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O8 Land Use Benefits of Transport Initiatives

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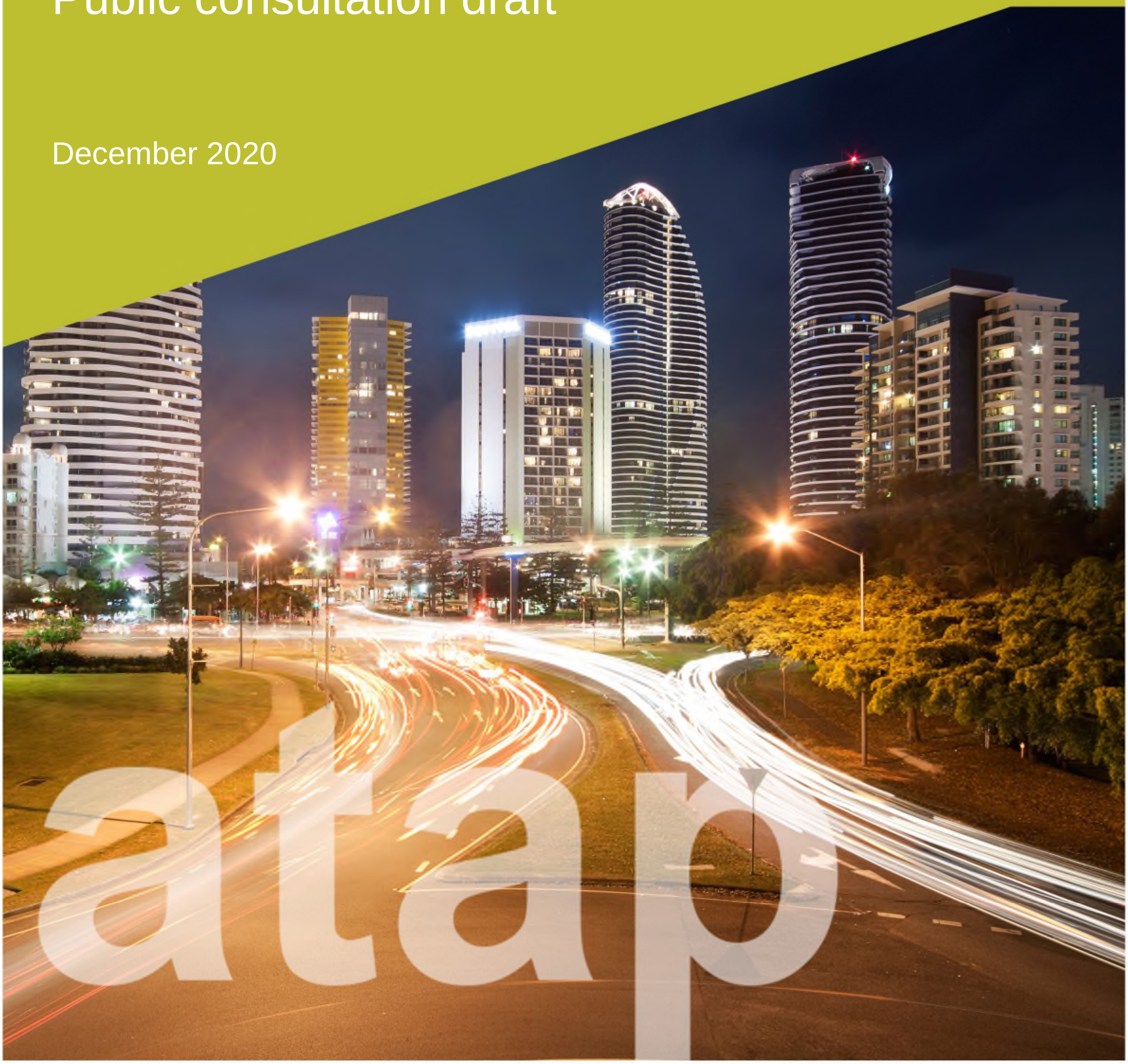

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Contents

Land Use Benefits of Transport Initiatives 1

1. Introduction..2

2. Overview..5

2.1 Introduction to land use benefits 5
2.2 Defining land use change...6
2.3 When to include land use benefits 6
2.4 What land use benefits can be captured in a CBA 8

3. Land use forecasting 10

3.1 Land use change... 10
3.2 Common approaches to land use forecasting.. 11
3.3 Key considerations for land use forecasting 13
3.3.1 Determine the spatial area of assessment 14
3.3.2 Specify the Base Case.. 14
3.3.3 Determine the change in land use in the project case................................... 15

4. Estimation of land use benefits 16

4.1 When to include land use benefits 16
4.2 Key challenges to estimating land use benefits 17
4.2.1 Double counting 17
4.2.2 Dependency and conditionality... 17
4.2.3 Redistribution approach 18
4.2.4 Net negative benefits 19
4.3 Presentation of land use change benefits... 19

5. Higher value land use 21

5.1 Estimating higher value land use 23
5.2 Higher value land use practical example 25

6. Second-round transport impacts.. 27

6.1 Estimating second-round transport benefits... 28

7. Public infrastructure costs savings 30

7.1 Estimating public infrastructure cost savings 31
7.2 Public infrastructure cost savings example... 32

8. Sustainability benefits 33

8.1 Estimating sustainability benefits 34
8.2 Household energy consumption sustainability benefit example 34

9. Public health cost changes... 35

9.1 Estimating public health benefits.. 36

9.2 Public health benefits example ... 37

10. Areas for further research ... 38

10.1 Parameter values ... 38

10.2 Land value uplift ... 38

10.3 Displacement and its impact on land use benefits ... 38

10.4 Establishing dependency and conditionality ... 39

10.5 Alternative approaches - TAG unit depended development ... 40

Appendix A Infrastructure-land use transmission mechanisms ... 42

A.1 Demand-side mechanisms ... 42

A.2 Supply-side mechanism ... 43

Appendix B Extent to which transport models account for land use change ... 45

References ... 47

Figures

Figure 1 Illustrative land market value creation curve from a transport initiative ... 23

Figure 2 Illustration of iterative approach to land use transport modelling ... 28

Figure 3 Transport / land use demand modelling runs ... 29

Figure 4 Establishing whether a development is dependent ... 39

Figure 5 Effect of an increase in demand on market for developed land ... 42

Figure 6 Effect of a decrease in cost of private development ... 43

Figure 7 Impact of a regulatory constraint ... 44

Tables

Table 1 Land use benefits summary ... 8

Table 2 Common approaches to land use forecasting ... 11

Table 3 Example of core appraisal results table ... 20

Table 4 Higher value land use market imperfections ... 22

Table 5 Forecasted change in floorspace by development type (square metres of GFA) ... 25

Table 6 Residual land values ($2017 per square metre of GFA) ... 25

Table 7 Capital costs of public infrastructure in greenfield and established areas ($2020 per dwelling) ... 30

Table 8 Household energy consumption sustainability benefits by density type ($2020 per dwelling pa) ... 33

Table 9 Health system benefits of active travel per km according to physical; activity ($2020) ... 36

Table 10 Overview of travel behavior ... 46

Land Use Benefits of Transport Initiatives

At a glance

- Transport infrastructure has long been recognised to have the potential to affect land use. Moreover, because of market imperfections and feedback effects between land use and transport demand, changes in land use can result in a range of additional benefits to those that are captured in a fixed land use transport appraisal
- If correctly estimated, these benefits are additive to the conventional transport benefits typically estimated for transport initiatives, as outlined in other parts of the Guidelines
- In order for and use benefits to be included in cost-benefit analysis, the land use forecasting approach and land use benefit estimation must establish that the change in land use is directly attributable to the project. Forecast land use change must be both principally dependent on the transport project in question (as opposed to being dependent on other factors) and the necessary conditions (such as zoning changes, other infrastructure, excess demand or associated public and private investment) must be present in order for the identified land use impacts to materialise
- Not all transport projects will result in land use impacts, however, those projects that do cause changes in land use across a given area may create benefits such as *Higher value land use*, *second round transport impacts*, *sustainability benefits*, and *public health benefits*, which can be estimated and included in cost-benefit analysis of transport projects
- Transport projects also have the potential to create *public infrastructure cost savings* where they redistribute population and employment changes to areas with lower associated infrastructure costs. At present, available parameter values which have been estimated at city-wide levels in the past may not be accurate enough for application to specific regions impacted in a transport project
- The estimation of land use benefits is a complex and challenging activity, and there is little consensus on the parameter values to be used when quantifying land use benefits. This largely stems from the unsuitability of general parameters values for quantifying land use benefits - land use benefits, by their nature, tend to be location specific. There is not one value which suits all locations
- As a result, the parameters presented in this report should be used with a high degree of caution. They should be interpreted as indicative rather than definitive. The use of sensitivity testing to assess the robustness of parameters, and land use benefits in general, is strongly encouraged. It is also recommended that, where possible, practitioners should undertake analysis to investigate land use parameters on a project by project basis.

Public Consultation Note

The ATAP Guidelines welcomes feedback and comments on any part of the guidance document. However, we have included a set of public consultation questions below which are of particular interest for the finalisation of the guidelines. Comments on these consultation questions or on the preliminary ATAP position are greatly appreciated.

Consultation Questions - Higher Value Land Use Benefit

Question 1: Should the economic benefit from higher value land use be incorporated into CBA at the time the potential for the higher land use is unlocked, or the time that actual land use change is forecast to occur?

ATAP position: the benefit should be counted at the point in time that the actual land use change is forecast to occur. This mirrors the approach used in conventional transport appraisals, where travel rather than access or accessibility is used to estimate economic benefits – i.e. it is the behaviour that should be measured, not the potential for behaviour.

Question 2: How should the loss of existing capital be considered when estimating the higher value land use benefit?

ATAP Position: The approach in the draft guidance only counts benefits for *incremental* floor space made available as a result of the project. The economic value of existing capital destroyed to make way for new construction is ignored. Say a three story building in the base case is demolished in the project case to make way for an eight story building. One estimate of the land use benefit would be the RLV for all eight floors of the new building minus the present value of economic returns from the three story building demolished. Under the recommended incremental approach, only RLV of the additional five floors of the new building are counted as land use benefits. The incremental approach is simpler to implement because it does not require valuation of existing capital. To the extent that the RLV of new floor space that replaces old (the lower three stories in the example here) is more valuable than existing building, the incremental approach will understate the full benefit and is therefore conservative.

Question 3: Should real escalation of land values be included in the CBA?

ATAP Position: In theory, yes, but due to difficulty of forecasting future land values, the conservative approach of not including them is preferred.

Question 4: Does the potential for negative or ‘lower-value land use’ impacts exist in the CBA framework?

ATAP position: There are likely to be specific cases where a negative or lower-value land use disbenefits is required to offset the higher value land use measured in the appraisal. For example, where land on the metropolitan fringe is rezoned from rural to residential land in the base case, but this rezoning is not required under the project case as the need for greenfield development is avoided.

Consultation Questions – Second Round Transport Benefits

Question 1: There are two alternative approaches available to capture the consumer surplus benefits from transport users that change *origin*. The first, outlined in Chapter 6, is to apply conventional transport user benefit approaches. An alternative approach recommended by the UK Transport Appraisal Guidelines (TAG) A2.2 *Appraisal of Induced Investment Impacts* pp26-28 is to estimate conventional transport user benefits without land use changes only. Both second round transport impacts and higher value land use are instead captured in a single land value uplift benefit, estimated by subtracting the value of the land in its 'without development' use from its value in new use. Because the transport scheme is assumed to have been implemented when this is assessed, the value of the land in its new use reflects the improved accessibility provided by the transport scheme as well as any unlocked development capacity. Transport and other externalities from the land use change are separately assessed.

ATAP position: direct measurement of second round benefits is preferred, though it requires a robust assessment of dependency and conditionality in the land use forecasting approach, as well as a robust land use redistribution approach that accounts for the considerations outlined in s4.2.3

Consultation Questions – Infrastructure Costs

Question 1: Should public infrastructure cost savings be included in CBA?

ATAP position: While there may be a theoretical basis for the inclusion of this benefit, it is heavily contested on the basis that available ‘city level’ data may not be applicable when applied to individual areas or for individual projects. While most literature supports that infill development is cheaper than Greenfield development, the actual values are likely to vary significantly on a case-by-case basis. ATAP’s position is that public infrastructure cost savings should not be included in the core CBA results unless evidence specific to the areas being impacted is obtained.

Question 2: Should the costs for all public infrastructure, not just transport, not recovered from users that are required to achieve the land use change be included in the cost benefit analysis? An example is that of a major new greenfield rail line for which a great deal of other infrastructure (communications, electricity, roads, water, schools, public parks etc.) is required to allow development.

ATAP Position: There is a theoretical basis for the inclusion of these impacts in CBA, though an important consideration is that these impacts when assessed in CBA reflect the net change in costs between the base case and the project case, not just the absolute change in costs in the project case. The impacts (and associated benefits or costs) will differ depending on whether an ‘open city’ or ‘closed city’ approach is used.

1. Introduction

This part of the Guidelines considers the land use benefits of transport initiatives.

It reviews the different types of land use benefits that can be attributed to transport initiatives, and outlines approaches for estimating these benefits in cost–benefit analyses (CBAs). Transport initiatives give rise to land use changes where they impact the type, pattern, and location of activities across a region. In some cases these land use changes give rise to benefits (both positive and negative) that, if correctly estimated, are additive to the conventional transport benefits typically estimated for transport initiatives, as outlined in other parts of the Guidelines.

Land use benefits should be identified and appraised alongside the other benefits outlined in ATAP part T2 Cost-Benefit Analysis, and ATAP Part T3 Wider Economic Benefits, where appropriate for a transport initiative.

- Chapter 2 provides an overview of the concepts of land use change and land use benefits
- Chapter 3 provides more detailed discussion and initial guidance for forecasting land use changes
- Chapter 4 provides an overview of challenges and considerations for estimating land use benefits
- Chapter 5 discusses the theory and estimation approach for the Higher Value Land Use benefit
- Chapter 6 discusses the theory and estimation approach for the Second Round Transport benefit
- Chapter 7 discusses the theory and estimation approach for the Public Infrastructure Cost Savings benefit
- Chapter 8 discusses the theory and estimation approach for the Sustainability benefit
- Chapter 9 discusses the theory and estimation approach for the Public Health benefit
- Chapter 10 provides an overview of areas for further research or consideration

Readers are directed to Infrastructure Australia (2018) for a comprehensive discussion of how the theoretical considerations for inclusion of land use benefits in cost-benefit analysis. Other international guidance documents such as UK Department for Transport (2020) and New Zealand Transport Agency (2019) provide advice which may supplement the information provided in this part of the Guidelines.

2. Overview

2.1 Introduction to land use benefits

Land use benefits arise from changes in land use associated with a transport initiative. Benefits refer to the direct and indirect impacts on social welfare from a project. They can be positive or negative. In the interest of brevity, 'benefits' is used for both these positive and negative impacts.

Traditionally, transport appraisals have held land use fixed and not allowed it to change in response to a transport initiative. Transport infrastructure, however, has long been recognised to have the potential to affect land use. Moreover, because of market imperfections and feedback effects between land use and transport demand, changes in land use can result in a range of additional benefits to those that are captured in a fixed land use transport appraisal.

There are a number of ways in which land use change from a transport initiative can give rise to land use benefits that. For example:

- Where there is demand for floorspace over and above what is permissible given prevailing transport network capacity, a transport investment that unlocks capacity may generate a net economic benefit from allowing **higher value land use**. This benefit relates to the ability of a piece of land to generate a higher 'use value', by permitting it to hold additional capital, such as residential, commercial or other floorspace.
- A change in land use in response to a transport improvement can affect travel patterns, and can allow additional travellers to access the affected areas (essentially a form of induced demand). These **'second-round'** demand changes can give rise to additional benefits that will not be counted in a CBA if land use is held constant. Changes in travel distance, mode choice and destinations can have externality impacts, such as congestion, crowding, toll and fare revenues, which if significant, should be included in a CBA.
- Changes in travel distance, mode choice and destinations can have **externality impacts**, such as congestion, crowding, toll and fare revenues – all impacts that, if significant, should be included in a CBA.
- A change in development patterns can also have implications for public infrastructure and service needs. If the cost of public infrastructure in areas that receive additional growth is lower (higher) than the cost faced by households and businesses, encouraging land use densification may lead to net public **infrastructure cost benefits** (disbenefits), however, this impact is disputed because limited evidence on public infrastructure costs is available.
- A change in development patterns can have an effect on public health through changing active travel behaviour. In particular, an area in which land-use density and diversity were increased and distances to public transport were reduced can lead to low motorised mobility, namely a modal shift from private sector motor vehicles to walking, cycling and public transport, resulting in **public health benefits**.
- A change in development patterns can impact the number and type of dwellings that are built. These changes in built form can lead to **sustainability benefits** from upstream and downstream externality cost savings (costs) from differences in energy efficiency.

- A change in development patterns can affect productivity. In particular, enabling more firms and workers to locate in proximity to each other can generate agglomeration economies, a key part of **Wider Economic Benefits**.[1]

These land use benefits are discussed in greater detail in Section 2.4.

2.2 Defining land use change

For the purpose of these guidelines, land use change is defined as a change in the type and/ or intensity of activities that occur in places. In practical terms, land use change generally refers to changes in the level of population, employment, or developed floorspace within an area, and in the spatial distribution across areas. Transport projects have the potential to affect land use through multiple channels, the main impact being through changes in the demand and supply for developed floorspace:

- Changes in **demand** result from a transport project making a location more attractive. Households and firms value access to amenities, services, jobs and workers. When a transport project changes accessibility to these attractiveness factors, household and firms may choose to relocate, trading off between improved accessibility and price.
- Changes in **supply** result from a transport project either directly lowering the cost of private development or indirectly through the removal of a regulatory constraint such as zoning or planning restrictions. For example, a new bridge may significantly improve access to a potential development site, lowering the cost of construction as a result. Alternatively, improved local road capacity may allow for the approval of development applications that would otherwise have been unsuccessful. In both of these cases, demand for the location has already been established, but the transport project was necessary to unlock supply.

Land use impacts of transport can be modelled using a variety of approaches. There is no single best approach or model for forecasting land use change. Different approaches have different strengths and weaknesses, and may be more or less suitable for individual projects. For example, demand-side approaches focus on the impact that transport initiatives can have by making a location more attractive, while supply side approaches consider how transport projects can unlock additional development through lowering the cost or private development or allowing a relaxation of planning controls.

Regardless of the land use approach selected, it is recommended that population and employment totals are kept constant across the base case and project case for the area of assessment. Where a particular transport investment is described in this document as being expected to result in an *increase* in land use, this refers to an increase in the intensity of activity in the specific local area where the investment will occur (for example, surrounding a rail station catchment). This increase represents a change in the location of activities rather than a net increase — i.e. the localised land use increase would be offset by decreases in activity elsewhere in the city or region being modelled.

2.3 When to include land use benefits

Not all transport projects will be eligible to incorporate land use benefits. Projects should only include land use benefits where:

[1] WEBs, including dynamic or land use WEBs, are addressed in ATAP Part T3 Wider Economic Benefits.

- The project is expected to result in significant land use change, and
- There are market imperfections in the land use market so that prices differ from marginal social costs or,
- there are feedback effects between land use and the transport network.

If a transport initiative does not result in land use change, it cannot create land use benefits. Land use changes are expected to occur where there is both a large change in the relative accessibility of a location, and the location has the capacity to cater to the forecast land use. A location that experiences a large change in accessibility, but which is constrained from change (through zoning or existing capital on the land) would not experience land use change. On the other hand, a location that has capacity to accommodate new uses may not experience land use change where the relative change in accessibility from the transport project is inadequate to justify relocation by households or firms.

Because of this, mass transit projects are more likely than individual road upgrades to affect the location decisions of households and to unlock development constraints. Project size is also likely to play a key role in whether a project results in land use change, with larger city-shaping projects more likely to result in land use change than small projects.

As explained in ATAP Parts T2 and T4, it is a well-established theoretical result that, when measuring welfare changes, the only markets that need to be considered in addition to the market directly affected by a project or policy change are those with distortions. 'Distortions' here, also called 'market imperfections', refers to prices being different from marginal social costs. If a project causes shifts in demand curves in other markets where prices equal marginal social costs, benefits and costs will exactly cancel out. Where prices are above or below marginal social costs and demand curves shift in a related market, quantity changes in that market can give rise to additional benefits or costs.

For example, if the households and businesses that locate on the urban fringe as result of a transport project pay for the full resource cost of the additional land, infrastructure and services they require and the externalities they create, then the resource cost is fully offset by the benefits to the land users. If the public infrastructure they require is subsidised there would be a disbenefit equal to the size of the subsidy (the additional resource cost minus the benefit to the households and businesses indicated by the price they pay for the infrastructure.

An example of externalities is where there are feedback effects between land use and the transport network. If traffic flows between different origin–destination pairs change, there will be increased externalities of congestion, emissions and crashes on roads with increased demand and conversely on roads with reduced demand.

Zoning restrictions are a market imperfection where they cause the market price of land differ from its opportunity cost. However, benefits from a zoning change that could be made in the absence of a transport project ought not to be attributed to the transport project. Where land use is restricted by inadequate transport capacity, in the absence of zoning restrictions, base case transport infrastructure would be highly congested and the transport benefits estimated in the usual way would capture all the benefits from land use change. Zoning restrictions can suppress base case congestion so that, in the project case where transport capacity is increased and zoning restrictions eased, the transport benefit under-estimates the full benefit and there is an additional land use change benefit. Situations where a transport improvement permits higher value land use are referred to as 'unlocking' land supply.

Avoiding double counting is critical to being able to reliably quantify land use benefits and justify their inclusion in a CBA. A transport improvement may cause land value uplift but the uplift is only capitalisation of transport benefits, such as travel time savings, into land values. Counting both transport benefits (primary impact) and land value uplift (secondary impact) in a CBA would therefore double count benefits and lead to distorted results.

2.4 What land use benefits can be captured in a CBA

Land use change may give rise to a range of costs and benefits that are additional to those already captured in a standard CBA. These may include higher value land use, second-round transport benefits, public infrastructure cost savings and public health cost savings, outlined in the table below.

Table 1 Land use benefits summary

Benefit	Description	Implication for measurement	Disputes in application
Higher value land use	When a transport improvement unlocks additional land use supply, the change in land use will generate a net economic benefit if the value of the new use is higher than the value of the current use, less the cost of achieving the change.	It is important to distinguish between higher value land use and land value uplift. Land value uplift reflects the change in land values resulting from the capitalisation of primary benefits (such as transport user benefits) into land values. Higher value land use, in contrast, reflects the change in land values resulting from a transport development allowing more, or a different type of, floorspace on the land.	• Whether this value is additional to first and second-round transport benefits. Higher value land use should be differentiated from the 'land value uplift', which is capitalisation of transport benefits • Whether the benefits should be measured at the point in time in which the land use is 'allowable' or from when the land use change actually occurs
Second-round transport benefits	By changing land use, a transport project can change transport user patterns and external costs (crowding, congestion, pollution, crash costs, etc.). These second-round effects are considered as benefits of a transport initiative.	Second-round transport benefits requires land use change forecasts and separate transport demand forecasts that take account of both the project and the forecast land use changes. Second-round transport benefits should be captured using the rule-of-half approach akin to other sources of induced demand	• UK Department for transport (2020, pp.26-27) TAG suggests conventional transport appraisal methods cannot be used if land use changes in the project case, and instead recommends estimating full land value uplift minus externalities, rather than second round transport benefits • Whether the 'rule of half' area under the demand curve is an accurate reflection of the consumer surplus benefit for transport users that change location
Public infrastructure cost savings	Connecting and providing public infrastructure services such as utilities (water, electricity and gas), transport and larger scale social infrastructure (e.g. schools and hospitals) in less dense urban environments tends to be more expensive per dwelling or per capita than providing or expanding the same infrastructure in denser environments.	Changes in the costs of providing public infrastructure and services should be based on location specific evidence, taking into account variability in the type of housing. Benefits should also be based on the *net* cost to government, rather than the full resource cost.	• Whether existing estimates of per-unit public infrastructure costs are accurate enough to be used in CBAs

Sustainability benefits	Changes in built form may result in sustainability benefits or costs where they have upstream or downstream environmental impacts.	Sustainability benefits should be based on location specific evidence on energy consumption patterns. Benefits should also be based on externalities of energy use (such as CO2-e emissions) rather than the full resource cost.	
Public health cost savings	Transport projects that result in a denser pattern of urban development have grounds to claim public health cost savings associated with net increased incidence of trips using active transport.	Public health cost savings should be based on active travel benefit parameters that reflect the external impact on the health system and not the value to the person themselves.	
Land Use WEBs	Land use or dynamic WEBs reflect the potential productivity benefits that result from a change in land use.	The treatment of WEBs, including land use WEBs is addressed in ATAP Part T3.	• Estimation of Wider Economic Benefits from the tax impacts of moves or less productive jobs is not supported in the ATAP Guidelines at this stage because of inadequate understanding of productivity differentials between locations in Australia.

3. Land use forecasting

3.1 Land use change

Estimation of the land use benefits of a transport initiative requires forecasting of the expected land use changes. Land use change is a change in the type and/or intensity of activities that occur in places. Changes in activity may be from a change in use of the existing built form or a change in the built form itself. For the purpose of understanding land use impacts from transport initiatives, in practical terms land use change generally refers to the spatial distribution and level of population, employment and developed floorspace.

Transport induced land use change results from the inherent relationship between land use and transport infrastructure. Although it is generally accepted that transport infrastructure affects land use in a variety of ways, the interaction is a complex and dynamic process, as transport infrastructure is both a response to, and determinant of, land use change. Nonetheless, the relationship between land use and transport infrastructure can be viewed through two main mechanisms:

- Demand-side mechanisms — where transport infrastructure can impact land use by making a location more attractive through improving accessibility; encouraging intensification of current built form and/or new development.
- Supply-side mechanisms — where transport infrastructure can unlock additional development through either reducing the cost of private development, and/or allowing a relaxation of planning controls.

Appendix A provides a detailed overview of these mechanisms, and examples.

Land use change generally results in an increase in population or employment in a localised area, in response to a transport policy, investment, or initiative. This localised increase could occur entirely at the expense of growth elsewhere within the modelled area, or from attracting new residents from elsewhere in the State or Country outside of the area that is explicitly modelled. These alternative approaches to modelling land use change are referred to as ‘closed city’ and ‘open city’ approaches, respectively.[2]

For example, a new rail station at Bondi, Sydney would be anticipated to increase population within the station catchment. Under a closed city approach, the total population of the modelled area would be held constant between the base case and the project case – the additional population growth would be redistributed from other parts of the modelled area. Under an open city approach, some (but not all) of the growth in Bondi could be drawn from outside the area, with the remainder redistributed from within. While

The land use benefit guidance in this document is written on the basis that closed city modelling is undertaken, but does not preclude open city approaches. However, practitioners should note that open city approaches would require additional analysis to determine whether any other positive or negative externalities occur outside of the modelled area, as well as to determine any other (non-transport) costs that may be incurred to support the additional population or employment in the modelled area.

[2] The terms ‘open city’ and ‘closed city’ does not necessitate that modelling is done for an entire city only. The approaches apply to the given geography that is being modelled, which may be larger or smaller than a city based on the scale and location of the project being assessed. For instance, If only a sub-region is being modelled, then a closed city approach would hold population and employment control totals constant for that specific sub-region.

The scale and pattern of forecast land use change should realistically reflect the change in accessibility from the project, as well as demand and supply side considerations for the local area. In general, where land use change is estimated for a CBA, the forecasting approach should:

- Provide a robust estimate of the **demand** for a location relating to its relative accessibility
- Provide a robust assessment of the total available **capacity** for the new land use (for example, the maximum new floorspace that could be provided in the area, reflecting existing capital, planning, heritage, and other relevant constraints)
- Constrain the localised change in land use to the minimum of the demand or capacity estimate.
- Redistribute population and/or employment from other parts of the identified region to support the localised change in land use

3.2 Common approaches to land use forecasting

There are a variety of different models and approaches to forecasting land use change, which can be delineated along multiple lines of separation.

Demand-side approaches assess the impacts transport infrastructure can have on land use through making a location more attractive. In contrast, supply side approaches consider how transport initiatives can unlock additional development through reducing the cost of private development or alleviating planning or zoning controls. Supply-side analysis has generally become more sophisticated in recent times, with Geographical Information Systems (GIS) increasingly used to capture location-specific land use information at the level of individual lots or parcels.

Land use approaches can also be separated into static or dynamic models. Static models will focus on a single year, while dynamic models will present an evolution over time.

Additionally, land use models can be grouped according to whether they are linked or integrated. Linked models involve separate land use and transport models, although there may be an iterative approach between the two. Integrated models, in contrast, have an interaction of land use patterns and transport needs within the same model.

There is no single best approach for forecasting land use change, as different models have strengths and weaknesses. In practice, the preferred land use forecasting model will depend on a number of factors, including the type of transport project, the purpose behind the project, data requirements and availability, modelling efforts and model availability. The table below provides an overview of the strengths and weaknesses of some common approaches to forecasting land use impacts.

Table 2 Common approaches to land use forecasting

Approach	Strengths	Weaknesses
Land use attractiveness models	• More sophisticated versions typically use econometric modelling techniques to produce robust causal relationships between the demand for land use and variables such as accessibility and other amenity and attractiveness factors.	• Less sophisticated models may only consider a limited number of variables. • Less sophisticated models may not correct for reverse causality are not as appropriate for measuring demand response.

This class of models consider how transport improvements increase the relative attractiveness of locations through improving accessibility to amenities, services, jobs, workers and other geo-spatial features firms and households' value when making location decisions. They are typically calibrated on historical relationships between accessibility and density across space and/or time.	• Can be comprehensive in terms of the number of different variables impacting land use that are measured – including both accessibility and other attractiveness and amenity factors.	• Generally do not consider supply-side constraints very effectively by themselves, for example if current land use regulations permit forecasted demand to be realized.
Land Use and Transport Interaction (LUTI) models LUTI models can be viewed as an extension of land use attractiveness models, where the latter is integrated with a transport model. Several LUTI models have been developed over the past 30 years (Wegener, 2004), with models being capable of forecasting changes in land use, socioeconomic and demographic data; of linking land use and transport interactions (with transport itself being modelled either endogenously or by an exogenous transport model); and of assessing the impacts of different policy scenarios in land use and transport.	• Are an extension of land use attractiveness models that can be integrated with transport models. • A measure of demand for land use which can be used in conjunction with supply-side evaluations. • Provides outputs that can be used as inputs into traffic modelling. • Appropriate level of spatial disaggregation.	• Can be data hungry. • Can be expensive to set up (both in terms of time and cost). • Some are proprietary models or have licensing requirements. • Some require significant expertise to operate.
Dependent development framework Developed by the UK Department for Transport, provides a framework for how new developments that are dependent on the provision of transport investment could be treated in appraisal. The approach proposes that in these cases the transport project and the housing development should be considered as a combined project, with the assessment of impacts combining the impacts of land use development, including the benefits flowing from additional housing services, with those of transport.	• Extends existing CBA methodologies and utilises traditional CBA outputs, minimising the modelling effort required. • Relatively inexpensive (time, data requirements, etc.) compared to other approaches such as LUTI. • Works well for land use developments that are fully dependent on infrastructure, and all of the land use change is as a result of the infrastructure investment.	• Limited to instances where land-use development is dependent on a transport scheme (although this could be desirable). • Issues of attribution—land use development not only 'dependent' on transport infrastructure, but also on enabling infrastructure such as water, sewerage and electricity. • Similarly, there are questions around the extent to which impacts (that is, gains) are attributable – often developments are only partly attributable to transport. This approach lacks the flexibility to capture only a proportion of the land use change. In this sense it is an 'all or nothing' tool.
Spatial Computable General Equilibrium (CGE) models	• A theoretically robust economic approach able to measure economic shocks brought about by infrastructure • Useful in explaining the attractiveness of a region for firms in terms of economic infrastructure	• Highly resource intensive • Significant expertise required • Open to significant criticism given the extensive assumptions required • Typically a macro-based model which lacks the necessary microeconomic relationships that govern behavior and land use change • Often lacks the level of spatial disaggregation to be used in conjunction with traffic models

CGE models are computable implementations of General Equilibrium theory – a workhorse theoretical economic model that represents the key actors in an economy – firms, households and government – and the transaction between them in terms of supply and demand of goods, labour, capital and land. Spatial CGE models put the theoretical framework into practice by introducing distinct spatial units that trade with each other.		• Does not consider a number of non-accessibility based attractiveness or amenity factors
GIS based methods This approach converts a traditional land use planning analysis of potential changes (or scenarios) to land uses and development densities (i.e. capacity that may be unlocked) into dwelling, population and job numbers over time. This can be informed by development feasibility and market take-up analysis, with resolution at the travel zone, precinct or lot level, depending on the level of detail required for reporting and modelling purposes.	• Assists in quantifying the potential benefits of a transport or infrastructure project. • Can inform cross-Government decision-making in regard to land use and infrastructure integration. • Community expectations for city-building can be addressed. For example, addressing community issues, such as a perceived lack of schools or open space, can be built into the analysis at an early planning stage, as opposed to a reactionary approach.	• It is not always clear on what basis the underlying land use forecasts have been made. • There is the potential for supply-side capacity analysis to overstate or understate potential land use impacts, unless market and demand assumptions have been integrated into the analysis. • Analyses are often undertaken over large study areas, with multiple options, and hence, the analysis is strategic in nature. This affects the level of detail that can reasonably be achieved within a prescribed timeframe.
Urban Simulation models Urban simulation models are computer simulations where the functioning of a city is analysed through a simulation, allowing for theoretical frameworks of city growth to be applied and tested in a visual format. Examples include UrbanSim, LEAM (Land Use Evolution and Impact Assessment Model), and various urban simulation models developed by the University of Wollongong's SMART Infrastructure Facility.	• Flexible in terms of the level of spatial disaggregation it can be used for. Can drill down into the parcel level of land • Are able to integrate accessibility-driven demand change on a network, thereby incorporating demand side considerations • Parameters reflect local conditions	• Similar to GIS based models however, urban simulations are heavily reliant on the assumptions that are input to allow them to run • This can require a substantial amount of disaggregate data to be collected at a fine grain level, which is not always possible

3.3 Key considerations for land use forecasting

There are a number of theoretical and practical challenges to consider when forecasting land use change. These challenges need to be addressed if land use change is to be measured in a robust manner. Only then can benefits and costs associated with land use change be included in a CBA.

1. Determine the **spatial area of assessment**
2. Specify the **base case**
3. Determine the change in land use in the **project case**
    a) Supply and demand side factors
    b) Attribution
    c) Time dimension

4. Account for non-static strategic planning

3.3.1 Determine the spatial area of assessment

It is recommended that the spatial area that is assessed by the land use model is commensurate with the area that is assessed by the transport model. For urban projects this is likely to be defined as the full metropolitan area of the relevant city. The total population and employment of the area of assessment would be held to a constant 'control total' between the base case and project case. This means that any change in land use in proximity to a transport project results from a spatial *redistribution* of population and employment, rather than a net increase or decrease in the number of people and employees between the Base Case and Project Case.

This has important implications for land use change and transport demand modelling. For example, a common criticism of major urban infill development is the additional costs in terms of local congestion, and the impact on services or utilities in the area. When control totals are held constant, however, this infill development occurs by displacing other developments elsewhere (be it alternative infill development, or new greenfield developments at the urban fringe).

3.3.2 Specify the Base Case

When assessing land use change as a result of a transport project, there may be challenges associated with establishing the appropriate Base Case. Over the time horizon of any land use assessment there is likely to be a level of 'natural' land use change independent of any infrastructure change. It may be tricky to keep this natural change separate to the change in land use attributable to the transport project. Mixing these two effects can result in an over (or under) estimation of the true incremental land use change resulting from the transport project. To prevent this intermingling of effects, the assessment should be performed on a Base Case that includes the 'natural' change in land use over time.

In addition, when estimating land use change attributable to a transport project, there needs to be a good understanding of existing exogenous land use forecasts (e.g. from State Planning Departments). Some forecasts represent a 'Business as Usual' scenario land use that excludes future non-committed improvements, whilst others provide projections that assume the transport infrastructure necessary to enable them will be put in place. Of particular importance is ensuring that the exogenous land use change does not already consider the transport project in question. This would result in the land use modelling and the exogenous land use forecasts both measuring the impact of the transport investment. The two effects in this case would not be independent or additive.

It is recommended that if the base the case land use is dependent on non-committed transport projects being delivered, then a new project-specific base case would need to be developed to reflect the level land use growth that could occur naturally over time in the absence of the project. This may include changes in present day zoning conditions, to ensure that the benefits from a zoning change that could be made in the absence of a transport project are not attributed to the transport project.

Zoning restrictions that are left unchanged in the base case can suppress congestion so that, in the project case where transport capacity is increased and zoning restrictions eased, the transport benefit under-estimates the full benefit and there is an additional land use change benefit.

3.3.3 Determine the change in land use in the project case

This section provides an overview of some of the major considerations for developing project case land use forecasts for CBA. Specific land use forecasting guidance is intended to be developed as part of a separate, forthcoming ATAP work stream; in the interim CBAs should demonstrate that the following considerations have been addressed in the methodology that has been applied. These considerations align with those outlined in Infrastructure Australia Assessment Framework (IA, 2018).

Dual causality

Approaches to measuring land use change need to correct for the dual causality between infrastructure and density. Dual causality arises through both infrastructure improving accessibility to change density and density itself driving infrastructure change (i.e. infrastructure is more likely to be developed in areas of higher density where demand for it is highest) (NZTA, 2019). It is critical that, when estimating land use change, that this reverse causality is corrected for so as to isolate the impact of accessibility and attractiveness of an area on density, as opposed to density impacting an area's accessibility and attractiveness. It is recommended that if the land use assessment is based on, or established some relationship between accessibility and density, any reverse causality should be corrected for.

Attribution

Often a change in both the regulatory environment and the transport project are needed for land use change to occur. In these cases, it would be inappropriate to attribute all the change in land use to the transport project in question. It is therefore critical that the base case land use forecasts reflect a future where rezoning is permitted to the extent that is possible in the absence of the transport project.

Time dimension

Often there may be a time lag (or lead) between a transport project and its associated land use change. For example, there may be a delay between an accessibility change brought about by a transport project, and a response from households and firms to relocate closer to the affected corridor. Likewise, land use change could lead a transport project where planning change and investment happen in anticipation of the completion of the project.

A fundamental element of the supply-side assessment of land use change is the fluctuations in property markets that occur over time. Due to the number of variables involved and the temporal nature of the market, quantifying future development feasibility and market take-up over time can be imprecise. Changes and fluctuations in the market will affect the realisation of the capacity unlocked as a result of the project. The CBA should use conservative assumptions when forecasting the rate at which land and property markets will adjust to a transport project.

4. Estimation of land use benefits

Land use benefits arise from changes in land use associated with a transport initiative. Traditionally, transport appraisals hold land use fixed between the base case and project case. If there are land use changes in response to a transport initiative, however, they can cause a range of additional benefits. These benefits result from market imperfections that cause prices to differ from marginal social costs, and feedback effects between land use and the transport network.

4.1 When to include land use benefits

Not all transport projects will be eligible to incorporate land use benefits and costs. The transport infrastructure and land use connection is a complex and dynamic process that is difficult to disentangle. For example, not all transport projects impact land use equally, and a variety of exogenous factors can hinder or assist in generating land use change.

It is recommended that transport appraisals should only include land use benefits where:

- The project is expected to result in significant land use change, and
- There are market imperfections in the land use market so that prices differ from marginal social costs or
- there are feedback effects between land use and the transport network

Transport appraisals should only include land use benefits when there is compelling supportive evidence and clear justification for the reasons why the project is expected to generate significant land use change. In practice, this means that proponents should demonstrate that any potential land use change is dependent on the infrastructure project in question and that the necessary supportive conditions are present.

Empirical evidence, while mixed, suggests that large scale, mass transit projects are the most likely to result in land use change. For example, a meta-analysis of over a hundred studies on the relationship between transport and land use found that bus rapid transit projects increased land values by 9.7%, light rail by 9.5%, and heavy rail by 6.9% (Smith et al, 2015). Similarly, estimates of land value elasticities from LUTI Consulting suggest that access to light rail infrastructure has the largest impact on land values, with mixed results for road infrastructure and minor (and negative) results for heavy rail infrastructure (LUTI Consulting, 2020). Although such change in land value are not the same as land use changes, they are indicative of the potential for such change.

Project size is also likely to be a key factor for establishing whether a given transport project is likely to result in land use change. In particular, land use tends to display nonlinear effects, where land use changes may only result once a certain threshold is passed. This means that transport projects should only claim land use change where the project is of significant size and nature to have material impacts on land use. In other words, including benefits of land use changes is only justified where transport projects are large enough to make an observable and sustained impact on land use.

Land use change will only result in land use benefits when there are market imperfections. Market imperfections lead to inefficient markets where prices differ from marginal social costs and there are externalities. The presence prices differing from marginal social costs or externalities is a necessary condition for land use benefits. For example, if the households and business that locate on the urban fringe pay for the full resource cost of the additional land, infrastructure and services they require and the externalities they create, then the resource cost is fully offset by the benefits to the land users.

A special case of externality is where there are feedback effects between land use and the transport market. As transport demand is largely a function of the location of households and firms, if households and firms change locations, there will be corresponding impacts on the transport network. These impacts will result in net transport benefits in the same way that a transport project can result in benefits.

It is recommended that any claimed land use benefits are supported by a clear articulation of the underling market failure that gives rise to the benefit.

4.2 Key challenges to estimating land use benefits

There are a number of key challenges to consider when estimating land use benefits. These challenges need to be addressed if land use benefits are to be included in a transport appraisal as failure to do so may result in the under or over estimation of benefits.

4.2.1 Double counting

When incorporating land use benefits and costs in a CBA, the possibility of double counting needs to be guarded against. This principally concerns the extent to which land use benefits or costs may be implicitly included in other benefits or costs that are captured as part of standard CBAs. For land use benefits and costs, there are two main sources of double counting:

- Inclusion of both primary and secondary impacts — primary impacts refer to the direct and indirect benefits attributable to an infrastructure initiative. Secondary or flow-on impacts are the benefits and costs that are passed on, or redistributed, within the economy. Some land use effects, such as land value uplift, are secondary impacts which largely reflect the capitalisation of primary impacts that are typically included in standard CBAs, such as transport user benefits. Counting both primary and secondary impacts that reflect the same underlying benefit driver would double count benefits and lead to distorted results.
- Land use change in traffic modelling — in transport projects, if the traffic model includes induced demand and this (implicitly or explicitly) reflects induced demand from a change in land use, then the benefits to households and businesses changing location, as well as the impacts on the wider transport network, will already be captured in the 'first-round' transport benefits and costs. Where this is the case, a CBA cannot also attempt to account for the costs and benefits of this land use change on the transport network. In other words, if land use change is a source of induced demand in the transport model, then second-round transport benefits will already be accounted for.

As a general principle, the most accurate measurement of benefits and costs can be achieved by measuring them as close to their sources as possible. In practice, this means that it is preferable to identify and estimate primary benefits rather than secondary or flow on benefits. The exception to this is where there may be additional benefits that are underestimated or not reflected by the primary benefits and the inclusion of secondary benefits does not lead to double counting.

4.2.2 Dependency and conditionality

Land use benefits should only be captured in a CBA to the extent that the land use change itself is attributable to the transport investment. For example, any land use change that could be achieved through supply-side regulatory interventions should not be used to inform any CBA land use benefit quantification, unless it can be shown that the supply-side intervention is itself dependent on the infrastructure investment. This ensures that the land use benefits are incremental and result from the infrastructure investment itself.

In practice, this means ensuring that any potential land use change – and therefore any additional land use benefits or costs – are both principally dependent on the transport project in question (as opposed to being dependent on other factors) and that the necessary conditions (such as zoning changes, other infrastructure, excess demand or associated public and private investment) are present in order for the identified land use impacts to materialise. This is expanded on below:

Dependency means that transport infrastructure proposals should establish that the change in land use (i.e. any land use impacts) directly depends upon implementing the proposed infrastructure investment. Any land use change that would be permissible without the project in question — that is, changes to land use that could have gone ahead anyway — should not be used to inform any land use benefit quantification. It is important to distinguish between what could happen in theory and what would happen in reality. For example, theoretically the densification of inner-city areas could be achieved through supply side regulatory intervention alone (e.g. zoning change). In practice, however, planning regulations (and public sentiment) could prohibit this as it would impose negative impacts on existing residents or the existing transport system. If a project ameliorates these negative impacts and thus enables the planning regulations to be changed, then there are grounds to claim that the land use change is dependent on the project. Supporting material for dependency could include evidence of current or predicted capacity constraints on nearby infrastructure, modelling of land use change in absence of the transport project demonstrating adverse outcomes on the network, infrastructure needs assessments from infrastructure providers and/ or government agencies, or findings from consultation with local, regional and state planning agencies.

- **Conditionality** refers to the supporting conditions and activities necessary for the expected land-use impacts to materialise and ensuring that costs and delivery of these are part of the economic appraisal and business case. For example, whether the underlying demand for residential or commercial stock are likely to exceed supply, whether the necessary supply-side factors such as zoning changes to allow densification, and public and/or private investment (e.g. water upgrades or remediation) are in place. It should also take account of factors that can hinder the realisation of benefits and costs (for example, local opposition to increased density). In order to include land use benefits in a CBA, the associated cost of all necessary supporting conditions must also be considered.

Valid consideration of dependency and conditionality are critical for ensuring that land use benefits are not overestimated, particularly where the land use forecasting approach is determined exogenously to the demand model. Overestimating the increase in population or employment, or including land use change that is above what would be dependent on the project will lead to a corresponding overestimate of the land use benefits.

4.2.3 Redistribution approach

Land use benefits and costs captured in the CBA using where population and employment control totals are held constant reflect a redistribution of population and employment in the geographic area that is modelled by the transport model, rather than a net increase. The modelled area boundary must be defined so that that all positive and negative impacts are captured. This ensures that the benefits and costs reflect all displacement of activity elsewhere and are net incremental benefits.

Similar to consideration of dependency and conditionality, redistribution approaches that are determined exogenously to the demand model have the potential to impact the accuracy of the land use benefit estimate, particularly for second round transport benefits. The redistribution approach used in the CBA should reflect the following considerations:

- Whether the base case and project case locations for firms and households are broadly comparable markets

- Whether the redistribution approach results in net decreases in population or employment in any regions or sub-regions relative to present-day levels
- Whether the change in location choices between the base case and the project case has resulted in an overall increase or decrease in accessibility (e.g. to employment or recreation) across the region or in particular sub-regions
- Whether any constraints or market failures exist that may limit or prevent the redistribution of households and firms away or to a particular region or sub-region

The redistribution approach used in the CBA should be documented and the resulting changes in locations reported transparently.

4.2.4 Net negative benefits

Land use change can result in positive and negative benefits. Where proponents have good reason to believe a project will result in land use change, all positive and negative benefits of this change should be included. In some projects, this may result in land use change generating a net negative benefit.

4.3 Presentation of land use change benefits

In common with wider economic benefits, there is a higher level of uncertainty surrounding land use change benefit estimates compared with usual benefits estimated in conventional transport CBAs and size of land use benefits can be large. The Guidelines therefore recommends that they be presented in a way that clearly highlights the effect of adding land use change benefits.

The ATAP Guidelines requires that the core CBA results table be presented in two parts — without and with land use change benefits and WEBs. Where land use change benefits have been estimated, they should be reported as follows:

In the core appraisal results table as shown in table 1:

- First present the CBA results (NPV, BCR etc.) *without* land use change benefits and WEBs
- Then show the land use change benefits by category (higher value land use, other)
- Then show the WEBs by category (WB1, WB2a: change in labour supply and WB3)
- Then show the CBA results (NPV, BCR, etc.) *with* land use change benefits and WEBs included.

The ‘other’ category of land use change benefits comprises public infrastructure cost savings, sustainability benefits and public health cost changes. These should be separated out if large. If not separated out, they should be provided somewhere in the report to ensure transparency and help reviewers assess the realism of the estimates. If the combined other land use benefits are small, all land use benefits can be shown in a single row.

Table 3 Example of core appraisal results table

Impact	Present value ($ millions)
Benefit 1	
Benefit 2	
Benefit 3	
Total benefits	
Investment costs	
NPV	
BCR1	
BCR2	
FYRR	
Higher value land use benefits	
Other land use benefits	
Total land use benefits	
NPV with land use benefits	
BCR1 with land use benefits	
BCR2 with land use benefits	
FYRR with land use benefits	
Agglomeration WEBs	
Labour market tax WEBs	
Imperfect competition WEBs	
Total WEBs	
NPV with land use benefits and WEBs	
BCR1 with land use benefits and WEBs	
BCR2 with land use benefits and WEBs	
FYRR with land use benefits and WEBs	

Note: The first year rate of return (FYRR) with land use change benefits and WEBs need not be presented if, due to ramp-up, the value is little different from the FYRR without land use change benefits and WEBs.

5. Higher value land use

When a transport improvement unlocks additional density, the change in land use will generate a net economic benefit if the value of the new use is higher than the value of the current use, less the cost of achieving the change (Hensher and Mulley, 2016). For example, where there is excess demand for residential floorspace and additional supply is constrained by a market imperfection imposed due to a lack of transport infrastructure (e.g. planning controls), higher value land use benefits may occur to the extent that the transport initiative alleviates the market imperfection (e.g. relaxing planning controls).

It is important to distinguish between *higher value land use* and *land value uplift*. *Land value uplift* reflects the total change in land values attributable to the new transport infrastructure. This demand-driven impact includes the capitalisation of primary benefits (such as transport user benefits) into land values. In other words, land value uplift would mean an increase in the value per square metre of floorspace. As a land value uplift includes the capitalisation of the same benefits that are included in a standard CBA, including the uplift as a benefit of land use change would result in double counting.

Higher value land use, in contrast, is a subset of the broader land value uplift a transport project can deliver and reflects the change in land values resulting from a transport development allowing more, or a different type of, floorspace on the land. In other words, higher value land use reflects a supply-driven impact where an increase in the supply of floorspace, holding the price per square metre by type constant, results in net additional value. Land use is often constrained by planning controls, such as development capacity or zoning restrictions that are imposed, at least partly, in order to avoid putting undue stress on existing transport infrastructure. Therefore, transport investment that unlocks development constraints may generate social surplus from higher and better use where there is excess demand for residential or commercial product.

It is important to note, however, that controls are in place for a reason. Whilst a transport project can allow them to be relaxed, there may be other negative consequences of relaxation (e.g. congestion, cost of additional infrastructure and services, overshadowing). These should be included and explored as part of a CBA. There may also be other costs required to relax controls, which should be accounted for in the CBA if this benefit is to be included.

Higher value land use only results in the instances where a transport project unlocks a supply constraint. An increase in supply that occurs primarily in response to an increase in demand (and price) would not result in higher value land use benefits. Importantly, the implication is that the amount of land use change for which the higher value land use benefits apply could be a subset of the overall land use change attributable to the project. If a transport project increases demand for floorspace in a location, developers could respond by increasing supply within prevailing planning controls. This is a demand-side impact that does not lead to higher value land use (although it would lead to other land use benefits). However, if the transport project changes permissible densities because it alleviates a transport network constraint, higher value land use benefits may exist by unlocking a supply-side constraint. For this benefit to be included in a CBA, the land use assessment must identify the subset of the overall land use change that would otherwise not be permissible.

There are a number of market imperfections that may constrain the supply of developed land which a transport initiative might address. These are outlined in the table below.

Table 4 Higher value land use market imperfections

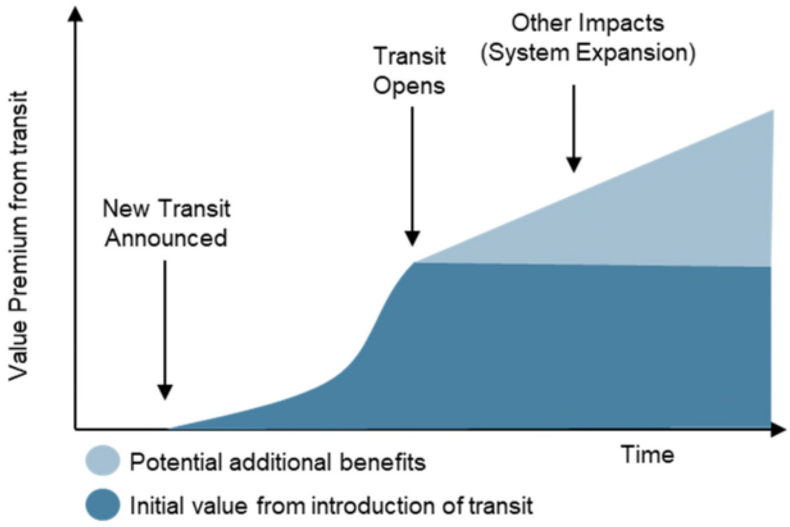
Market failure	Explanation	Potential context-specific evidence to identify market failures
Land rationing	• Planning policies may be inefficiently restrictive, resulting in an inefficiently low level of investment in new developments.	• Significant differential between the price of developed and un-developed land (or land zoned for different densities) in the local area.
Coordination failure	• Individual developers may under-invest in network infrastructure leading to co-ordination failure characterised by inefficiently low levels of investment in local transport and land use infrastructure.	• Evidence that there are a number of developers who might benefit from local transport improvements.
Transport exceeding acceptable service standards	• Capacity levels of transport networks can result in restrictive planning controls and/or zoning to ensure that demand for transport does not exceed supply.	• Evidence of unacceptable transport outcomes (e.g. crowding, congestion, reliability) • Evidence of restrictive planning controls or zoning tied to the lack of transport capacity.

Note: The first two rows are taken from UK DfT (2020), p. 5.

Not all transport projects can be expected to unlock additional supply. The magnitude of the change in supply depends on the additional capacity provided by the transport project and the level of excess demand. For example, a low frequency, low capacity suburban transit service would be much less likely to induce an increase in development capacity than a high capacity service to the CBD. For this reason, the localised change in land use used in the CBA should be constrained to the minimum of the excess demand for land or the available capacity of the land:

The timing of when Higher Value Land Use benefits will occur is debated. This issue has two key components. First, the timing of the land use change in reality (i.e. do rezoning and densification start occurring at the time of announcement of a project, or later when the transport project has been delivered)? Second, what is the most appropriate timing to adopt in a CBA framework? With regards to first question, markets are forward-looking and reflect the expectations of participants. As such, land markets will start to respond as soon as participants start to anticipate a potential future change. Initially this will be observed through increasing land values, later in development/ rezoning applications and building approvals, and finally in building completions. The result may be that Higher Value Land Use benefits will start occurring in advance of the delivery of the transport project and continue for years after. This response has been demonstrated in literature that find transport benefits start to be monetised into the surrounding land markets from the announcement of a funding commitment (e.g. see McIntosh et al, 2014). This is illustrated in the figure below.

Figure 1 Illustrative land market value creation curve from a transport initiative



Source: LUTI Consulting 2020

In regard to the second issue, it is recommended that higher value land use benefits are captured in a CBA in line with the modelled land use change. This could involve calculating the benefits on a per gross floor area (GFA) and/ or dwelling basis and introducing the benefit gradually as new floorspace is delivered in line with change in actual use. This may involve a time series before and after the project start date and ensures ensure that higher land value benefits will reflect changes in actual use rather than the potential for land use change.

The most appropriate timing in a CBA would depend on the size of the project and the length of time the land use responses are expected to take. For a smaller project where land use changes are likely to happen within 5 to 10 years of opening, it would be appropriate to recognise Higher Value Land Use benefits as ramping up during that period. Larger projects may have much longer timeframes, and may continue to impact land use outcomes from project announcement through to the end of the appraisal period. Incorporating the timing of land use changes into the benefit estimation could involve calculating the benefits on a per GFA and/ or dwelling basis and introducing the benefit gradually as new floorspace is delivered in line with change in actual use.

While land values are known to increase in anticipation of future redevelopment and zoning changes, this reflects developers' expectation of the timing of the realisation of new stock. For CBA, the timing of the benefits should reflect the actual change in land use as it occurs

.

5.1 Estimating higher value land use

Higher value land use benefits can be estimated using land use forecasts of change in floorspace by type, together with evidence on land value per square metre of floorspace.

Not all floorspace change forecasted by a land use model, however, will result in higher value land use benefits. Higher value land use benefits only arise where a transport initiative unlocks additional (or change in) floorspace supply that was constrained by a market imperfection. Note that a change in floorspace supply can result from an increase in physical supply (i.e. an increase in densification) or from a change in use/ zoning (i.e. commercial floorspace being converted to residential). As such, it is recommended that higher value land use benefits be only estimated for areas that are subject to a supply constraint that is expected to be alleviated by the transport infrastructure in question.

Only benefits for *incremental* floor space made available as a result of the project are counted. The economic value of existing capital destroyed to make way for new construction is ignored. Say a three story building in the base case is demolished in the project case to make way for an eight story building. One estimate of the land use benefit would be the RLV for all eight floors of the new building minus the present value of economic returns from the three story building demolished. Under the recommended incremental approach, only RLV of the additional five floors of the new building are counted as land use benefits. The incremental approach is simpler to implement because it does not require valuation of existing capital. To the extent that the RLV of new floor space that replaces old (the lower three stories in the example here) is more valuable than existing building, the incremental approach will understate the full benefit and is therefore conservative.

It is recommended that higher value land use benefits are calculated based on estimated of land value per square metre of GFA using the residual land value (RLV) approach. RLV is the present value of the total revenue from a potential development, minus the present value of all development costs, including the developers' profit margin. Residual land values will vary between sites, based on the specific location, amenity, size and shape, and other factors and could also be estimated using data on site sales, feasibility studies and/ or unimproved land values.

Land use forecasts need to include both base case and project case stock (i.e. change in residential and commercial GFA) and use (i.e. change in population and employment) at a spatially disaggregated level commensurate to the transport modelling. Assuming that suitable land value data is available, higher value land use can then be estimated as follows:

Step 1: Identify areas that in the base case are subject to a supply constraint that is expected to be alleviated by the transport initiative.

Step 2: Analysis market evidence to establish average RLV per square metre of GFA by development type (e.g. residential, commercial, retail) and density (e.g. low, medium, high).[3] It is recommended that RLV per square metre of GFA is held constant across base and project case to avoid double counting with transport user benefits.

Step 3: If necessary, convert estimated land use uplifts into square metre of GFA using assumptions about average intensity of use (e.g. average occupancy per dwelling and average dwelling size, average square metre per worker for different commercial uses). These assumptions should reflect the type of product that is expected in each area.

Step 4: Estimate higher value land use benefits as the product of RLV per square metre by development type by the amount of additional square metre of GFA by development type for each area where a supply constraint is alleviated.

[3] It is recommended that the definition of GFA used is commensurate with the prevailing definition of GFA within the jurisdiction that the transport initiative is being developed in

$$HVLU = \sum_{\alpha} \Delta GFA_{\alpha}^{t,d} \times RLV_{\alpha}^{t,d}$$

Where:

- ΔGFA_{α}^{t} is the incremental square metre of GFA of type t and density d in area α
- RLV_{α}^{t} is average RLV per square metre of development type t and density d in area α

Step 5: Sum the benefits by type and by area to arrive at the total benefits in the base year. Use advice from other parts of the ATAP Guidelines to estimate higher value land use benefits in subsequent years of the analysis period.

5.2 Higher value land use practical example

Assume that that certain key project areas are subject to planning controls which are in place due to a lack of capacity on the local transport infrastructure. It is expected, however, that the new transport project will alleviate the need for these planning controls, allowing the development of additional floorspace.

Assume that land use forecast reveals the following changes in GFA by development type for the areas that have been identified as subject to planning constraints in the base case.

Table 5 Forecasted change in floorspace by development type (square metres of GFA)

Area	Residential	Retail	Commercial
Wentworth Town Centre	3,000	1,500	(500)
Merrylands Town Centre	2,000	200	250
Auburn Town Centre, North	1,500	500	(500)
Auburn Town Centre, South	2,000	(500)	200
Lidcombe Town Centre	1,750	250	0

The following table presents estimates of average RLV per square metre of GFA for these key areas.

Table 6 Residual land values ($2017 per square metre of GFA)

Area	Residential	Retail	Commercial
Wentworth Town Centre	$2,200	$900	$400
Merrylands Town Centre	$1,700	$1,000	$400
Auburn Town Centre, North	$2,200	$400	$300
Auburn Town Centre, South	$2,200	$800	$300
Lidcombe Town Centre	$1,750	$800	$300

Source: Keck Cramer 2017, in SGS Economics and Planning 2017

Based on these assumptions, higher value land use is estimated to be:

- $7,750,000 for Wentworth town centre, consisting of $6,600,000 for residential, $1,350,000 for retail and -$200,000 for commercial.
- For Merrylands Town Centre, higher value land use is estimated $3,700,000, made up of $3,400,000 for residential, $200,000 for retail and $100,000 for commercial.
- For Auburn Town Centre North, higher value land use is estimated $3,350,000, made up of $3,300,000 for residential, $200,000 for retail and -$150,000 for commercial.
- For Auburn Town Centre South, higher value land use is estimated $4,060,000, made up of $4,400,000 for residential, -$400,000 for retail and $60,000 for commercial.
- For Lidcombe Town Centre, higher value land use is estimated $3,262,500, made up of $3,062,000 for residential and $200,000 for retail.
- In total, higher value land use for the project is estimated at $22,122,500 across all areas.

6. Second-round transport impacts

As the demand for transport is primarily determined by the location of households and firms, land use change will affect transport demand. Like other sources of induced demand within transport models, land use change can affect trip distribution, trip generation, route choice, mode choice and the time of day travel occurs. Second-round transport impacts therefore capture the transport benefits and costs associated with induced demand attributable to land use change:

- Second-round transport user benefits – once land use is allowed to change in response to a transport initiative, there may be additional user benefits to those that are captured in a CBA with constant land use. For instance, new residents that are attracted to a location in order to access improved amenities, better transport, etc., do so because they are better off. These benefits should be captured using the rule-of-half approach to consumer surplus – the same way any other new user benefit is captured for a transport initiative.
- Second-round transport externalities – by changing land use, a transport initiative can change transport patterns and external costs (e.g. congestion, emissions, crash costs, etc.) of the total transport task. These externality benefits and costs are an established feature of transport economic appraisals and can be reliably quantified using standard guidelines.

It is important to note that when considering the inclusion of second-round transport benefits and costs in a CBA, it is first necessary to understand the extent to which land use change is already implicitly (or explicitly) included in the transport model. In principle, transport models can implicitly include land use change as a source of induced demand (e.g. if accessibility affects trip-rates), although this is rarely observed in practice.

Most transport models are designed to represent the travel behaviour arising from changes in land use over time. In principle, allowing land use to change between the Base Case and Project Case should be within the capability of these models. However, there are known challenges that can cause the modelled responses to be biased or inaccurate. Transport models are calibrated to reproduce the observed travel behaviour of households and firms, depending on their underlying characteristics. Households, for instance, are typically segmented by household size/ type and car ownership, and each segment will have different travel behaviour. When land use changes over time, or in response to a transport investment, the composition of the population and jobs in a location will change. Travel behaviour should then change accordingly, independently of any change in transport supply.

For example, a suburb with a high share of large households living in large single dwellings is likely to have a larger than average car model share. If the suburb is expected to see large future population growth, this is likely to involve a change in the residential urban form to smaller dwellings, such as townhouses and apartment buildings. The future residents would therefore be likely to have different travel behaviour than the current population. Furthermore, in response to the densification the local area would be likely to see more retail, entertainment and job opportunities, further driving a change in travel behaviour by the local populace.

If the transport model used is not designed to model such changes in travel behaviour in response to density changes, then an accurate modelling exercise would need to manually adjust model inputs to ensure an accurate prediction of future travel patterns.

While acknowledging this problem in relation to land use impacts of a transport project, it is a general challenge for transport models that also affect the ability to reliably predict the demand response to base case land use changes.

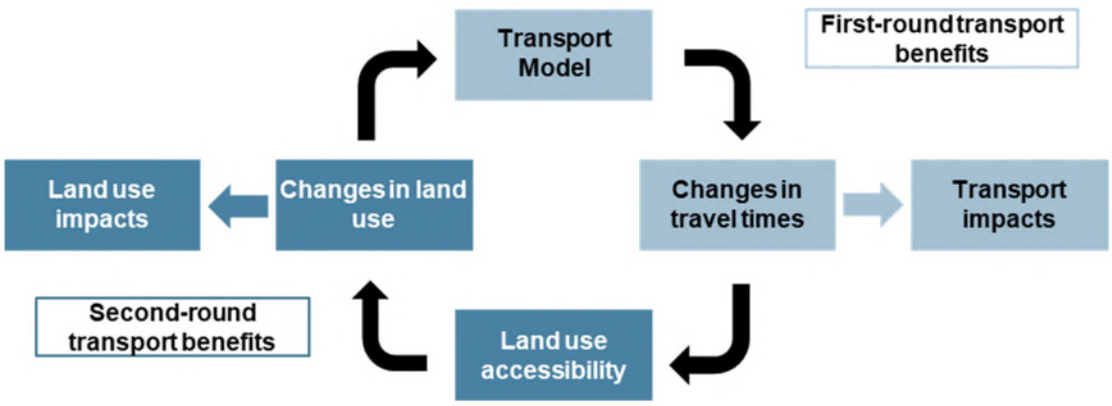
6.1 Estimating second-round transport benefits

Second-round transport benefits arise from the feedback effects between land use and the transport market. This benefit would only occur where there are land use impacts associated with the transport project in question. If no land use change occurs as a result of a transport improvement, then there will be no second-round transport benefits.

In order to be able to measure second round transport impacts, the land use forecasting approach used needs to be able to produce land use outputs that are conducive to being used as inputs in a traffic model. Typically, these would include updated population and employment forecasts on a designated spatial level.

When estimating second-round transport benefits it is necessary to isolate the land use impact from the actual transport intervention impact (i.e. the first-round transport benefits and costs). In other words, a two-step approach is recommended whereby second round transport impacts are measured in isolation. The figure below illustrates this approach.

Figure 2 Illustration of iterative approach to land use transport modelling



Source: EY

This approach enables the isolation and separation of the transport and land use impacts. Second-round transport benefits should include all the same benefit items that are captured in a fixed land use CBA and, where appropriate, should be quantified using the rule-of-half – the same as other sources of induced demand:

Step 1: Compare the Project Case to the Base Case, holding land use constant (i.e. no land use change). This is equivalent to comparing Scenario D to Scenario A from Figure 3. This will evaluate the 'first-round' benefits of the transport initiative, with no land use change. Using the method in ATAP Part M2, section 7.4 to estimate the total consumers' surplus change and resource correction from transport model outputs

$$Tranport\ only\ consumers'\ surplus\ change = \sum_{All\ trips}\left[\frac{1}{2}(Q_A + Q_D)(P_A - P_D) + (P_D - ASC_D)(Q_D - Q_A)\right]$$

Where:

- P_A is the perceived cost of travel and Q_a the quantity of trips between an origin–destination pair in the base case without land use change (scenario A in Figure 4)
- P_D is the perceived cost of travel, ASC_D is average social cost of travel and Q_D the quantity of trips between an origin–destination pair in the project case without land use change (scenario A in Figure 4)

Step 2: Compare the Project Case to the Base Case, allowing variable land use (i.e. with land use change). This is equivalent to comparing Scenario C to Scenario A from Figure 3. This will evaluate the benefits of the transport initiative with land use change.

$$Total\ consumers'\ surplus = \sum_{All\ trips} \left[\frac{1}{2}(Q_A + Q_C)(P_A - P_C) + (P_D - ASC_C)(Q_C - Q_A)\right]$$

Where:

- P_C is the perceived cost of travel, ASC_c is average social cost of travel and Q_C the quantity of trips between an origin–destination pair in the project case with land use change (scenario C in Figure 4)

Step 3: Subtract the result of Step 2 from the result of Step 1 to arrive at the second-round round transport benefits for a given year.

Figure 3 Transport / land use demand modelling runs

		Transport infrastructure	
		Base case	Project case
Land use	Base case	Scenario A	Scenario D
	Project case	Scenario B	Scenario C

Source: UK DfT (2020, p. 10).

7. Public infrastructure costs savings

The cost of public infrastructure required to facilitate growth is typically lower per dwelling for established areas compared to greenfield areas. Consequently, if a transport initiative results in a more compact land use so there is less urban sprawl in the base case, there may be a net change in the cost of facilitating this growth. Importantly, the private cost of public infrastructure is often lower than the marginal social cost, as the government tends to meet some of the costs of development.

The cost of public infrastructure can differ significantly between greenfield and infill locations. For example, a study by Infrastructure Victoria found that the capital cost of providing public infrastructure typically varies from being two to four times more expensive in greenfield areas than established areas (Infrastructure Victoria, 2019) as shown in the table below. In practice, however, public infrastructure costs are often highly location-specific and vary substantially on a site-by-site basis. As such, it is desirable that the public infrastructure costs specific to the locations in question are considered and that these costs reflect variability in the type of housing and the availability of infrastructure capacity.

Table 7 Capital costs of public infrastructure in greenfield and established areas ($2020 per dwelling)

Public infrastructure	Established area		Greenfield	
	Low	High	Low	High
Civil infrastructure	$1,900	$42,100	$25,200	$110,000
Education infrastructure	0	$30,000	$15,300	$18,000
Community infrastructure	0	$39,400	$14,900	$18,500
Emergency service infrastructure	0	$1,500	$800	$800
Health infrastructure	0	$2,500	$1,200	$1,200
Sewerage	$2,600	$9,400	$6,400	$23,500
Water	$1,000	$8,100	$4,200	$15,900
Electricity	$2,400	$17,400	$7,700	$21,700
Gas	$1,700	$8,600	$2,900	$3,500
Telecommunication	$2,500	$5,600	$3,100	$6,100

Source: Infrastructure Victoria 2019

Not all of these public infrastructure costs are fully recovered. The Australian Property Institute, in a Productivity Commission report, has noted that in many instances, cost recovery from infrastructure charges is only in the order of 50-70% (Productivity Commission 2011). All states and territories in Australia have some arrangements in place to enable to collection of contributions to public infrastructure, however, the approach and level of contributions varies greatly. For example, while Sydney has pursued a full cost recovery approach (albeit not fully successfully), Brisbane has historically subsidised infrastructure charges (Productivity Commission 2011). In general, a range of market imperfections often prevent prices equalling marginal social costs. Some jurisdictions impose caps on infrastructure charges while others limit the types of infrastructure that can be included in contribution plans. In addition, some public infrastructure is provided by the Commonwealth (such as telecommunications) and capital costs are not passed on to users.

To the extent that public infrastructure costs faced by households and business are below marginal social costs, there may be additional benefits resulting from land use change. If all households and businesses face the full resource cost of the additional infrastructure and services they require, there would be no public infrastructure cost savings. On the other hand, if public infrastructure costs are not fully passed on to developers and landowners, and instead the government meets some of the costs of establishing and maintaining new developments, there could be a net benefit associated with increasing or decreasing the need for such infrastructure and services.[4] Since the cost of infrastructure and services per dwelling or per capita are lower for more compact urban forms, transport projects that increase or decrease densities can cause incremental net savings or costs that should be accounted for in CBA.

7.1 Estimating public infrastructure cost savings

Public infrastructure cost savings can be estimated by multiplying the change in dwellings by the cost of infrastructure provision and by the percentage of this cost that is borne by the government.

Calculating public infrastructure cost savings requires estimates of per dwelling infrastructure costs for established/greenfield areas and estimates of how much of this cost is borne by the government. Where public infrastructure costs are captured, it should be based on the net cost to government rather than the full resource cost. This benefit would only occur where there is a cross-subsidisation of costs for a good or service (such as water provision) across an area (e.g. where a flat rate is charged). Where this is the case, the benefit would be equivalent to the difference between the subsidised amount and the resource cost of provision (i.e. the net cost to government).

The level of evidence for public infrastructure cost savings needs to be carefully evaluated before it can be used in a CBA. Public infrastructure cost estimates need to be specific to the jurisdiction and areas being evaluated and should be supported by discussions with infrastructure providers about where capacity is located. Assuming that information is available, the benefit estimation steps are:

Step 1: Estimate the number of dwellings in each area in both the base case and project case with land use change. Where the land use modelling does not explicitly model the number of dwellings, this may be done by converting population into dwellings based on projected occupancy rates by sub-area.

[4] To the extent that developers contribute to the cost of public infrastructure and services, it is expected that these costs are ‘passed back’ to landowners in the negotiated price of land and/or reflected in the price that households and business face to locate on the urban fringe.

Step 2: Estimate the cost of public infrastructure provision for each area. The cost of public infrastructure provision should be specific to the jurisdiction and areas being evaluated and should be supported by discussions with infrastructure providers about where capacity is located. In the absence of location specific evidence, the parameters presented in Table 7 may be used and each area should be classified as either ‘established’ or ‘greenfield’ accordingly.

Step 3: Calculate public infrastructure cost savings as follows:

$$PIC = \sum_{i,\rho} \left(Dwlg_{i,\rho}^{LU} - Dwlg_{i,\rho}^{B}\right) \times -PI_{i,\rho} \times (1 - CRR_i)$$

Where:

- $Dwlg_{i,\rho}^{X}$ is the number of dwellings at location i in scenario x (LU = project case with land use change, B = base case) of density type ρ (established, greenfield).
- $PI_{i,\rho}$ is the cost for public infrastructure provision per dwelling of ρ density at location i.
- CRR_i is the cost recovery rate for public infrastructure in location i.
- Step 4: Use advice from other parts of the ATAP Guidelines to estimate higher value land use benefits in subsequent years of the analysis period.

7.2 Public infrastructure cost savings example

If there is an increase of 60 dwellings in an established area, and a reduction of 40 dwellings in a greenfield area, with a public infrastructure cost of provision of $88,350 and $100,950 for established and greenfield areas respectively, with 30% of public infrastructure costs borne by the government (i.e. a cost recovery rate of 70%), then the public infrastructure disbenefit for the established area would be:

60 x -$88,350 x 0.3 = -$1,590,300

While public infrastructure benefit for the greenfield area would be

-40 x -$100,950 x 0.3 = $1,211,400

The net benefit is therefore:

$1,590,300 - $1,211,400 = $378,900

8. Sustainability benefits

Changes in built form may result in sustainability benefits or costs where they have upstream or downstream environmental impacts. For example, lower ongoing energy use (e.g. electricity, gas and water consumption) or lower environmental impacts of construction for high/medium density developments compared to low density housing. To the extent that prices (and hence marginal willingness to pay) differ from marginal social costs due to environmental externalities, such as greenhouse gas emissions, transport initiatives which lead to a more compact urban form may result in savings in sustainability benefits.

Higher density development tends to be more energy efficient than lower density development. On average, households living in low density dwellings (such as freestanding houses) tend to consume more electricity and gas than those living medium (such as semi-detached dwellings) or low-density dwellings (such as flats or apartments). For example, low density dwellings in Sydney consume on average 93% more electricity than high density dwellings (IPART 2010).

To the extent that energy prices are below marginal social costs, there are additional net benefits associated with a reduction in energy consumption as a result of land use change. Energy production has environmental externalities, which result in the price of energy not reflecting the full resource cost of production. In particular, energy production results in C02-e emission, the costs of which are not fully internalised by households and business. The social cost of this misalignment is extensive with the International Monetary Fund estimating that if energy prices equalled marginal social costs, global carbon emissions would be reduced by 25% and premature deaths from fossil-fuel air pollution by 60%.

Indicative parameters for sustainability benefits association with household energy consumption are presented in the table below. Note that there is a gap for parameters associated with energy consumption during the construction of built form. Nevertheless, studies show that 80-90% of building lifecycle energy use occurs during the operation phase. Sustainability benefits are also expected to apply to non-residential development although the evidence is limited.

Table 8 Household energy consumption sustainability benefits by density type ($2020 per dwelling pa)

	Low density	Medium density	High density
Energy consumption (MWh pa)	8.7	5.5	4.5
CO2-e emissions per MWh (tonnes)	0.73		
CO2-e emission (tonnes pa)	6.4	4.0	3.3
Externality unit cost of CO2-e emission ($2020 per tonne)	$60 ($57-$63)		
Household energy consumption environmental externality ($2020 per dwelling pa)	$384 ($365-$403)	$243 ($230-$255)	$198 ($189-$208)

Source: EY analysis based on IPART, Clean energy Regulator and ATAP Guidelines

8.1 Estimating sustainability benefits

Sustainability benefits can be estimated as the change in dwelling mix multiplied by the externality cost of household energy consumption.

The level of evidence for sustainability benefits needs to be carefully evaluated before it can be used in a CBA. In particular, sustainability benefits should be specific to the energy consumption patterns of the areas being evaluated.

The following approach is recommended for the estimation of sustainability benefits associated with changes in household energy consumption as a result of land use change:

Step 1: Estimate average externality cost of household energy consumption per dwelling of density ρ (low, medium, high) for each area. In the absence of location-specific data on energy patterns by dwelling density, the parameters presented in Table 8 can be used.

Step 2: Estimate the number of dwellings by density type in each area in the Project Case with land use change. Where the land use modelling does not explicitly model the number of dwellings, this may be done by converting population into dwellings based on projected occupancy rates by area.

Step 3: Calculate the household energy sustainability benefit as follows:

$$SB = \sum_{i,\rho} \left(Dwlg_{i,\rho}^{LU} - Dwlg_{i,\rho}^{B} \right) \times -EE_{\rho}$$

Where:

- $Dwlg_{i,\rho}^{X}$ is the number of dwellings at location i in scenario x (LU = project case with land use change, B = base case) of density type ρ (low, medium, high).
- EE_{ρ} is the environmental externality cost of household energy consumption per dwelling of density ρ or the environmental externality cost of construction per dwelling of density ρ.

Step 4: Use advice from other parts of the ATAP Guidelines to estimate higher value land use benefits in subsequent years of the analysis period.

8.2 Household energy consumption sustainability benefit example

If in the area being examined, there is an increase of 60 high density dwellings, and a reduction of 40 low density dwellings, with a household energy consumption environmental externality per annum of $384 and $198 for low and high density respectively (as per Table 8), then the sustainability disbenefit for the high density dwellings would be 60 x -$198 = -$11,880 per annum, while the sustainability benefit for the low density dwellings would be -40 x -$384 = $15,360 per annum. The net sustainability benefit is therefore $15,360 – $11,880 = $3,480 per annum.

9. Public health cost changes

Transport projects that result in a denser pattern of urban development have grounds to claim public health cost savings associated with net increased incidence of trips using active transport. For instance, residents in dense urban environments tend to walk and cycle more than residents at the fringe. The health benefits accruing to individuals will be incorporated into land values and, as such, will be captured in the net benefit estimated for additional square metres of floor space made available in the project case. Savings in health system costs that are paid for by governments and so are not reflected in individuals' willingness to pay, constitute an additional active travel benefit that would not be captured in a standard CBA.

Multiple studies have found more compact urban forms are associated with a modal shift away from private vehicles towards walking, cycling, and low-emission public transport. High density environments tend to incentivise low motorised mobility through shorter travel distances, reduced distances to public transport and higher road network congestion costs. This is supported by data from the ABS census which suggests there are significant differences in the rate of active travel as part of travel to work in infill and greenfield areas. Although workers living in greenfield areas that walk or cycle to work travel further than infill residents, the vast majority are heavily dependent on motor vehicles. It is important to note that these patterns of active travel may not hold for leisure trips and that residents in greenfield areas may walk or cycle more for leisure purposes than those in high density environments.

Public health benefits associated with land use change can legitimately be included in CBAs without double counting. This because public health benefits are externalities which are not reflected in standard transport CBAs. Specifically, public health benefits reflect reduced health system costs because active individuals are less prone to illness and place less demand on health system resources. While increased active travel gives rise to other externalities associated with the transport network, such as reduced congestion costs, these benefits will be reflected in second-round transport benefits (see section 6). In contrast, because active travel trips are not typically included in transport models, public health benefits due to land use change are not implicitly included in other benefits.

Recommended parameter values for estimation of public health benefits are shown in the table below. It is recommended that for public health benefits should only include for projects that are expected to result in increases in activity greater than 10 minutes in line with the ATAP 2016 M4 Active Travel guidelines. It is important to note that the active travel benefit per kilometre is the external impact on the health system and not the value to the person themselves.

Table 9 Health system benefits of active travel per km according to physical; activity ($2020)

	Health system benefits per km/activity level			
	Inactive	**Insufficiently active**	**Sufficiently active**	**Weighted per km benefit**
Walking				
Benefits of additional activity per person	$889	$756	$133	
Km over which activity benefits are received	625	450	312	
Proportion of population	20.5%	36%	43.5%	
Willingness to pay benefit per km	$0.29	$0.61	$0.19	$1.08
Cycling				
Benefits of additional activity per person	$889	$756	$133	
Km over which activity benefits are received	1250	900	624	
Proportion of population	20.5%	36%	43.5%	
Willingness to pay benefit per km	$0.15	$0.30	$0.09	$0.54

Source: ATAP 2016, M4 Active Travel

Note that public health impacts arise from a difference in the prices faced by individuals and the marginal social costs. If travellers face the full resource costs of their actions, including the public health externalities, then the resource cost would be fully offset by the benefits to travellers and there would be no public health benefits.

9.1 Estimating public health benefits

Public health benefits can be calculated by applying the active kilometres travelled per person for each area to the change in estimated population for each area and multiplying by the health benefit per active kilometre travelled.

Estimating public health benefits requires evidence on active travel patterns by location, and health cost savings per km of active travel. Where suitable trip data is available (zonal origin, zonal destination, and route), the public health benefits estimation steps are:

Step 1: Estimate average length in kilometres of active travel trips in each area (i.e. walking and cycling).

Step 2: Calculate the public health benefit as follows:

$$PH = \sum_{i,\propto} (Pop_i^{LU} - Pop_i^{B}) \times KT_i^{\propto} \times AT^{\propto}$$

Where:

- Pop_i^X is the number of residents who live at location i in scenario x (LU = project case with land use change, B = base case).

- $KT_i^{\propto}$ is the average kilometres travelled per person via active transport α (c = cycling, w = walking) in location i.
- $AT^{\propto}$ is the active travel health benefit per kilometre travelled that result from increase active transport α (c = cycling, w = walking).
- Step 4: Use advice from other parts of the ATAP Guidelines to estimate higher value land use benefits in subsequent years of the analysis period.

9.2 Public health benefits example

If there are two locations with the average kilometres travelled per person via walking is 2.3km in location A and 2.5km in location B, and if there are 100 people in location A in the base case and 90 in the project case while for location B there are 100 in the base case and 110 in the project case, and the active travel health benefit per kilometre is $1.08, then public health disbenefit for location A would be -10 x 2.3km x $1.08 = -$24.84, while the public health benefit for location B would be 10 x 2.5km x $1.08 = 27.00. The net public health benefit would be $27.00 - $24.84 = $2.16.

10. Areas for further research

10.1 Parameter values

It is important to note that the estimation of land use benefits is a complex and challenging activity, involving significant uncertainty. This is especially the case with land use benefit parameter values.

A review of the literature has revealed little consensus on the parameter values to be used when quantifying land use benefits. In part, this lack of consensus stems from a lack of agreed framework on which costs and benefits to include when measuring land use impacts in a CBA framework. Mostly, however, it stems from the unsuitability of general parameters values for quantifying land use benefits. Land use benefits, by their nature, tend to be location specific. For example, the costs to government of public infrastructure provision varies across suburbs, states and nations. There is not one value which suits all locations.

As a result, the parameters presented in this report should be used with a high degree of caution. They should be interpreted as indicative rather than definitive. The use of sensitivity testing to assess the robustness of parameters, and land use benefits in general, is strongly encouraged. It is also recommended that, where possible, practitioners should undertake analysis to investigate land use parameters on a project by project basis. Further analysis of additional data and new evidence is required.

10.2 Land value uplift

Land value uplift reflects changes in land values attributable to a transport project. As discussed in section 5, land value uplift is generally not recommended for inclusion in a CBA due to the risk of double counting.

Land value uplift, however, has been proposed as an alternative approach to valuing standard transport benefits arising from changes in household location (Applied Economics, 2017). This approach is an alternative to the rule-of-half approach for induced demand associated with land use change and is not a land use benefit per se. Rather, it is a proxy approach to the measurement of standard welfare benefits. If this approach is adopted, then the standard transport benefits for the relevant induced demand should not also be included. In general, however, this approach is not recommended as it is, in principle, more accurate to measure benefits and costs as close to their source as possible (see section 4.2.1).

Further research is required in identifying instances where land value uplift could be included in CBA without double counting. This may be possible in instances where standard transport benefits may be underestimated, or possibly not estimated at all.

10.3 Displacement and its impact on land use benefits

As discussed in section 4.2.3, it is recommend that land use benefits are based on a redistribution of population and employment (i.e. totals are kept constant in the land use forecasting model), rather than a net increase in the amount of population and employment. In general, controlling totals in this way is a more conservative approach to land use forecasting and requires less demanding assumptions about how transport affects migration, population growth rates and employment decisions/opportunities.

Recent developments, however, have started to challenge this stance. For example, a recent paper by Hensher presented a land use forecasting framework which allowed the number of jobs to be endogenously determined with respect to a transport improvement (Hensher et al, 2019). This new class of models is still in its infancy and further research is required before it would be recommended that control totals are allowed to change.

It is important to note, however, that the recommended land use benefits are ambiguous to the source of land use change. In other words, the recommended benefits are equally valid whether the change in land use reflects only a redistribution of population and employment, or 'additional' land use. If a net growth in population and/ or employment, and any associated benefits, was to be contemplated, it would also be essential that the cost of facilitating that growth is also accounted for (such as the costs of the services and infrastructure required to support a growing population).

10.4 Establishing dependency and conditionality

In order to claim additional land use benefits to those captured in a standard CBA, it should be established that the transport project in question is both a necessary and sufficient condition for land use change. In practice, this means proponents should demonstrate the dependency and conditionality of land use impacts of a transport project, as discussed in section 4.2.2. Projects that can demonstrate that both conditions are met, have a reasonable basis for claiming that the transport project in question is necessary and sufficient for land use change.

One way to establish the dependency and conditionality of land use impacts of a transport project is to undertake modelling of future scenarios with and without both transport infrastructure and land use impacts. Transport models routinely undertake 'model runs' with and without a transport initiative assuming a fixed land use. This is commonly referred to as the base and project case and is represented as scenario A and D respectively in the table below. Undertaking equivalent model runs with variable land use (i.e. the land use that is forecast to result with the transport initiative in place) results in scenario B and C. Comparison of the transport outcomes under these scenarios (i.e. level of crowding, congestion, reliability, etc.) can provide compelling supporting evidence that the land use impacts are dependent and conditional on the transport project in question.

Figure 4 Establishing whether a development is dependent

		Transport infrastructure	
		Base case	Project case
Land use	Base case	Scenario A	Scenario D
	Project case	Scenario B	Scenario C

Source: UK DfT (2020, p. 10)

The underlying principle behind establishing dependency is to compare the transport flows and costs on the existing transport network (i.e. base case transport infrastructure), with and without the change in land use (i.e. base and project case land use). Under the project case land use, demand for the local transport network will increase. As such, dependency can be demonstrated through showing that transport outcomes are unacceptable in either Scenarios A or B:

- Scenario A (i.e. with base case transport and base case projected land use) – if transport outcomes are unacceptable under scenario A, then there is a clear need for a transport investment and it is likely the case that a change in land use is wholly dependent on some form of transport improvement. Moreover, unacceptable outcomes under scenario A in combination with planning and zoning restrictions provides evidence for a transport investment to 'unlock' land and result in higher value land use benefits
- Scenario B (i.e. with base case transport and base case projected land use) – if transport outcomes are unacceptable under scenario B, then it is likely that at least some of the land use is dependent on some form of transport scheme.

Note that while this provides a logical framework for defining dependency and establishing how much of the development is dependent, defining acceptable and unacceptable transport outcomes is somewhat subjective, as most urban transport systems are subject to crowding and congestion at some points in time. In particular, there is no precise definition of 'acceptable service outcomes', such that decisions regarding dependency are ultimately judgement based. It is recommended that service standards that are considered acceptable are defined on a case by case basis according to the challenges and opportunity that the transport project in question is seeking to address. Note also that conditionality and dependency may depend on many other factors than transport outcomes.

10.5 Alternative approaches - TAG unit depended development

An alternative approach to estimating higher value land use (and implicitly second-round transport benefits) is the land use dependent development methodology outlined by the UK DfT2020). This approach involves estimating land value uplift arising from land use development, assuming that the transport initiative already exists. It relies heavily on the views on developers in estimating the final value of a development and the development costs. It is also important to note that this approach internalises second-round transport benefits and therefore including both would constitute double counting.

A dependent development is a particular case of land use change where there is a clear intention to develop a specific site, and the existing transport network cannot reasonable accommodate the additional traffic associated with the development. This differs from other types of land use change where development or the redistribution of population and employment may not be the intended outcomes sought by a transport project. An advantage of the dependent development approach is that it does not require forecasting of land use impacts as it is limited to specific sites (see section 3.2). This is also a disadvantage, however, as it cannot be used to account for wider land use changes that may result from a transport project. For instance, it cannot be used for transport projects that are likely to cause land use impacts over a large geographically dispersed area.

This approach is undertaken as follows for each identified site where a) there is a clear intention to develop a specific site; and b) the existing transport network cannot reasonable accommodate the additional traffic associated with the development:

- Step 1 – determine the maximum value households and business will place on land before the development, assuming the transport initiative already exists. This involves estimating the final value of the development (Gross Development Value[5]) and subtracting from this an estimate of the development costs[6] to establish the residual land value.
- Step 2 – determine the maximum value households and business will place on land after the development, assuming the transport initiative already exists. This is done in the same way as step 1.
- Step 3 – estimate the land value uplift from the price of land after development minus the price of land before development. Note that because the transport scheme is assumed to have been implemented, the value of land in its new use will reflect the improved accessibility provided by the transport initiative. As such, this estimate of land value uplift estimate internalises the incremental benefits of the land use development including second-round transport benefits and costs.

It is noted that this approach is highly conceptual and relies heavily upon the views of developers to estimate the change in land values under hypothetical future scenarios for specific sites. The need to undertake the analysis on an ad hoc, site by site basis also makes it challenging for large areas of analysis and unsuitable for projects that are likely to have a geographically dispersed impact on land use.

[5] The Gross Development Value is equal to the expected total revenue which the developer will receive from the sale of the completed development.

[6] Development costs typically include the costs of construction, feed charged for professional services, and the developer margin.

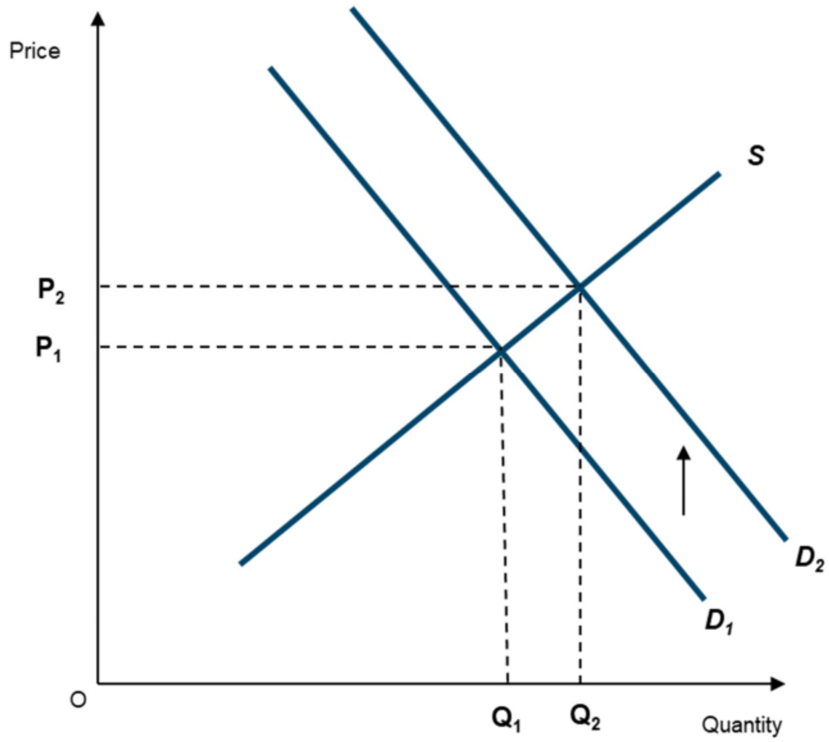
Appendix A Infrastructure-land use transmission mechanisms

A.1 Demand-side mechanisms

The main demand-side role of transport infrastructure on land use is through affecting the attractiveness of locations for households and firms through improving accessibility. While location choice is driven by a diverse range of factors and preferences, such decisions are largely a matter of access to amenities and services, or to jobs and workers. Households wish to locate close to amenities, services, jobs and other opportunities and priorities such as family and friends. Similarly, firms wish to locate close to suppliers, customers and workers, as well as to institutions and facilities.

The relationship between attractiveness and accessibility is not only reflected in higher property prices and rents of high access locations, but also in higher levels of social, environmental and cultural value (CABE, 2007). This suggests a demand-side relationship, between transport infrastructure and land use, where agents' willingness to pay for developed locations (i.e. houses or commercial floor space) may increase in response to a transport improvement. This is illustrated in the figure below, which shows the effect of an increase in demand on the market for developed land. As can be seen, an increase in demand from D1 to D2 leads to an increase in both the price (P1 to P2) and quantity supplied (Q1 to Q2) of developed land.

Figure 5 Effect of an increase in demand on market for developed land



Source: EY

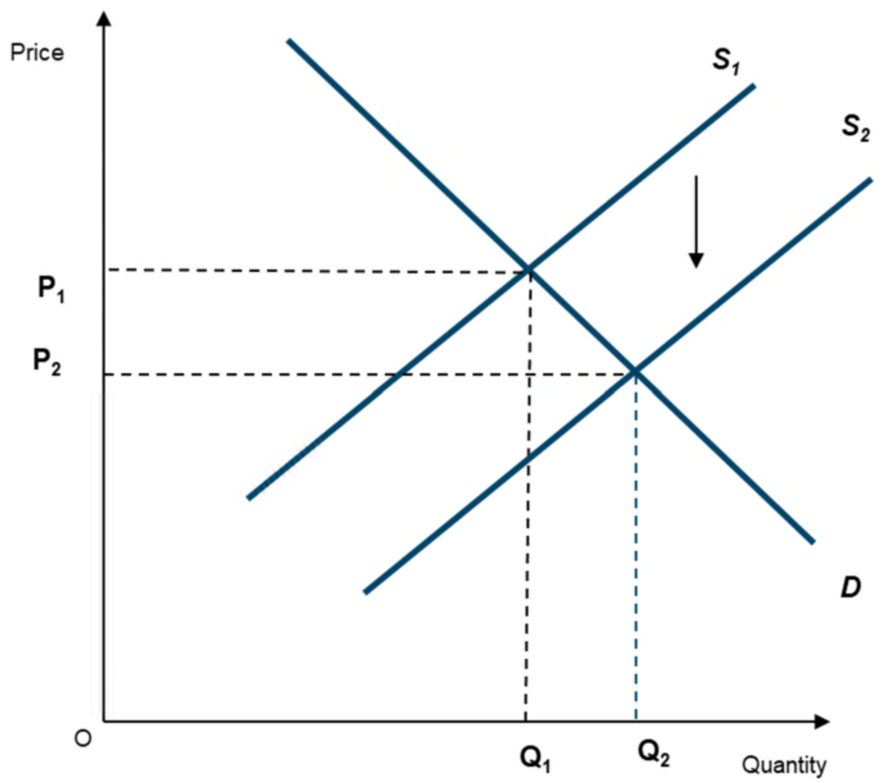
A.2 Supply-side mechanism

The main supply-side role of transport infrastructure on land use can include ‘direct’ and ‘indirect’ impacts. Both, however, have the impact of ‘unlocking’ the potential for additional development.

Direct supply-side impacts result from the provision of critical transport infrastructure. Without the necessary transport connections, the potential uses of land are limited. While this infrastructure could be provided by the private sector, the transport system is characterised by economics of scale, lumpiness and non-exclusivity which means that it is more efficiently provided by the public sector. In this way, public infrastructure investment in transport can facilitate land use change through lowering development costs/risks and unlocking the potential for private development.

The figure below displays the effect of a decrease in the cost of private development. Here, a decrease in supply costs from S_1 to S_2 generates a decrease in price but an increase in quantity supplied of developed locations.

Figure 6 Effect of a decrease in cost of private development

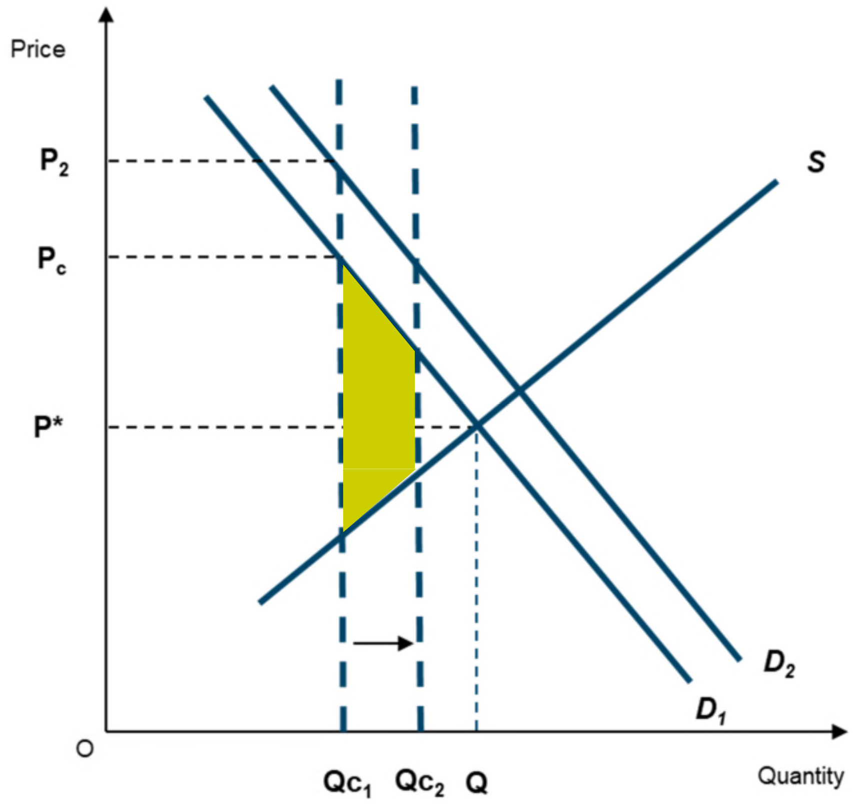


Source: EY

Indirect supply-side impacts result from the removal of regulatory constraints. Planning regulations exist, in part, to ensure that developments only occur if they do not have substantial adverse effects. To the extent that controls are in place because of a lack of transport capacity, investment in transport infrastructure can help unlock these regulatory constraints and facilitate land use change.

A regulatory constraint is illustrated in the figure below. Here the constraint results in a hard limit to the density permitted on a site. Note that increase in demand (shown by D_2), only results in a price change (from P_C to P_2) and that there is no change in the quantity of floorspace developed on the land. Relaxing the constraint (from Q_{C1} to Q_2), however, would unlock land use change and potentially bring the market closer to the equilibrium (indicated by P^* and Q^*). The resulting welfare benefit from higher value land use is shaded in green.

Figure 7 Impact of a regulatory constraint



Source: EY

In summary, the main driver of land use change is changes in demand and supply. Demand side effects involve infrastructure that affects the attractiveness of locations for households and firms; while supply side effects involve infrastructure that either lowers the cost of private development or affects regulatory constraints. It is important to note that any benefits associated with land use change, whether demand or supply side driven, can only be claimed where the change is fully depended on the transport improvement.

Appendix B Extent to which transport models account for land use change

In order to understand the extent to which transport models account for land use change – and therefore the extent to which the benefits and costs of land use change are currently included or excluded – it is necessary to assess the behaviour responses to new transport infrastructure. CBAs of transport projects rely extensively on transport models which aim to forecast future travel behaviour, as well as travel times and costs, with and without a project. The need to consider land use change (and by extension, land use benefits) as a separate component of CBA is therefore dependent on the extent to which transport models already model such behavioural changes.

Agents' responses to a transport initiative that changes travel times or cost could include:

- Trip rates: If the cost of transport is reduced, individuals would be likely to undertake more trips as they seek to substitute into activities associated with more travel. Other factors impacting upon trip rates independent of the transport investment include more working from home, trip consolidation, use of phone/ video conferencing instead of face to face meetings, etc.
- Trip length: Faster transport is likely to encourage longer trips. For instance, commuters would be willing to take up jobs further away from home and businesses might start servicing customers over a larger spatial area.
- Modal shift: An improvement in the performance of one transport mode will attract users away from competing modes.
- Route choice: Transport systems are networks and changes or additions to this network will cause individuals to change the routes they are using to reach their destinations.
- Time of day: Congestion and crowding during peak periods may cause some travellers to choose to travel outside the peaks. Reduced travel times or crowding during peaks would likely encourage some to start travelling during peaks.
- Land use change: As improved transport increases accessibility, and therefore attractiveness of locations, firms and individuals may respond by intensifying use of existing land use (e.g. hot desking and flat sharing), and landowners and planners may permit higher density use.

Importantly, different transport models have different scope in terms of the behavioural responses they model. The main differentiating transport model features are:

- Fixed and variable matrix models: In a fixed matrix model the number of trips between each origin and destination is constant. These models mainly consider route and mode choice response to a transport investment. A variable demand model, in contrast, keeps total trips from and to each zone constant, but allows a change in the 'matching' of origins and destinations – typically leading to growth in travel from trip lengthening.
- Single and multi-modal models: There are highway and public transport models that only focus on behavioural responses on the roads and public transport, respectively. They therefore do not explicitly allow for growth in travel on a mode in response to mode shift. Multi-modal models, in contrast, model individuals' choice of mode, allowing for growth in demand on individual modes.
- Fixed and variable land use: The vast majority of transport models used for CBA hold land use constant. Transport models with variable land use, typically called Land Use and Transport Interaction (LUTI) models, explicitly model the relationships between transport and land use.

- Fixed and induced travel models: Fixed demand models keep the total number of trips constant, only allowing growth in travel from one or more of trip lengthening, mode choice, and route choice. Induced travel models allow for travel growth from sources not explicitly modelled. Hence, for a single-mode model, adding induced travel may implicitly allow for trip growth from mode choice. A fixed matrix model may use induced demand to implicitly allow for trip lengthening and time of day choice. Any model may also use induced travel responses to implicitly allow for growth in travel from a change in land use – although such a model has not been observed as part of this literature review.

The table below provides an overview of the travel behavioural responses of typical strategic transport models in use in Australia.

Table 10 Overview of travel behavior

Transport impacts	Single Mode Model – fixed matrix	Single Mode Model – Variable matrix	Full Network Model – multi-modal	Land Use Model
Trip rates (generation)	×	✓	✓/×	×
Trip length (distribution)	✓	✓	✓	×
Modal shift (mode choice)	×	✓ (implicitly)	✓	×
Route choice (assignment)	✓	✓	✓	×
Timer period (time of day choice)	×	✓ (implicitly	× (typically not)	×
Land use transport change	×	×	×	

Source: EY

When considering including second-round transport benefits within a CBA, it is therefore important to understand to what extent such responses may already be implicitly included in the transport model. Where such responses are already captured, the CBA cannot also attempt to separately account for the costs and benefits of land use change on the transport network.

Where they are not, as is likely to be the case for the majority of transport models, practitioners undertaking CBAs where land use change are likely to be important will need to look to other tools to understand these. Indeed, the most common approaches to assessing land use impacts of transport do not involve amending transport models but use separate specialist tools that are designed to work alongside them.

References

Alonso, W. (1964) Location and Land Use, Harvard University Press, Cambridge

Australian Transport Assessment and Planning Guidelines (ATAP) (2016) Integrated Transport and Land Use Planning, Transport and Infrastructure Council, Australia

Australian Transport Assessment and Planning Guidelines (ATAP) (2016), M4 Active Travel, Transport and Infrastructure Council, Australia

Australian Transport Assessment and Planning Guidelines (ATAP) (2016), Wider Economic Benefits, Transport and Infrastructure Council, Australia

Australian Transport Assessment and Planning Guidelines (ATAP) (2018), Urban Amenity and Liveability, Transport and Infrastructure Council, Australia

Australian Transport Assessment and Planning Guidelines (ATAP) (2018), Cost Benefit Analysis, Transport and Infrastructure Council, Australia

Ben-Akiva, M., Lerman, S.R. (1985) Discrete Choice Analysis, MIT Press, Cambridge, MA

Berry, H.L. (2007) “Crowded suburbs and Killer cities: A brief review of the relationship between urban environments and mental health”, NSW Public Health Bulletin, Cities, Sustainability and Health (part 2), vol.18, nos. 11-12, November-December

Brandes, U. et al (2010), “Land use and driving: The role compact development can play in reducing greenhouse gas emissions- Evidence from three studies”; Urban Land Institute

Brey, R. et al. (2012). “Is the widespread use of urban land for cycling promotion policy cost effective?” Land Use Policy, 63 pp. 130-139

Burns, L.D. (1979) Transportation, Temporal and Spatial Components of Accessibility, Lexington Books, Lexington/Toronto

Cervero, R. & Landis, J. (1997) “Twenty years of the Bay Area Rapid Transport System: Land use and development impacts”, Transport Research (A), vol. 31, no. 4, pp. 309-333

Chen, X. et al. (2019). Redefinition of Cost-Benefit Efficiency of Land-Use projects: focusing on Environmental Cost”

Cheshire, P. & Sheppard, S. (1993) “On the Price of Land and the Value of Amenities”, Econometrica, vol. 62, pp. 247-267, Mathematical Problems in Engineering

Cho, E.J., Rodriguez, D.A., Song, Y. (2008) “The role of employment subcenters in residential location decisions”, Journal of Transport and Land Use, vol.1, issue. 2, pp. 121-151

Cochrane, W., Grimes, A., McCann, P. & Poot, J. (2010) “The spatial Impact of Local Infrastructure Investment in New Zealand”, Motu Working Paper 10-12, Wellington: Motu

Commission for Architecture and the Built Environment (CABE) (2007) Paved with gold: The real value of good street design, Commission for Architecture and the Built Environment, London

Craft, N. & Leunig, T. The Historical Significance of Transport for Economic Growth and Productivity, Background Paper for the Eddington Report, London.

Dalvi, M.Q., Martin, K.M. (1976) "The measurement of accessibility: some preliminary results", Transportation 5, pp. 17-42

David Simmonds Consultancy (2005) "Using a Land-use/Transport/Economic Model in Edinburgh", Working paper 2005

David Simmonds Consultancy (2005) Land-use modelling with delta: update and experience, Conference: Computers in Urban Planning and Urban Management, UK

David Simmonds Consultancy (2009). "Transport/Economic/Land-use Model of Scotland: Land-use modelling with DELTA", Working paper 2009

Du, H., Mulley, C. (2007). "The short-term land value impacts of urban rail transit: Quantitative evidence from Sunderland, UK", Land Use Policy, pp. 223-233

Duranton, G. & Guerra, E. (2016) Developing a Common Narrative on Urban Accessibility: An Urban Planning perspective, Brookings Institute, Washington, D.C.

Efthymiou, D., Hurtubia, R., Bierlaire, M. & Antoniou, C. (2013) The integrated Land-Use and Transport Model of Brussels, 13TH Swiss Transport Research Conference, Mote Verita

Ewing R. & Cervero, R (2010), "Travel and the built environment: A meta-analysis", Journal of the American Planning Association, 76(3), pp. 265-294

Francisco, j. & Martinez, C. (1995), "Access: The transport-land use economic link", Transport Research (B), vol. 29, no. 6 pp. 457-470

Glaesar, E.L. & Glottlieb, J. (2009) "The wealth of cities: Agglomeration Economies and Spatial Equilibrium in the United States", Journal of Economic Literature, vol. 47 no.4, pp.983-1028

Gospodini, A. (2005), 'Urban Development, Redevelopment and Regeneration Encouraged by Transport Infrastructure Projects: The Case Study of 12 European Cities', European Planning Studies, vol. 13, no.7

Hansen, W.G. (1959) 'How Accessibility Shapes Land Use', Journal of the American Institute of Planners, vol. 25, issue. 2, pp. 73-76

Hensher, D.A., HO, C.Q. & Ellison, R.B. (2019). "Simultaneous location of firms and jobs in a transport and land use model", Journal of Transport Geography 75, pp. 110-121

Higgens, C., Kanaroglou, P. (2018). "Rapid transit, transit-oriented development, and the contextual sensitivity of land value uplift in Toronto", Urban Studies, Vol. 55 2197-2225

Higgens, C., Kanaroglou, P. (2015). "Forty years of modelling rapid transit's land value uplift in North America: Moving beyond the tip of the iceberg", Taylor & Francis Online, pp. 610-634

Hoyt, H. (1939) The Structure of Growth of Regional Neighbourhoods in American Cities, U.S. Government Printing Office, Washington D.C.

Infrastructure Australia (IA) (2018) Infrastructure Australia Assessment Framework For initiatives and projects to be included in the Infrastructure Priority List

Jones, P & Eyers, T. (2004) The Jubilee Line Extension Impact Study: Main Findings and Lessons for Future Appraisal of Major Public Transport Investments, Paper from The Association for European Transport Conference held in Strasbourg, France

Kasraian, D., Maat, K., Stead, D. & van Wee, B. (2016) “Long-term impacts of transport infrastructure on land-use change: an international review of empirical studies”, Transport Reviews, vol. 36, issue. 6, pp. 772-792

Krugman, P. (1996) The Self-organizing Economy, Oxford: Blackwell, UK

LUTI Consulting. (2020). Sydney Hedonic Price Model 2020 Update Report

Mare, D., Grimes, A. & Morten M. (2009) “Adjustment in Local Labour and Housing Markets”, Australasian Journal of Regional Studies, vol. 15, no. 2, pp. 229-248

Martinez, F., Araya, C. (200) “Transport and land use benefits under location externalities”, SAGE,

Muth, R. F. (1969) Cities and Housing: The Spatial Pattern of Urban Residential Land Use, The University of Chicago Press, Chicago

NZIER, (2013) Appraising transport strategies that induce land use changes: estimating benefits of long-term land use change from standard model outputs, NZIER public discussion document, Working paper 2013-14

New Zealand Transport Agency, (2012), “The economic and land use impacts of transformational transport investment”, research report

New Zealand Transport Agency, (2019), “Transformative transport projects (dynamic webs and land use benefits and costs)” Investment Decision-Making Framework Review

Saujot, M., Lapparent, M. de, Arnaud, E., Prados, E., (2016) “Making land use – Transport models operational tools for planning: From a top-down to an end-user approach”, Transport Policy, vol. 49, pp. 20–29

Simmonds, D., Waddell, P. & Wgener, M. (2011) Equilibrium v. dynamics in urban modelling, Symposium on Applied Urban Modelling, University of Cambridge, UK

Standing Advisory Committee on Trunk Road Appraisal (SACTRA) (1999) Transport and the economy: full report, Department of Transport, UK

Stevenson, M. et al. (2016). “Urban design, transport and health 2”, Lancet, 388: 2925-35

TfNSW (2016) Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Transport Economic Appraisal Guidelines, Australia

Teulings, C., Ossokina, J., de Groot, H., “Land use, worker heterogeneity and welfare benefits of public goods”, Journal of Urban Economics, 103 pp. 67-82

Transport for the North, (2019), Land Value and Transport (Phase 2): Modelling and Approach, Institute for Transport Studies

Ustaoglu, E., Williams, B., Murphy, E. “Integrating CBA and land-use development scenarios”, Case Studies on Transport Policy, 4 pp. 101-121

UK Department for Transport (2014) Supplementary guidance

UK Department for Transport (2016) TAG unit A2-3 transport appraisal in the context of dependent development

UK Department for Transport (2020) TAG unit A2-2 Appraisal of induced investment impacts

Waddell, P. (2002) "UrbanSim: Modeling Urban Development for Land Use, Transportation, and Environmental Planning", Journal of the American Planning Association, vol. 68, issue. 3, pp. 297-314

Waddell, P. (2011) "Integrated Land Use and Planning and Modelling: Addressing Challenges in Research and Practice", Transport Reviews, vol. 31, no. 2, pp. 209-229

Wang, W., Zhong, M., Hunt, J. (2019). Analysis of the Wider Economic Impact of a Transport Infrastructure Project Using an Integrated Land Use Transport Model, MDPI

Wang, Y., Potoglou, D., Orford, S., Gong, Y. (2014). "Bus stop, property price and land value tax". Land Use Policy, Vol. 42, pp.381-391

Wegener, M. (2004) Overview of Land Use Transport Models, in Hensher, D.A., Buton, K.J., Haynes, K.E., Stopher, P.R. (ed.), Handbook of Transport Geography and Spatial Systems (Handbooks in Transport, vol. 5), pp. 127-146

Wegener, M. (2004) Overview of land-use models, In D. A. Hensher & K. Button (Eds.), Transport geography and spatial systems, pp. 127-146, Kidlington: Pergamon/Elsevier Science

Whelan, J. (2003). "Developing a methodology to capture land value uplift around transport facilities", GCA Grimley

Xiong, C., Beckmann, V., Tan, R. (2018). Effects of Infrastructure on Land Use and Land Cover Change, MDPI

Zhao, F. & Chung, S. (2006) A Study of Alternative Land Use Forecasting Models, Final Report to the Florida DOT Systems Planning Office

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