
- Recognition that user perception of the theoretical spare capacity on a mode influences travel behaviour in terms of mode choice and the timing of a trip.

The results presented in this study are based upon calculated capacity only and have not been normalised.

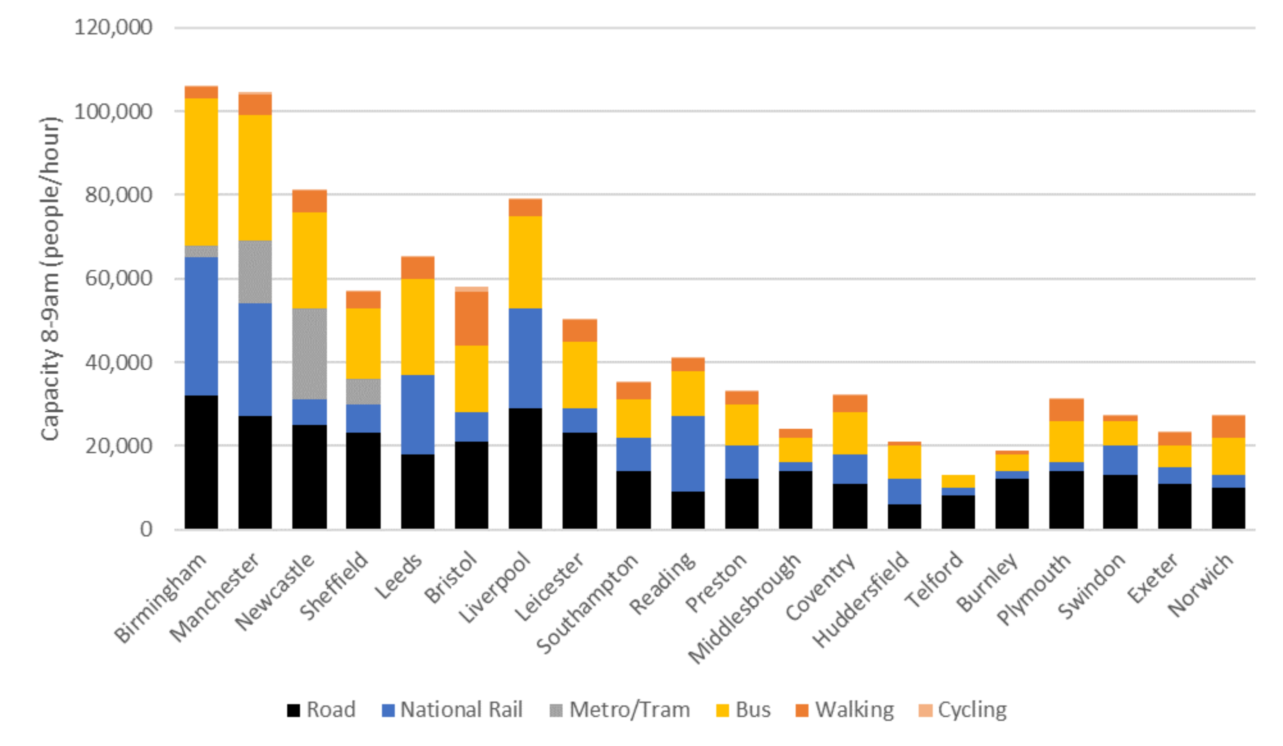

Figure 1 Morning peak hour inbound capacity across city centre cordon - case-study cities

WHAT COULD A CAPACITY UPLIFT LOOK LIKE?

This section details the core element of this paper: *if we want to increase transport capacity in built-up urban areas, how can we achieve this?* Urban areas by their very nature are constrained; particularly in city centres, which often have the highest development density. An overview of the elements considered in this study to define what a transport capacity uplift could 'look like' is provided in Figure 2.

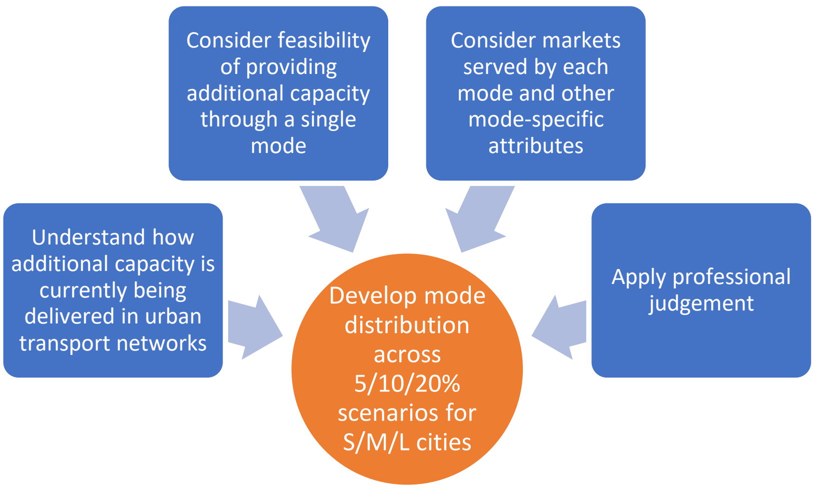

Figure 2: Overview of considerations in developing mode distribution by scenario and city size

Providing a representation of what a given uplift could 'look like' is based, for the purposes of this study, on technology and modes that are currently widely utilised in the United Kingdom, and are also consistent with existing modes and transport planning in New Zealand. Technology, and its interface with the transport system, is constantly developing. However, until new technologies are implemented, including the enabling regulations, it is difficult to project how their impact on urban mobility will be manifested. Defining how capacity uplifts could be delivered is based, therefore, on current contemporary themes in delivering transport infrastructure. Four core modes are the focus of the scenario building (bus, rail, light rail and private vehicle).

Contemporary themes in transport planning

Over time, as the transport knowledge base expands and societal preferences evolve, the way in which transport capacity is delivered is changing. This is most notable in the shift away from prioritising the car as a mode, and is also reflected in a much wider range of decisions. These changes in the focus and delivery of transport capacity are termed 'contemporary themes' in transport planning for the purposes of this paper.

Contemporary themes consider how local authorities and other bodies are currently approaching the challenge of building transport capacity into urban/built-up environments. The most notable themes considered include:

- Focus on reducing private vehicle trips, for example with the goal of improving air quality and health outcomes.
- Ongoing upgrades to/ optimisation of urban road networks to release capacity constraints.
- Implementation and extension of light rail networks in large UK cities.
- Light rail/ metro aspirations, including commissioning of studies, in medium size UK cities.
- Investigation of tunnelled metro/public transport infrastructure due to city centre space constraints.
- Planning for and implementation of integrated BRT networks, and better coordination of bus service provision.

Generic City Definitions

Capacity uplift scenarios are defined for groups of cities (large, medium and small), as opposed to for each individual city. Within the context of the original study's objectives, grouping provides a sufficiently generic approach to allow the extrapolation of results across all English cities.

The twenty case-study cities can be broadly grouped into large, medium and small categories based on primary urban area population. For the cities in each group, a range of metrics were considered, to understand the scale and nature of an average large, medium and small city. Generic city definitions (and capacities), based on mean values for groups of case-study cities, are set out in **Error! Reference source not found.**. Further information about the city characteristics and banding is provided in Appendix A.

Table 1: Generic City Definitions (0800-0900 metrics)

Generic City	Current Capacity (people/hr)	5% of Capacity	10% of Capacity	20% of Capacity	Existing Inbound Traffic Lanes	Current Train Arrivals	Current LRT/Metro Arrivals	Current Bus Arrivals
Large	75,000	4,000	8,000	15,000	36	38	33	283
Medium	31,000	2,000	3,000	6,000	16	19	-	143
Small	23,000	1,000	2,000	5,000	14	8	-	96

Capacity Uplift Scenarios Overview

This study considers three capacity uplift scenarios for each defined 'generic city' (L/M/S):

- 5% capacity uplift
- 10% capacity uplift
- 20% capacity uplift

Within each scenario, we hypothesise how each mode could reasonably contribute to additional transport capacity within a city, and paint a picture of what a capacity increase could 'look like'.

The 5/10/20% uplifts were defined as part of the scope of the original study. The uplifts are used as a proxy for actual growth in travel demand, as it relates to employment and population growth expected in regional English cities.

Considerations within each scenario are focused on how transport capacity into city centres can be increased, as opposed to more general consideration of capacity for all origin-destination pairs across a city/region. Where possible, scenarios consider the available policy levers at a local level.

The remainder of this section discusses:

- **Scenario contexts;** providing an overview of the scale of change that may be required to deliver the specified capacity uplifts;
- **Scale of change required for capacity uplift;** considers the nature of intervention required to achieve each uplift level;
- **Mode considerations;** assumptions specific to each mode that provide an understanding of the markets served by each mode and the extent to which each mode may be appropriate in each scenario; and
- **Scenario definition;** sets out the potential mode combinations to achieve the capacity uplift for each scenario.

Scenario Contexts

In understanding what transport capacity uplifts could 'look like', the potential to provide all required additional capacity through a single mode has been considered. This identifies limits of the potential for individual modes to contribute to capacity uplifts.

Delivery of capacity through a single mode

Representations of the additional services/lanes required if uplifts were delivered by a single mode are set out in Table 2 to Table 4. Table 2 to Table 4 show that delivery of the specified capacity through a single mode would, in most cities, not be possible. For example, for a generic large city delivery of a 10% uplift in capacity (8,000 people/hr, see Table 1) would mean either:

- 13 additional road lanes (unlikely to be able to be accommodated within the available space); or
- 74 additional rail carriages, this is approximately equivalent to adding 2 carriages to every existing train, or increasing service frequencies by 30 trains in the peak hour (~80% uplift in frequencies); or
- 27 new trams (>80% uplift in frequency); or
- 93 new buses (>30% uplift in frequency)

The large uplifts required relative to existing provision by each mode suggests the current system would struggle to accommodate the level of change if delivered through a single mode. On this basis, an approach to developing scenarios using a combination of modes is considered appropriate and necessary.

Table 2: 5% uplift scenario – requirements if capacity delivered through a single mode

	Additional Units Required (by mode)				Uplift as a Proportion of Existing Capacity			
Size	**Road (inbound lanes)**	**Rail (carriages)**	**Metro/ Tram (vehicles)**	**Bus**	**Road (inbound lanes)**	**Rail (trains requiring additional carriages)**	**Metro/ Tram (vehicles)**	**Bus**
L	6	37	14	47	18%	98%	41%	16%
M	3	15	6	22	17%	82%		15%
S	2	11	4	16	14%	145%		17%

Table 3: 10% uplift scenario – requirements if capacity delivered through a single mode

	Additional Units Required (by mode)				Uplift as a Proportion of Existing Capacity			
Size	**Road (inbound lanes)**	**Rail (carriages)**	**Metro/ Tram (vehicles)**	**Bus**	**Road (inbound lanes)**	**Rail (trains requiring additional carriages)**	**Metro/ Tram (vehicles)**	**Bus**
L	13	73	27	93	35%	195%	82%	33%
M	5	30	11	44	33%	164%		31%
S	4	23	8	33	29%	290%		34%

Table 4: 20% uplift scenario – requirements if capacity delivered through a single mode

	Additional Units Required (by mode)				Uplift as a Proportion of Existing Capacity			
Size	**Road (inbound lanes)**	**Rail (carriages)**	**Metro/ Tram (vehicles)**	**Bus**	**Road (inbound lanes)**	**Rail (trains requiring additional carriages)**	**Metro/ Tram (vehicles)**	**Bus**
L	25	147	54	186	71%	390%	164%	66%
M	11	61	22	88	66%	328%		61%
S	8	46	17	66	58%	580%		68%

Difference in markets served by modes

For some scenarios it may be possible to deliver all additional capacity required through a single mode, however this is unlikely to be the most effective method of delivery. Different modes serve different markets, which means a balanced portfolio of capacity increase across modes will be needed if the full benefits are to be realised. One demonstration of this is through disaggregating by trip length (see Figure 3), whereby different modes are more convenient or appropriate for different trip lengths. Other travel market segmentations could be based on accessibility of modes due to cost, residential densities at the trip origin, geographic location of infrastructure and physical requirements for use (e.g. ability to drive).

Error! Reference source not found. Figure 3 shows distribution of trip length by mode based on journey to work data used for the 20 case-study cities, only trips up to 20km in length are included. Walking and cycling are most prevalent for trip lengths up to 3km (slightly longer for cycling). Bus is a common mode for short to medium distance trips, while rail serves medium to long distance trips. Car trips are relatively dominant for all, except very short, trip lengths.

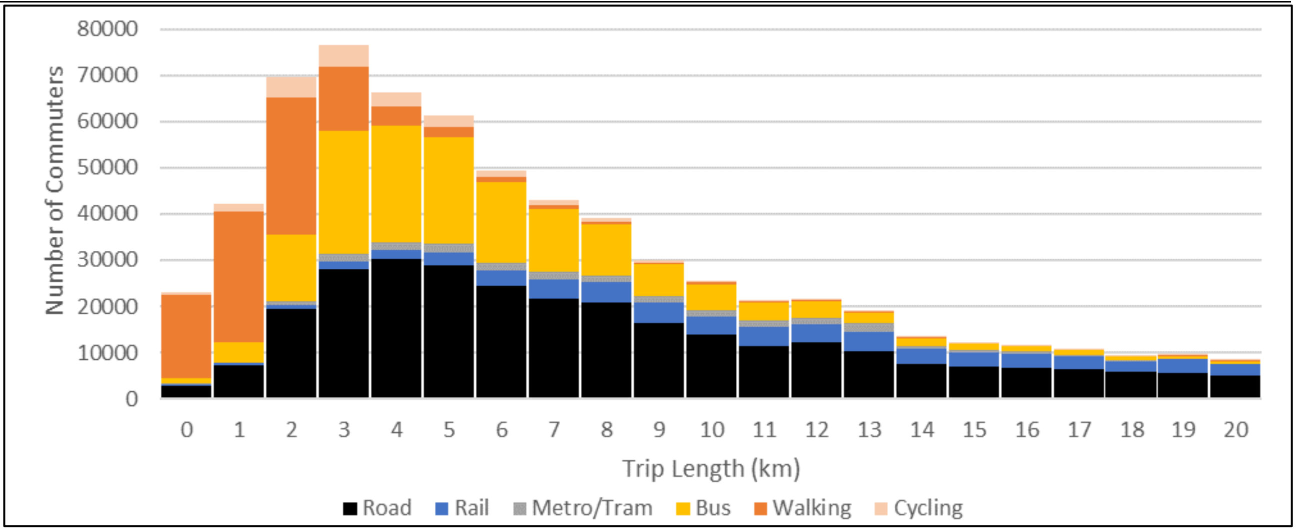

Figure 3: Distribution of trip lengths by mode (cumulative across case-study cities), based on 2011 Census journey to work data

City centres, by their built-up nature, are space constrained. Modes vary in terms of their space efficiency, which is an important consideration in city centres where multiple routes converge. For example, while a light rail route may only operate with six trams per hour outside the city centre, within the city centre a single length of track can accommodate much higher frequencies where multiple routes converge.

Scale of change required by scenario

The following text summarises the scale of change required to achieve the capacity uplifts in each scenario. This builds on the analysis in Table 2 to Table 4 and sets the context for the types of investment that may be required to achieve the uplift targets in each scenario. Contemporary themes in transport planning are drawn upon in developing these contexts as discussed earlier in this paper.

1: 5% Capacity Uplift

A 5% uplift in capacity is relatively incremental. It can generally be achieved through maintaining a similar transport offer within a city with increases to bus frequencies, train lengths, intersection optimisation, and short sections of additional road lanes.

2: 10% Capacity Uplift

To achieve a 10% uplift in capacity more significant changes to the transport offer are required. For example, in medium and large cities this may mean the introduction of new tram lines (serving new origins), in smaller cities differentiated (i.e. high-quality) bus services may be introduced.

3: 20% Capacity Uplift

Transformational change is required to achieve a 20% uplift in capacity. In larger, established cities this may include interventions such as a tunnelled public transport route in the city centre, due to surface level space constraints. For rail services this will likely require major reconstruction of the terminus or main station to accommodate additional services.

Mode Considerations

In defining the mix of modes to understand what a capacity uplift could ‘look like’ in each scenario and as the basis for cost estimates, we have considered the attributes of each mode. This builds on the earlier discussion of the differences in markets served and contemporary themes. The following assumptions/assertions are central to the distribution of capacity across modes used in each scenario:

Road

- Large cities tend to have better developed public transport networks and actively seek to minimise travel by private vehicle into city centres.

- Large cities have generally maximised the amount of road capacity that can be provided into city centres. A small amount of additional road capacity could be achieved in large cities, however the contribution of road capacity to additional capacity is fixed across all scenarios.
- Small and medium cities have less developed public transport networks and are therefore more car-dependent.
- Due to lower absolute capacity uplifts required, a greater proportion of the required uplift can be achieved by investment in roads in small and medium cities, the contribution of road capacity is fixed across all scenarios.

Rail

- Rail is very efficient at providing high capacity levels, however it is also an expensive mode to implement. The importance of rail capacity is greatest in the higher uplift scenarios.
- Rail network coverage is poorer in smaller cities, with only a selection of trip origins served by rail. The contribution of rail to providing capacity increases in small and medium cities, therefore, is expected to be lower.
- In the UK rail is a national network, and not necessarily focused on maximising capacity into each and every case-study city. Constraints on the rail network outside of cities may be the limiting factor on the ability to provide additional rail capacity. Light rail is therefore considered a more targeted mode for providing urban transport network capacity in many instances.

Bus

- Large cities are likely to experience kerb space constraints within their city centres for providing bus stops. Moreover, in large cities road capacity constraints are likely to affect bus journey times. For this reason, buses are utilised to a lesser extent in the higher uplift scenarios.
- In small and medium cities, it is assumed there is greater capacity to accommodate additional buses. However, medium cities may also need to extend to higher capacity modes (such as light rail) in the higher uplift scenarios.
- Currently, in England local authorities have limited ability to influence how bus services are provided, although additional powers are being made available to elected local decision makers through devolution deals. Bus utilisation, outside of London, has faced long term downward trends. Therefore, any uplift in bus capacity will likely require additional incentives to drive any marked uptake in utilisation.
- Despite long-term downward trends in bus utilisation, buses continue to provide the greatest cumulative capacity of any public transport mode for urban trips, see **Error! Reference source not found.**.
- Buses are a flexible transport mode. Unlike trams, which require fixed infrastructure on a specified route, bus routes can change over time as origin-destination pairs change.

Metro/Tram

- Light rail is perceived as a more attractive mode than bus and therefore does not face the same issues as bus with attracting passengers who would otherwise use car.
- For the purposes of this study, additional metro/tram capacity is assumed to be light rail, not underground capacity (except where a section of tunnelling may be required).
- Due to the high cost of implementation, and the ultimate need to demonstrate value for money, light rail is considered in the scenario building for large and medium cities only.

Active Modes

- Active modes are not explicitly considered. New transport infrastructure generally has provision for active modes, therefore the cost estimates account for some investment in active modes, however the impact of this on active mode utilisation is not accounted for.

- For the majority of the population, active modes are only attractive for relatively short trips, therefore the 'market' for these modes in this study is limited to people living in close proximity to a city centre.

Scenario Definition

What a capacity uplift could 'look like' for each of the large, medium and small generic cities are summarised in Table 5 to Table 7. These summaries set out:

- The assumed contribution of each mode to the capacity uplift in each scenario. For example, in the 5% scenario (Table 5) for large cities: 10% of the required uplift is assumed to come from road capacity, 25% from national rail, 25% from light rail and the remaining 40% from bus.
- A representation of what this mode contribution could mean in terms of required additional vehicles and lanes. This provides an understanding of the scale of the uplift required and works as a validation point to understand whether the uplift attributed to each mode is reasonable.
  - For example, in the 5% scenario for large cities set out above, the required uplift in capacity could be achieved through cumulatively implementing: 1 additional inbound road lane, 10 additional rail carriages, 4 additional light rail vehicles (LRVs) and 19 additional buses in the 0800 - 0900 morning peak.

Table 5: 5% Capacity Uplift Scenario Mode Distribution

	Contribution to Uplift by Mode				Equivalent Additional Units required			
Size	**Road**	**National Rail**	**Metro/ Tram**	**Bus**	**Road - Lanes**	**Rail - Carriages**	**Tram-LRV**	**Bus-Veh**
Large	10%	25%	25%*	40%	1	10	4	19
Medium	40%	15%		45%	2	3	0	10
Small	40%	10%		50%	1	2	0	9

*where a city already has a tram/metro network only, otherwise this proportion of uplift is provided by bus.

Table 6: 10% Capacity Uplift Scenario Mode Distribution

	Contribution to Uplift by Mode				Equivalent Additional Units required			
Size	**Road**	**National Rail**	**Metro/ Tram**	**Bus**	**Road - Lanes**	**Rail - Carriages**	**Tram-LRV**	**Bus-Veh**
Large	5%	25%	25%	45%	1	19	7	42
Medium	20%	20%	40%	20%	2	7	5	9
Small	20%	10%		70%	1	3	0	23

Table 7: 20% Capacity Uplift Scenario Mode Distribution

	Contribution to Uplift by Mode				Equivalent Additional Units required			
Size	**Road**	**National Rail**	**Metro/ Tram**	**Bus**	**Road - Lanes**	**Rail - Carriages**	**Tram-LRV**	**Bus-Veh**
Large	3%	25%	50%	23%	1	37	27	42
Medium	10%	30%	50%	10%	2	19	12	9
Small	10%	10%		80%	1	5	0	53

The resulting assumed distribution of all capacity across modes, and how this changes by scenario is summarised in Figure 4 to Figure 6. This shows that for large and medium cities, metro/tram is assumed to become more important as the uplift in capacity required increases. For small cities, bus is assumed to be an appropriate mode for providing large scale increases in capacity due to the need to demonstrate value for money before investing in infrastructure. Regardless of mode, capacity increases of 20% would be transformational and require a step change relative to existing transport provision in a city.

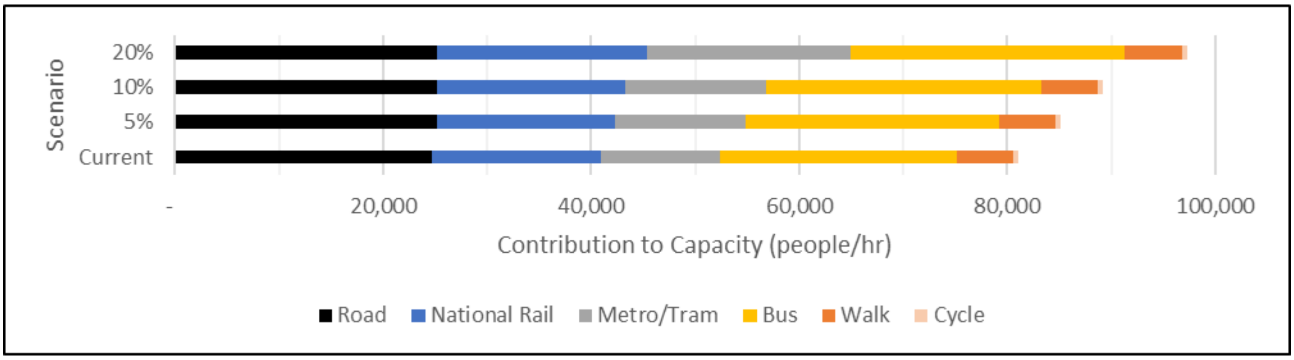

Figure 4: Capacity contribution by mode for generic large city – by scenario

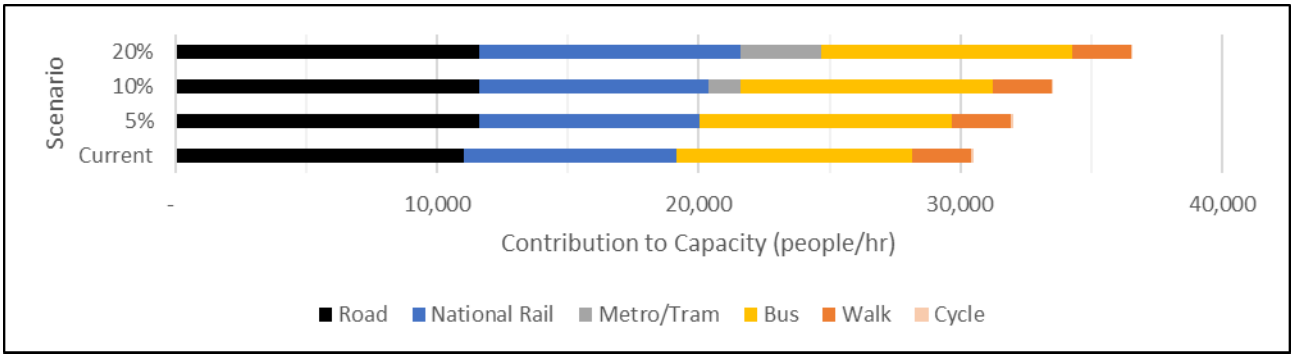

Figure 5: Capacity contribution by mode for generic medium city – by scenario

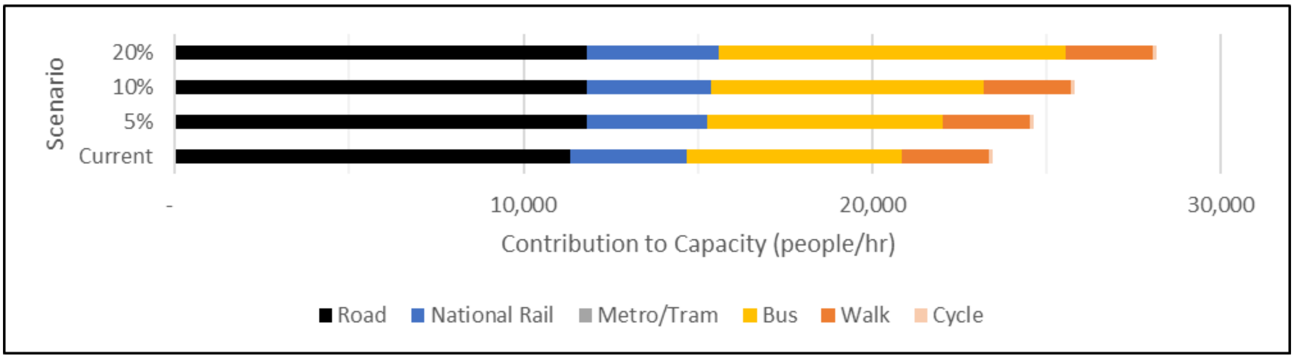

Figure 6: Capacity contribution by mode for generic small city – by scenario

Connected and Autonomous vehicles (CAVs)

As set out in the introduction, the development and increased market penetration of CAVs could affect road capacity. This section sets out the results of a sensitivity test to understand the impact of CAVs on capacity. The sensitivity test assumes that a 25-50% market penetration by 2050 could increase road capacity by c.5% in urban areas on average. This assumption is consistent with the ranges of capacity impacts reported at intersections in a study by Atkins (2016) on the basis that intersection capacity generally drives overall road network capacity in urban environments.

There is an additional cost, over and above the current supply of road infrastructure, to accommodate CAVs on the road network. Different CAV technologies require different infrastructure to operate safely in the road environment. Therefore, dependent on the technologies that come to the fore in mainstream CAV uptake, associated infrastructure costs will differ.

In lieu of published values for the cost of upgrading and implementing infrastructure to safely accommodate widespread CAV use in the UK, this sensitivity test considers the potential impact of CAVs on capacity only, see Table 8. The results of this sensitivity test show that if CAV uptake uplifts urban road network capacity by 5%, the uplift to total transport capacity into city centres could be in the range of 1.2% - 3.3%. Smaller cities would experience a larger uplift (by percentage) than larger cities due to the proportion of overall capacity contributed by the road network in these cities. The uplifts resulting from this sensitivity test show that further investment, over and above that required to accommodate CAVs on the network, is anticipated to be required in order to achieve the specified 5/10/20% capacity uplifts.

Table 8: Sensitivity Test Results - Possible Capacity impact of CAVs

Case-Study City	Road Capacity (8-9am)	Total Capacity (8-9am)	Additional Capacity due to CAVs*	**% Capacity uplift across all modes due to CAVs**
Birmingham	32,000	106,000	1,600	**1.5%**
Manchester	27,000	105,000	1,400	**1.3%**
Newcastle	25,000	81,000	1,300	**1.6%**
Sheffield	23,000	57,000	1,200	**2.1%**
Leeds	18,000	66,000	900	**1.4%**
Bristol	21,000	58,000	1,100	**1.9%**
Liverpool	29,000	80,000	1,500	**1.9%**
Leicester	23,000	50,000	1,200	**2.4%**
Southampton	14,000	34,000	700	**2.1%**
Reading	9,000	41,000	500	**1.2%**
Preston	12,000	34,000	600	**1.8%**
Middlesbrough	14,000	24,000	700	**2.9%**
Coventry	11,000	33,000	600	**1.8%**
Huddersfield	6,000	21,000	300	**1.4%**
Telford	8,000	13,000	400	**3.1%**
Burnley	12,000	18,000	600	**3.3%**
Plymouth	14,000	31,000	700	**2.3%**
Swindon	13,000	27,000	700	**2.6%**
Exeter	11,000	23,000	600	**2.6%**
Norwich	10,000	28,000	500	**1.8%**

*Assumes 5% increase in urban road network capacity

It should be noted that; the availability of CAVs may generate additional travel demand, as people that are currently unable to drive or access public transport can travel in CAVs (e.g. young people, the disabled, the elderly or those who simply don't have access to a car) and due to empty vehicles re-positioning themselves on the network. Therefore, the additional capacity generated may not be available to accommodate the morning peak trips that are the focus of this project. Note also, no bespoke analysis on the impact of CAVs has been undertaken as part of this study. Assumptions in this sensitivity test rely on published research at the time of analysis.

HOW MUCH WILL IT COST?

Order of magnitude cost estimates have been developed for each of the capacity uplift scenarios. Assumptions on specific interventions are used to understand the likely scale of cost, and are not intended to be representative of what a specific city would, or should, implement to achieve the specified capacity uplifts. Specific plans and programmes for individual cities should be developed at a local level, taking into account local context and need. The approach to cost estimates is, in line with the study specification, focused on being representative at an aggregate level. Variations between reported and actual values/scenarios are, therefore, anticipated at a city level.

The cost of delivering transport capacity uplifts varies by location and can be affected by a range of factors. Urban transport schemes are likely to become costlier over time. This is anticipated due to a range of factors including changes to minimum standards and exhaustion of 'low hanging fruit' (e.g schemes where additional land required is easily available), meaning schemes delivered later are often more complex. This potential trend is not considered explicitly within this study; however, the ease of delivery is accounted for to some extent through setting out the scale of change required relative to the existing transport offer to deliver the specified capacity in each scenario.

Cost estimates developed in this study are intended to be appropriate for scaling across all English cities. However, they are not developed to a level of detail that allows specific local features to be accounted for in the costs. Cost estimates are based on assumptions related to service frequencies and infrastructure quantities e.g. number and length of additional highway lanes required for each city. Further detail is provided in the original study report.

Cost Estimate Results

Order of magnitude capital costs for each scenario are presented in Figure 7 to Figure 9 for the generic large, medium and small cities. Costs do not have a linear relationship to the increase in capacity. Larger increases in capacity will require more transformational change to the transport system, which has a significant impact on cost. Generally, results show that as the uplift in capacity increases the cost per additional unit of capacity increases. Sensitivity testing results show capital costs for a given city and scenario could range from -45% to +307% relative to the reported central case in the following figures.

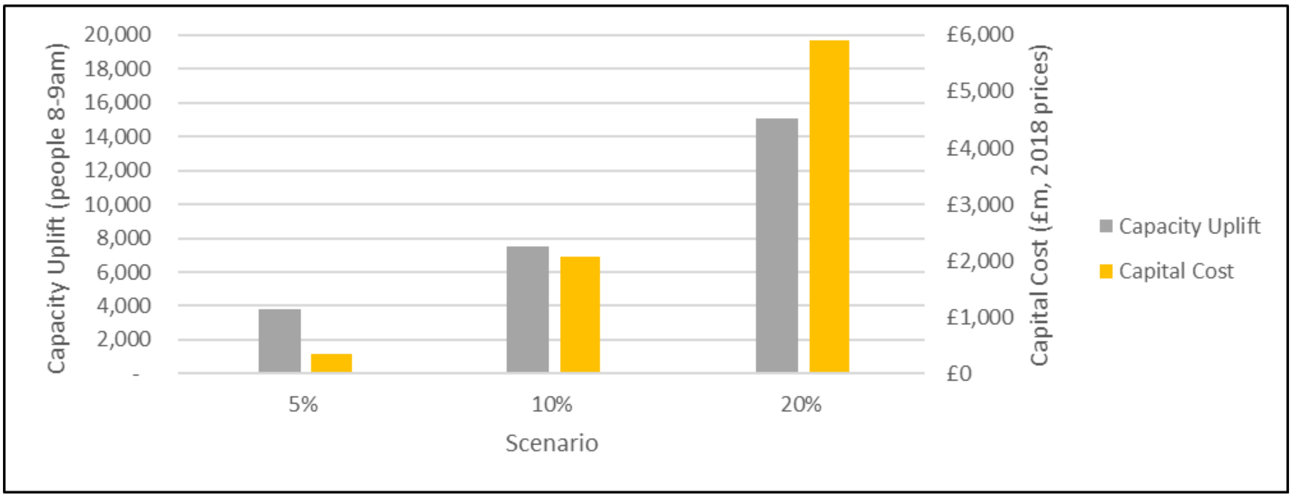

Figure 7: Capital Cost Estimate – Generic Large City

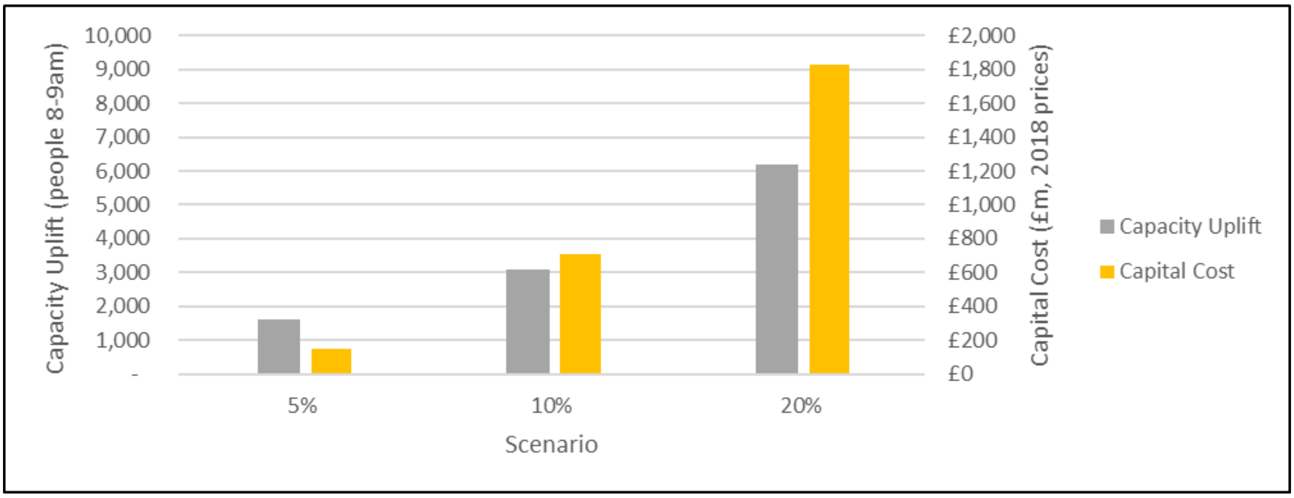

Figure 8: Capital Cost Estimate – Generic Medium City

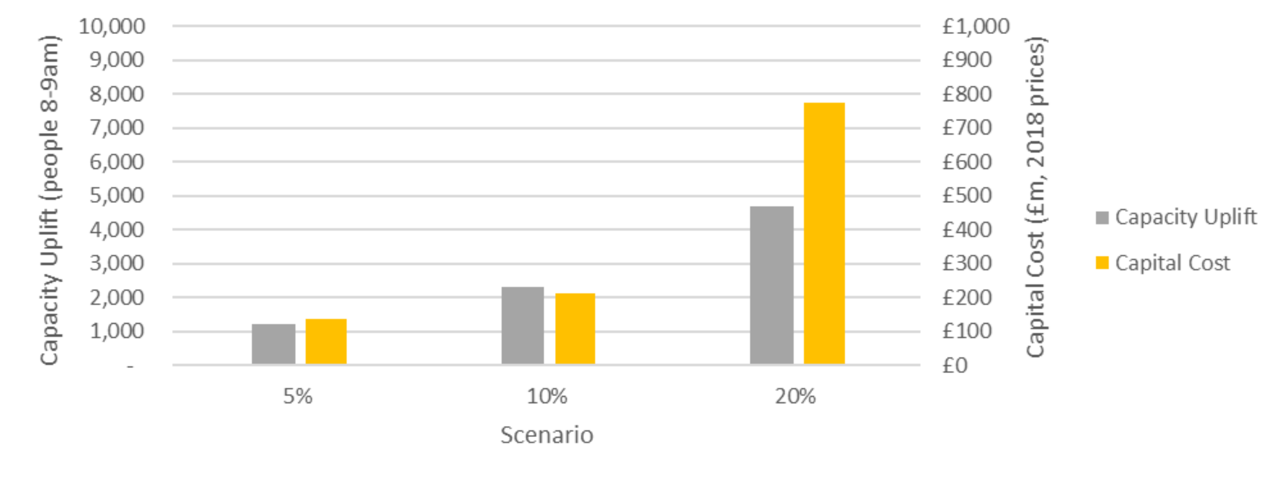

Figure 9: Capital Cost Estimate – Generic Small City

DISCUSSION AND CONCLUSIONS

In the context of New Zealand, this paper provides useful insight into how growth could be accommodated on our urban networks. Using the study's definitions, Auckland would be a large city and Christchurch and Wellington would be medium cities. The growth scenarios considered are not inconsistent with the levels of growth expected in some of our key growth areas. For example, Auckland's population is anticipated to grow by approximately 40% over the next 30 years, putting pressure on the existing transport infrastructure. Accommodating growth in our cities confronts many of the same challenges as cities in the UK: how do we provide for growth in a way that continues to support and facilitate economic prosperity, while at the same time protecting our people and environment, and contributing to reducing CO_2 emmissions.

As set out in the scenario development section, where transport capacity uplifts of circa 20% are planned, transformational change is required to achieve this. In larger, established cities this may include interventions such as a tunnelled public transport route in the city centre, due to surface level space constraints. Uplifts of circa 10% are also anticipated to require significant change such as augmenting the 'transport offer' of a network, for example introducing new tram lines. It should be noted that some medium sized cities in the UK are also looking at tunnelled public transport options due to surface level space constraints, as set out in the 'contemporary themes in transport planning'.

Where a city plans to increase its transport capacity the actual distribution of modes is likely to differ from that set out in the scenarios in this study. However, our mode considerations and results based on delivering capacity through a single mode demonstrate that there is no 'silver bullet' to solve our future transport needs. For anything more than an incremental uplift it is unlikely to be possible to deliver the required capacity through a single mode; a multi-modal approach is required. Different modes serve different 'markets', e.g. different modes are more convenient or appropriate for different trip lengths. This further reinforces the requirement to take a multi-modal approach to building additional capacity into the network. Other travel market segmentations could be based on accessibility of modes due to cost, residential densities at the trip origin, geographic location of infrastructure and physical requirements for use (e.g. ability to drive).

Results of sensitivity testing considering the possible impact of connected and autonomous vehicles show that while these may increase the available capacity of the network, CAVs alone are unlikely to provide a solution for accommodating large scale growth.

Urban transport schemes are likely to become costlier over time. This is anticipated due to a range of factors including changes to minimum standards and exhaustion of 'low hanging fruit' (e.g schemes where additional land required is easily available), meaning schemes delivered later are often more complex. Costs do not have a linear relationship to the increase in capacity. Larger increases in capacity will require more transformational change to the transport system, which has a significant impact on cost. Generally, results show that as the uplift in capacity increases the cost per additional unit of capacity increases.

Overall, while the specific outputs of this study (e.g. capital costs of increasing transport capacity) are not validated for the New Zealand context, the considerations in this study are useful to inform current decision making in New Zealand transport and land-use planning. As cities grow, the cost of providing additional transport infrastructure is anticipated to increase per capacity unit, and the findings and considerations in this study align with the current multi-modal direction in the Government Policy Statement . While it will be for each city to develop their own solutions, what this study helps make clear that the scale of investment needed to accommodate growth in cities is substantial. This is as true in New Zealand as it is in the UK.

It’s important that policy-makers and decision-takers understand the scale of investment that might be needed to accommodate growth. Now is the right time to start thinking about what we want this investment to look like and how it should be paid for.

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APPENDIX A: CASE-STUDY CITIES

Twenty case-study cities are used as a basis for the study. These have been chosen to reflect a range of different city sizes, locations and socio-demographic contexts. The selection does not reflect any assessment of investment priorities, either nationally or in the case-study cities. Case-study cities, size categories (applied for this study), and primary urban area populations are shown in the table below. Populations are based on Centre for Cities data for 2017 populations.

Variations between our assessment and locally reported data are anticipated. While this study considers potential interventions to achieve a range of transport capacity uplifts, and when transformational change may be required, it is not suggested that such interventions are required to meet local policy goals in individual cities. Specific plans and programmes for individual cities need to be developed at a local level, taking into account local context and need, as well as consideration of deliverability, affordability and value for money.

City	City Size Category	Primary Urban Area Population (2017)		City	City Size Category	Primary Urban Area Population (2017)
Birmingham	L	2,537,000		Preston	M	368,000
Manchester	L	2,474,000		Middlesbrough	M	473,000
Newcastle	L	852,000		Coventry	M	360,000
Sheffield	L	841,000		Huddersfield	M	437,000
Leeds	L	785,000		Telford	S	176,000
Bristol	L	738,000		Burnley	S	178,000
Liverpool	L	640,000		Plymouth	S	263,000
Leicester	L	510,000		Swindon	S	220,000
Southampton	M	383,000		Exeter	S	129,000
Reading	M	328,000		Norwich	S	269,000