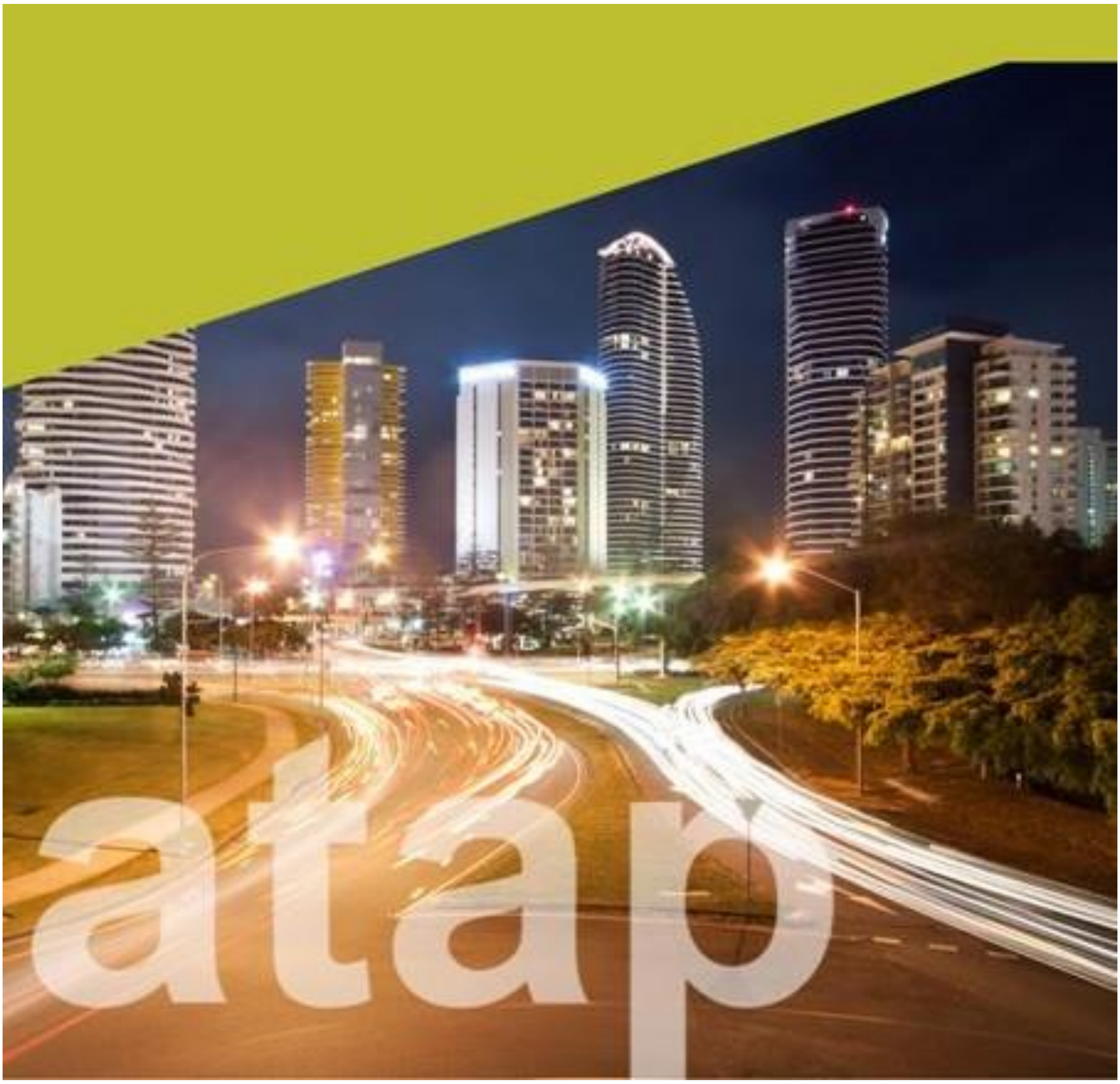
INFRASTRUCTURE AND TRANSPORT MINISTERS

Australian Transport Assessment and Planning Guidelines

O8 Land-use benefits of transport initiatives

August 2021



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About the report

Estimation of the land-use benefits of transport initiatives is a topic at the border of transport and urban economics and assessment. This is a relatively new field from both research and practice perspectives. As such, methodologies in the area are still being developed, debated, tested and refined.

The development of this report has relied on significant engagement with subject matter experts both internally and through public consultation. In the process, a wide range of views were encountered that demonstrated that consensus has not yet been established in some aspects of the topic.

This ATAP guidance has been released with this situation in mind. The ATAP steering committee:

- Has taken a balanced view of the information available through the above process and developed guidance that it considers most suitable for the majority of practitioners for the present
- Will continue to monitor ongoing research and debate in the field, and welcomes ongoing feedback from stakeholders
- Will consider the need for an update at some point in future as the field evolves further.

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 (i.e. second-round transport benefits), changes in land use can result in a range of additional benefits and disbenefits 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 land use benefits to be included in cost–benefit analysis (CBA), 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*, *sustainability*, and *public health benefits*, which can be estimated and included in CBAs 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. Where public infrastructure is subsidised by governments, the savings in subsidies can be counted as a benefit. However, 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 there is 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, it is recommended that CBA summary results (net present value, benefit–cost ratio) be reported without and with land-use change benefits.

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.

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.

Estimation of land use benefits of transport initiatives is relatively new. While it has received attention in overseas guidelines, it has rarely been applied in Australian practice. These guidelines have been developed to provide practitioners with a rigorous methodology and parameter values for consistent application across the country. However, as this area of knowledge is still evolving, we will continue to monitor developments in research and practice, and welcome ongoing feedback — which may lead to updates to the guidance as required.

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 higher value land-use benefits
- Chapter 6 discusses the theory and estimation approach for second-round transport benefits[1]
- Chapter 7 discusses the theory and estimation approach for public Infrastructure cost savings benefits
- Chapter 8 discusses the theory and estimation approach for sustainability benefits
- Chapter 9 discusses the theory and estimation approach for public health benefits
- Chapter 10 provides an overview of areas for further research or consideration
- Appendix A provides more information on the infrastructure-land use transmission mechanisms
- Appendix B contains the theoretical explanation of higher value land-use benefits
- Appendix C discusses the treatment of existing capital in estimating higher value land-use benefits
- Appendix D addresses second-round user benefits associated with land use-change
- Appendix C discusses land-use change in transport demand models
- Appendix F contains additional notes on the treatment of public infrastructure costs in appraisals.

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

[1] Note that second-round transport benefits resulting from land-use change should not be confused with 'secondary benefits', which are flow-on benefits and costs passed on or redistributed within the economy.

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. For example:

- Where there is demand for floor space 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 parcel of land to generate a higher 'use value', by permitting it to hold additional capital, such as residential, commercial or other floor space.
- 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 or disbenefits that will not be counted in a CBA if land use is held constant. Changes in travel distance, mode choice and destinations can also have impacts on externalities, such as congestion and crowding, and on toll and fare revenues, which 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 provision of public infrastructure is subsidised and land-use densification leads to net public **infrastructure cost impacts**, however, there may additional benefits. The ability to estimate these benefits 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. High density environments tend to be associated with shorter travel distances, reduced distances to public transport and higher road network congestion costs. Increased density can lead to a modal shift from private 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 impacts** 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**.[2]

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

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

The difference between *land value uplift* and *higher value land use*

- These guidelines make an important distinction between ***land value uplift*** and ***higher value land use***.
- ***Land value uplift*** is defined as the total change in land values attributable to a transport initiative. This means that land value uplift includes the capitalisation of primary benefits (such as transport user benefits) into land values. Consequently, including land value uplift in a CBA would result in double counting with conventional transport benefits that are typically captured as part of a standard CBA.
- In contrast, ***higher value land use*** is defined as the changes in land values resulting from a transport development allowing more, or a different type of, floor space on the land, where the market price of the additional or higher-value floor space exceeds the resource cost of providing it. Measured correctly, higher value land use excludes the uplift in land value from the capitalisation of primary benefits. As it arises from a market imperfection, higher value land use can be included in a CBA without resulting in double counting.
- For further clarification and discussion on the differences between land value uplift and higher value and use see section 5.

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 floor space within an area, and in the spatial distribution across areas. Land-use change can occur over long time horizons and does not necessarily indicate physical relocation by households and firms. Rather it may reflect a change in growth patterns and where development occurs over time.

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 floor space:

- 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. This is referred to as a 'closed city' approach, and differs from alternative 'open city' approaches, as discussed below.

Closed city and *open city* land-use approaches

In its consultation, the ATAP steering committee noted two potential approaches for forecasting land-use changes as a result of a transport initiative:

- Closed city approaches: under a closed city approach, the total population and employment of the area, city, or region being assessed are assumed to remain constant between the Base Case and the Project Case. Where a transport investment increases the intensity of activity in a specific local area, this is assumed to be a result of redistribution from elsewhere within the area of assessment.
- Open city approaches: under an open city approach, the total population and employment of the area, city, or region being assessed may increase in the Project Case, relative to the Base Case. This increase in population and employment is assumed to be redistributed from outside the area of assessment,

The guidance presented here is based on the closed city approach. The closed city approach was chosen because it is the approach most commonly used in CBA at this time, and its use simplifies the assumptions and calculations needed to estimate a number of land-use benefits. Project proponents can still proceed with using the open city approach in project appraisal. However, if they do, it is recommended that proponents:

- Seek input and advice from specialist resources with experience in open-city assessment
- Liaise closely with State, Territory and National bodies that will assess their proposal. This should commence early in the assessment process
- Clearly justify why the open city approach has been used
- Clearly document the details of their assessment, including assumptions made, and equations and parameter values used.

Open city approaches may be investigated further in future ATAP guidance.

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:

- 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’, or ‘region-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 to differ from its opportunity cost. Zoning restrictions may be imposed to suppress congestion, and the transport initiative permits the restriction to be eased allowing more intensive or different land use. Such cases of land-use change are referred to as ‘unlocking’ land supply. If there is adequate transport capacity in the Base Case to handle the increased traffic from removing the zoning restriction, the benefit should not be attributed to the transport initiative, because society can obtain the benefit without investing in the transport initiative. Where the capacity does not exist, so that easing the land-use restriction is dependent and conditional upon the transport initiative, a higher value land benefit can be a legitimate benefit to include in a CBA where the value of the additional floor space made available in the Project Case exceeds the resource cost of supplying it.

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 benefits and disbenefits 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 1.

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 additional land supplied exceeds the resource cost of achieving the change.	It is important to distinguish between higher value land use and land value uplift. Land value uplift reflects the general change in land values resulting from a project, including the capitalisation of primary benefits (such as transport user benefits) into land values. Higher value land use, in contrast, reflects the value resulting from a transport development allowing more, or otherwise higher value, floor space 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 includes 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 • Whether part of the benefit could be secured by easing the transport restriction in the Base Case without the transport initiative
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 require 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. In congested networks, the congestion costs imposed by additional trips due to land-use change can exceed the benefits leading to negative second-round transport benefits.	• 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 impacts	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

Benefit	Description	Implication for measurement	Disputes in application
Sustainability impacts	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 travel.	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.	• Whether private health benefits from densification are fully captured within land values • Whether all forms of densification lead to increased active travel
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 to more 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 floor space.

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.[3]

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 modelled area, with the remainder redistributed from within.

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.

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:

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[3] 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.

- 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 floor space 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.

Table 2 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 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.	• 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. • 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.	• 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. • 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.

<table>
<tr><th>Approach</th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Spatial Computable General Equilibrium (CGE) 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 implement the theoretical framework by introducing distinct spatial units that trade with each other.</td><td>A theoretically robust economic approach able to forecast economic shocks brought about by infrastructure changes
Useful in explaining the attractiveness of a region for firms in terms of economic infrastructure</td><td>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
Does not consider a number of non-accessibility based attractiveness or amenity factors</td></tr>
<tr><td>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.</td><td>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.</td><td>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.</td></tr>
<tr><td>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.</td><td>Flexible in terms of the level of spatial disaggregation it can be used for. Can drill down into the parcel level of land
Able to integrate accessibility-driven demand change on a network, thereby incorporating demand side considerations
Parameters reflect local conditions</td><td>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</td></tr>
</table>

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) Dual causality
    b) Attribution
    c) Time dimension

3.3.1 Determine the spatial area of assessment

It is recommended that the spatial area that is assessed by the land-use model be 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 at 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 Case land use is dependent on non-committed transport projects being delivered, then a new project-specific Base Case needs to be developed to reflect the level of 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 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 can result in land-use benefits when there are market imperfections. Market imperfections lead to inefficient markets where prices differ from marginal social costs. The presence of prices differing from marginal social costs is a necessary condition for all categories of land-use benefits except for second-round transport impacts. 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.

Another case where land-use change can result in land-use benefits is where there are feedback effects between land use and the transport market, that is, second-round transport impacts. 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 transport benefits and disbenefits in the same way as for a transport project.

It is recommended that any claimed land-use benefits be 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 that largely reflect the capitalisation of primary impacts 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 such that 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 recommends 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 3:

- 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, second-round, 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 impacts, sustainability benefits and public health cost changes. Note that second-round transport benefits from land-use change may be negative.

Table 3 Example of core appraisal results table

Costs and benefits	Present value ($ millions 202X)
Benefit 1	
Benefit 2	
Benefit 3	
[Insert rows as required, e.g. to separate existing and new user benefits]	
Total transport benefits	
Capital investment costs	
Operating costs	
Maintenance costs	
Total costs	
NPV	
BCR1	
BCR2	
FYRR	
Higher value land-use benefits	
Second-round transport benefits from land-use change	
Other land-use benefits (e.g. sustainability, public health)	
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 additional land supplied exceeds the resource cost of achieving the change. For example, where there is excess demand for residential floor space 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 permits alleviation of 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 floor space. 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, floor space on the land. In other words, higher value land use reflects a supply-driven impact where an increase in the supply of floor space, 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. A detailed explanation of the theory behind the higher value land-use benefit is provided in Appendix A and B.

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 floor space 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 4.

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.
Restrictive planning controls	• Transport exceeding acceptable service standards 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.

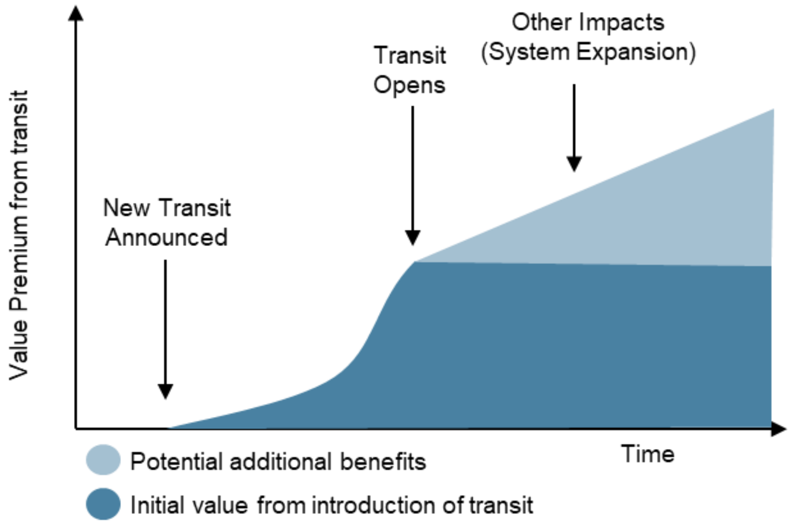
Not all transport projects can be expected to unlock additional supply. The magnitude of the change in supply depends on the additional capacity provided by the transport project and the level of excess demand. For example, a low frequency, low capacity suburban transit service would be much less likely 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 occur is debated. This issue has two key components:

1. The timing of the land-use change in reality (i.e. Do rezoning and densification start to occur at the time of announcement of a project, or later when the transport project has been delivered?)
2. What is the most appropriate point in time for the benefit to be included in the CBA.

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 to occur in advance of the delivery of the transport project and continue for years after. This response has been demonstrated in literature that finds that transport benefits begin to be capitalised into the surrounding land markets from the announcement of a funding commitment (e.g. see McIntosh et al, 2014). This is illustrated in Figure 1.

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 floor space is delivered in line with change in actual use. This may involve a time series that begins before the project start date and continues after operation has commenced. This approach ensures that higher value land-use 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 to the construction phase and through to the end of the appraisal period.

In summary, 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.

There may be certain circumstances where land-use change may result in a negative higher value land use. For example, it is possible that land could be rezoned to 'less valuable' uses that meet policy objectives. However, these cases are not anticipated to be the norm.

5.1 Estimating higher value land use benefits

Higher value land-use benefits (Hcan be estimated using land-use forecasts of change in floor space by type, together with evidence on land value per square metre of floor space.

Not all floor space change forecasted by a land-use model, however, will result in HVLUBs. HVLUBs only arise where a transport initiative unlocks additional (or change in) floor space supply that was constrained by a market imperfection. Note that a change in floor space 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 floor space being converted to residential). As such, it is recommended that HVLUBs be only estimated for areas that are subject to a supply constraint that is expected to be alleviated by the transport infrastructure in question.

Appendices A and B provide a theoretical explanation of HVLUBs and demonstrates that they do not double count second-round transport benefits. HVLUBs arise from additional floor space becoming available in the Project Case, where the value to society of the additional floor space, measured by the market price, exceeds the resource cost of providing the floor space due to scarcity of land available for the purpose for which it will be used in the Project Case. It is a case of increased output in a related market in the Project Case giving rise to additional benefits because price exceeds resource cost in the related market, as discussed in ATAP Part T2 Cost–benefit analysis, Chapter 7.

It is recommended that HVLUBs be calculated from estimates of land value per square metre of gross floor area (GFA) using the residual land value (RLV) approach. RLV is the present value of the total revenue from a potential development (or the market value, recognising that market prices of assets are present values of expected future net returns), minus the present value of all development costs, including the developers' profit margin. The RLV measures the gap between market price and resource costs assuming that development costs including developers' profit margins equal resource costs. Any under- or over-recovery of public infrastructure costs paid by developers can be ignored in the RLV calculation and addressed separately following the methodology in Chapter 7 of this guidance.

HVLUBs occur only for incremental floor space made available and existing floor space converted to a higher-value use as a result of the project. For example, say a three-story building is demolished in the Project Case to make way for an eight-story building. The incremental RLV applies only for the additional five floors. The HVLUB can be estimated simply from values and costs per square metre of GFA as recommended in the set of steps below.

An alternative detailed approach is to take:

- The present value of rents less owner expenses (or the market value) less the development costs for the eight-story Project Case building, minus
- The present value of rents less owner expenses (or the market value) less development costs of a new three-story building of equivalent quality and characteristics less the development costs.

This approach allows for the fact that building costs may rise more than proportionately as the number of floors is increased due to needs for lifts, more car parking and stronger foundations and structural supports for taller buildings. Since the Base Case and Project Case buildings occupy the same land, the opportunity cost of the unimproved land can be ignored.

RLVs will vary between sites, depending 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. Note that other approaches may be available to measure land value per square metre of GFA, however, strong evidence is required to justify their use.

The depreciated value of existing capital demolished to allow the land-use change to proceed should be deducted from the incremental RLV to obtain the HVLUB because the cost of replacing existing floor space is brought forward in time. Appendix C sets out the theoretical justification. The appendix shows that the approach implicitly takes into account the replacement costs of existing capital in the Base Case, so this does not need to be considered. Using the example of the three-story building demolished to make way for an eight-story building, in the Base Case the existing three-story building might be replaced in 30 years' time but in the Project Case, the first three stories are reconstructed in the early years of the appraisal period as part of the eight-story building. The cost of replacing the first three stories is therefore brought forward in time. Appendix C demonstrates that straight-line depreciation approximates the increased present value of costs. The older (newer) the existing building, the smaller (greater) the number of years replacement is brought forward and the lower (higher) the depreciated value.

It is acknowledged that the value of existing capital can be very difficult to estimate. The consequences of ignoring existing capital will not be great provided the existing capital is run-down, or close to the end of its economic life. Simplifying assumptions can be made about average ages and remaining economic lives of existing capital stock. Since land-use change occurs gradually, it could be assumed that, in the Project Case, existing buildings will not be replaced until they reach the end of their economic lives. This does away with the need to estimate depreciated values, but still requires assumptions to be made about replacement times for existing buildings at the ends of their economic lives, or at least the proportion of total floor space in each zone that reaches the end of its economic life in each future year. A highly conservative version of this approach is to assume that land-use change occurs only for buildings at or close to the end of their economic lives at the time of commencement of the transport project.

Land-use forecasts need to include Base Case and Project Case stock by development type (i.e. residential, retail and commercial GFA) at a spatially disaggregated level commensurate to the transport modelling. Assuming that suitable land value data is available, the HVLUB can 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: In each area affected, identify buildings existing in the Base Case that are likely to be demolished in the Project Case and replaced with buildings that generate higher value land use. The replacement buildings might have more floors and/or be of a different development type (residential, retail, commercial) with a higher RLV.

Step 3: Express the Base Case and Project Case buildings affected in square metres of GFA using assumptions about average intensity of use (e.g. average occupancy per dwelling and average dwelling size, average square metres per worker for different commercial uses). These assumptions should reflect the development type for each building. The result will be tables showing quantities of GFA demolished in the Base Case and quantities of GFA that will replace them in the Project Case with the cells in the tables representing all combinations development types (residential, retail, commercial) and density bands (low, medium, high) for each area.

Step 4: For each area–development type–density cell, take the difference between the Base Case and Project Case GFA affected to obtain the change in GFA, that is,

$$\Delta GFA_{\alpha}^{td} = PC.GFA_{\alpha}^{t,d} - BC.GFA_{\alpha}^{t,d}$$

where, for GFA of type *t* and density *d* in area *α*

- ΔGFA_{α}^{td} is incremental square metres of GFA, and
- $PC.GFA_{\alpha}^{t,d}$ and $BC.GFA_{\alpha}^{t,d}$ are respectively the Project Case and Base Case square metres of GFA that are affected by the transport initiative.

Step 5: Analyse market evidence to establish an average RLV per square metre of GFA for each area–development type–density combination ($RLV_{\alpha}^{t,d}$).[4] It is recommended that RLV per square metre of GFA for each area–development type–density cell be held constant across the Base Case and Project Case to avoid double counting with transport user benefits.

Step 6: Estimate the gross HVLUB for each area–development type–density cell as the product of the RLV and the incremental or change in GFA.

[4] 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.

$$Gross\ HVLUB_{\alpha}^{t,d} = \Delta GFA_{\alpha}^{t,d} \times RLV_{\alpha}^{t,d}$$

where, for GFA of type *t* and density *d* in area *α*

- $Gross\ HVLUB_{\alpha}^{t,d}$ is the HVLUB before deducting the cost of existing capital demolished, and
- $RLV_{\alpha}^{t,d}$ is average RLV per square metre (from step 5).

The approach here takes account of situations where GFA is repurposed to a higher value land use. Say ΔGFA in an area is repurposed from a commercial to residential development type with RLVs of RLV^{com} and RLV^{res} respectively. The gross HVLUB for the area is $\Delta GFA \times (RLV^{res} - RLV^{com})$. This can be rewritten in a form consistent with the formula given just above as $\Delta GFA^{res} \times RLV^{res} + (-\Delta GFA^{com}) \times RLV^{com}$, where $\Delta GFA^{res} = \Delta GFA^{com} = \Delta GFA$. Thus the formula gives the correct result provided ΔGFA for the commercial development type in the area has a negative sign.

Note that where $\Delta GFA_{\alpha}^{t,d} < 0$ for a particular area–development type–density cell, if GFA unaffected by the transport initiative has been fully removed, then Project Case GFA for the cell, $PC.GFA_{\alpha}^{t,d}$, should equal zero. For example, if Base Case GFA is 1500m^2 and Project Case GFA is 500m^2 so that $\Delta GFA = -1000m^2$, the implication is that 500m^2 of GFA is unchanged between the Base and Project Cases. To avoid treating the entire 1500m^2 of Base Case GFA as being demolished in step 8 below, such a situation should be represented as $BC.GFA_{\alpha}^{t,d} = 1000m^2$ and $PC.GFA_{\alpha}^{t,d} = 0m^2$. That way, only the 1000m^2 of Base Case GFA will be treated as existing capital to be demolished.

For the same reason, there should never be a situation where, $\Delta GFA_{\alpha}^{t,d} = 0$ and $BC.GFA_{\alpha}^{t,d} = PC.GFA_{\alpha}^{t,d} > 0m^2$. For example, having both Base Case and Project Case GFA at 1000m^2 implies that there is no change in land use between the two cases. It is necessary to set both to zero to avoid treating the 1000m^2 of existing capital as being demolished and deducting its depreciated value.

Step 7: Analyse market evidence to estimate the average depreciated value of existing capital per square metre based on straight-line depreciation ($ADVXKD_{\alpha}^{t,d}$) for each area–development type–density cell. For an existing building with a replacement cost of *K*, an economic life of *T* years and age *δ*, the depreciated value is

$$\left(\frac{T - \delta}{T}\right) K$$

Step 8: Estimate the total value of existing capital demolished for each area–development type–density cell as the product of Base Case GFA to be demolished and the average depreciated value of existing capital per square metre.

$$TVXKD_{\alpha}^{t,d} = BC.GFA_{\alpha}^{t,d} \times ADVXKD_{\alpha}^{t,d}$$

where, for type *t* and density *d* in area *α*

- $TVXKD_{\alpha}^{t,d}$ is the total depreciated value of GFA of existing capital to be demolished, and
- $ADVXKD_{\alpha}^{t,d}$ is the average depreciated value of existing capital to be demolished per square metre (from step 7).

The costs of existing capital demolished should only be applied only to existing Base Case buildings that are demolished in the Project case to make way for construction of buildings that are taller and/or of a different type. Buildings that do not change between the Base and Project Cases should be excluded in step 2.

Step 9: Estimate the net HVLUB for each area–development type–density cell area by deducting the total depreciated value of GFA to be demolished from the gross HVLUB.

$$Net\ HVLUB_{\alpha}^{t,d} = Gross\ HVLUB_{\alpha}^{t,d} - TVXKD_{\alpha}^{t,d}$$

Step 10: Sum net HVLUBs for the development types and densities for each area to obtain the net HVLUB for the area.

$$Net\ HVLUB_{\alpha} = \sum_{t}\sum_{d} Net\ HVLUB_{\alpha}^{t,d}$$

Note the warnings in Section 5.3 about instances where step 9 changes a positive gross HVLUB to a negative net HVLUB and, for step 10, where $\sum_t \sum_d Gross\ HVLUB_{\alpha}^{t,d} > 0$ and $Net\ HVLUB_{\alpha} < 0$ for an area.

Step 11: Sum the net HVLUBs for all areas to obtain the HVLUB.

$$HVLUB = \sum_{\alpha} Net\ HVLUB_{\alpha}$$

Since RLVs and depreciated values of existing capital are present values, the resulting HVLUB will be a present value discounted to the year in which the land-use change is complete. If this is later than the base year, the HVLUB will have to be discounted to the base year. If the land-use change occurs gradually, it may be appropriate to apportion the total HVLUB over a number of years.

5.2 Higher value land-use benefit estimation: numerical example

Steps 1,2 and 3

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

Assume that the land-use forecast predicts the Base Case and Project Case GFAs by development type for five areas identified as subject to planning constraints in the Base Case as shown in Table 5: $BC.GFA_{\alpha}^{td}$, and Table 6: $PC.GFA_{\alpha}^{td}$.

Table 5 Base Case floor space by development type (square metres of GFA)

Area	Residential	Retail	Commercial
Wentworthville Town Centre	2,000	500	500
Merrylands Town Centre	2,500	300	100
Auburn Town Centre, North	1,000	1,000	500
Auburn Town Centre, South	1,500	500	400
Lidcombe Town Centre	2,000	500	0

Table 6 Project Case floor space by development type (square metres of GFA)

Area	Residential	Retail	Commercial
Wentworthville Town Centre	5,000	2,000	0
Merrylands Town Centre	4,500	500	350
Auburn Town Centre, North	2,500	1,500	0
Auburn Town Centre, South	3,500	0	600
Lidcombe Town Centre	3,750	750	0

Step 4

Table 7 shows the changes in GFA between the Base and Project Cases, Table 6 minus Table 5: $\Delta GFA_{\alpha}^{t,d} = PC.GFA_{\alpha}^{td} - BC.GFA_{\alpha}^{td}$.

Three cells in Table 7 have negative ∆GFAs, indicating that floor space is forecast to be repurposed to a higher value use. This is plausible because the three cells that lose floor space are for the retail and commercial development types, which Table 8 below shows have lower RLVs compared with the residential development type. For each of these cells, Project Case GFA in Table 6 is zero, which confirms that GFA unaffected by the transport initiative has been removed from the analysis for those cells.

For commercial floor space in Lidcombe Town Centre, ∆GFA in Table 7 is zero. Base Case and Project Case GFA for this cell in Table 5 and Table 6 are also zero, which confirms that GFA unaffected by the transport initiative has been removed from the analysis for that cell.

Table 7 Changes in gross floor area (square metres of GFA)

Area	Residential	Retail	Commercial
Wentworthville Town Centre	3000	1500	–500
Merrylands Town Centre	2000	200	250
Auburn Town Centre, North	1500	500	–500
Auburn Town Centre, South	2000	–500	200
Lidcombe Town Centre	1750	250	0

Step 5

Table 8 presents estimates of average RLV per square metre of GFA by development type and area: $RLV_{\alpha}^{t,d}$.

Table 8 Residual land values ($2017 per square metre of GFA)

Area	Residential	Retail	Commercial
Wentworthville 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, in Cumberland Council 2017.

Step 6

Table 9 shows the gross HVLUBs before deducting the cost of existing capital demolished, Table 7 multiplied by Table 8: $\Delta GFA_{\alpha}^{t,d} \times RLV_{\alpha}^{t,d}$.

Table 9 Gross higher value land-use benefits ($'000)

Area	Residential	Retail	Commercial	Total
Wentworthville Town Centre	$6,600	$1,350	–$200	$7,750
Merrylands Town Centre	$3,400	$200	$100	$3,700
Auburn Town Centre, North	$3,300	$200	–$150	$3,350
Auburn Town Centre, South	$4,400	–$400	$60	$4,060
Lidcombe Town Centre	$3,063	$200	$0	$3,263
Total	$20,763	$1,550	-$190	**$22,123**

Step 7

Table 10 presents estimates of average depreciated value of existing capital per square metre of GFA: $ADVXKD_{\alpha}^{t,d}$.

Table 10 Depreciated value of existing capital ($2017 per square metre of GFA)

Area	Residential	Retail	Commercial
Wentworthville Town Centre	$1,000	$300	$200
Merrylands Town Centre	$750	$350	$200
Auburn Town Centre, North	$1,000	$150	$100
Auburn Town Centre, South	$1,000	$300	$100
Lidcombe Town Centre	$750	$300	$150

Step 8

The values for the existing capital deduction are shown in Table 11 obtained by multiplying together Table 5 and Table 10: $TVXKD_{\alpha}^{t,d} = BC.GFA_{\alpha}^{t,d} \times ADVXKD_{\alpha}^{t,d}$.

Table 11 Existing capital deductions ($'000)

Area	Residential	Retail	Commercial	Total
Wentworthville Town Centre	$2,000	$150	$100	$2,250
Merrylands Town Centre	$1,875	$105	$20	$2,000
Auburn Town Centre, North	$1,000	$150	$50	$1,200
Auburn Town Centre, South	$1,500	$150	$40	$1,690
Lidcombe Town Centre	$1,500	$150	$0	$1,650
Total	$7,875	$705	$210	**$8,790**

Steps 9, 10 and 11

Based on these assumptions, Table 12 sets out the estimated HVLUBs, Table 9 minus Table 11: $Net\ HVLUB_{\alpha}^{t,d} = Gross\ HVLUB_{\alpha}^{t,d} - TVXKD_{\alpha}^{t,d}$, and sums the results over development types and areas to arrive at the total HVLUB of $13,333,000 for all 15 cells combined.

Table 12 Higher value land-benefit estimates ($'000)

Area	Residential	Retail	Commercial	Total
Wentworthville Town Centre	$4,600	$1,200	-$300	$5,500
Merrylands Town Centre	$1,525	$95	$80	$1,700
Auburn Town Centre, North	$2,300	$50	-$200	$2,150
Auburn Town Centre, South	$2,900	-$550	$20	$2,370
Lidcombe Town Centre	$1,563	$50	$0	$1,613
Total	**$12,888**	**$845**	**-$400**	**$13,333**

5.3 Cautions when deducting existing capital costs

As discussed above and in Appendix C, deduction of the depreciated value of existing capital from the gross HVLUB adjusts for costs of bringing forward in time replacement of floor space demolished before the end of its economic life in the Project Case to make way for creation of new floor space. Straight-line depreciation approximates the increase in the present value of costs between the Base and Project Cases.

As discussed above, it is important that buildings that do not change between the Base and Project Cases are removed from the analysis in step 2 so the deduction for existing capital is applied only to GFA that is forecast to be demolished. If this has been done then,

- Where $\Delta GFA_{\alpha}^{t,d} < 0$, $PC.GFA_{\alpha}^{t,d}$ should equal zero.
- Where $\Delta GFA_{\alpha}^{t,d} = 0$, both $BC.GFA_{\alpha}^{t,d}$ and $PC.GFA_{\alpha}^{t,d}$ should equal zero.

Unfortunately, no such simple check exists for cells where $\Delta GFA_{\alpha}^{t,d} > 0$.

In the $\Delta GFA_{\alpha}^{t,d} < 0$ case, where GFA is repurposed to a higher value use, if a building or some floors of a building are not required in the Project Case and will be left unused until the end of its economic life, that GFA should be excluded from the Base Case. No replacement of existing capital is brought forward in time so there should be no existing capital deduction.

Because private costs to developers are assumed to equal resource costs (apart from public infrastructure subsidies, which are addressed separately, see Chapter 7), the entire HVLUB accrues as profit to land owners. Assumptions should be reviewed where they result in a negative HVLUB implying that land owners are acting irrationally by engaging in loss-making behaviour. Generally, where a land-use change results in a negative HVLUB because deduction of the depreciated value of existing capital more than offsets the RLV gain, it is it is likely that input assumptions are unrealistic. Assumptions for the unit values of RLVs and the depreciated value of existing capital, and the quantities of floor space changing to a higher value use and floor space of existing capital demolished should all be reviewed.

Such cases can be readily detected for type–density–area cells with $\Delta GFA_{\alpha}^{td} > 0$ by observing whether deduction of the depreciated value of existing capital changes a positive gross HVLUB to negative net HVLUB. Instances of positive net HVLUBs where the ratio of the increase in GFA to Base Case GFA demolished ($\Delta GFA_{\alpha}^{td}/BC.GFA_{\alpha}^{t,d}$) is small, might also be reviewed as they imply a large amount of existing capital is demolished for a small gain in floor space.

Where land is repurposed, for example from commercial to residential, causing $\Delta GFA_{\alpha}^{td} < 0$ in the commercial cell that loses GFA, accompanied by an offsetting increase in GFA in the residential cell for the same area, it may not be obvious whether deduction of existing capital in the commercial cell has changed the sign of the HVLUB. A positive gross HVLUB for the whole area (the sum of cells for all densities and development types for the area) that changes to a negative net HVLUB after deducting existing capital would indicate unrealistic assumptions. But changes in other cells for the area, for example, floor space transitioning from retail to residential or from commercial to residential, could lead to a positive net HVLUB for the whole area concealing the presence of an unrealistic assumption. It may be necessary to calculate the gross and net HVLUB for each instance of repurposed floor space in which GFA shifts from one cell to another for the same area.

6. Second-round transport benefits

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 benefits 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 for the additional trips made — 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.). These externality benefits and costs are an established feature of transport economic appraisals and can be reliably quantified using standard approaches.

Second-round transport benefits can be negative due to externalities exceeding user benefits. This is likely to occur for large projects in congested networks where the additional trips induced by land-use change cause high congestion externality costs for other users. Appendix D provides an explanation.

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 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, independent 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 mode 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. Appendix E discusses the extent to which transport models account for land-use change.

While acknowledging this problem in relation to land-use impacts of a transport project, it is a general challenge for transport models that also affects their ability to reliably predict the demand response to Base Case land-use changes.

Where second round transport impacts cause future transport infrastructure investments to be deferred or brought forward, there may additional benefits or disbenefits to count. ATAP Part T2 Cost–benefit analysis, Section 7.5 addresses this situation. The main point to note is that impact on the present value of costs of changing the timing of a future investment project through discounting needs to be offset against the change in benefits. For example, bringing an initiative forward in time increases the present value of capital costs, but also brings forward the benefits of the initiative. Conversely, there is an offsetting loss of benefit where a future initiative is deferred.

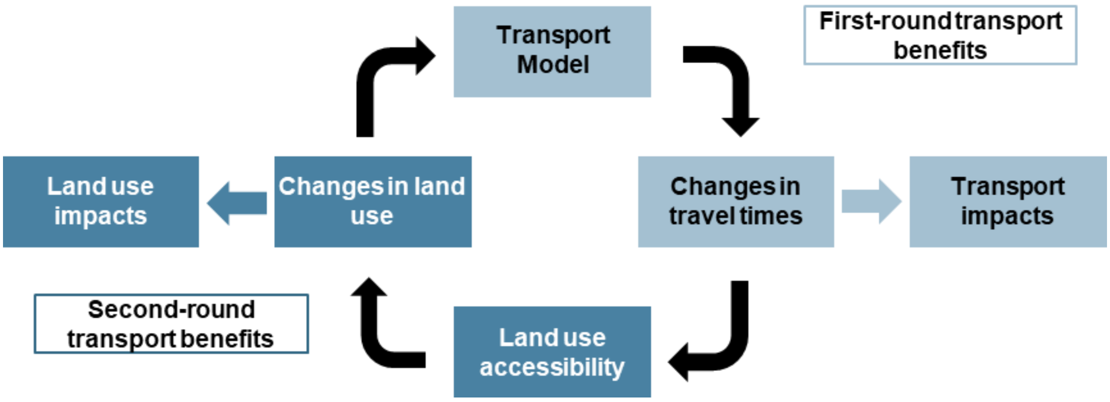
6.1 Estimating second-round transport benefits

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 benefits, 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 benefits are measured in isolation. Figure 2 below illustrates this approach.

Figure 2 Illustration of iterative approach to land use transport modelling



Source: EY 2020

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 for other sources of induced demand.

Four scenarios are possible as shown in Figure 3.

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

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 benefit comprising the consumers' surplus change and resource correction from transport model outputs,

$$Tranport\ only\ benefit = \sum_{\substack{All\ routes,\\ modes,\ OD\ pairs}} \left[\frac{1}{2}(Q_A + Q_D)(P_A - P_D) + (P_D - ASC_D)(Q_D - Q_A)\right]$$

Where:

- P_A is the perceived cost of travel and Q_A the quantity of trips between an origin–destination pair for a given mode and route 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 for a given mode and route in the Project Case without land-use change (scenario D 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.

$$Benefit = \sum_{\substack{All\ routes,\\ modes,\ OD\ pairs}} \left[\frac{1}{2}(Q_A + Q_C)(P_A - P_C) + (P_D - ASC_C)(Q_C - Q_A)\right]$$

Where:

- P_C is the perceived cost of travel, ASC_c is average social cost of travel and Q_C the quantity of trips for a given mode and route 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 1 from the result of Step 2 to arrive at the second-round round transport benefits for a given year.

7. Public infrastructure cost impacts

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 (less) compact land use so there is less (more) 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 (excluding open space) typically varies from being two to four times more expensive in greenfield areas than established areas (Infrastructure Victoria, 2019) as shown in Table 13. 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 13 Capital costs of public infrastructure (excluding open space) in greenfield and established areas ($2020 per dwelling)

	Established area		Greenfield	
Public infrastructure	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, cited 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 the capital costs are not passed on to users.

To the extent that public infrastructure costs faced by households and business differ from marginal social costs, there may be additional benefits (or disbenefits) resulting from land-use change. If all households and businesses face the full resource cost of the additional infrastructure and services they require, there will be no public infrastructure cost impacts (see Appendix F). 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 can be a net benefit (disbenefit) associated with increasing or decreasing the need for such infrastructure and services.[5] 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 impacts

Public infrastructure cost impacts 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 impacts 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 impacts 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. It is the responsibility of the proponents to provide evidence of the specific costs and level of cross-subsidisation for each individual public infrastructure cost component before this benefit can be estimated and included in a CBA.

Public infrastructure cost estimates should also be limited to the types of infrastructure which are not fully recovered within the jurisdiction in question. Not all types of public infrastructure are subject to under (or over) cost recovery and proponents should justify their inclusion on a case-by-case basis. It might be difficult to argue that costs of health and education infrastructure provided by or subsidised by governments are under-recovered because of the public good, merit good or community service obligation characteristics of these services.

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.[6] 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.

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[5] 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.

[6] It is important to note that greenfield development on the urban fringe as a default Base Case may not be appropriate in all circumstances.

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.

Step 3: Calculate public infrastructure cost impacts as follows:

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

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*.

7.2 Public infrastructure cost savings example

There is an increase of 60 dwellings in an established area, and a reduction of 60 dwellings in a greenfield area, with an average public infrastructure cost of provision of $88,350 and $100,950 for established and greenfield areas respectively. The government bears 30% of public infrastructure costs (i.e. a cost recovery rate of 70%). Then the public infrastructure benefit for the established area would calculated as:

60 x –$88,350 x 0.3 = –$1,590,300

While public infrastructure benefit for the greenfield area would be:

–60 x –$100,950 x 0.3 = $1,817,000

The net benefit is therefore:

–$1,590,300 + $1,817,100 = $226,800

Note that the cost recovery rates used in this example are indicative only. Cost recovery rates are expected to vary across different infrastructure types and locations, and it is the responsibility of proponents to provide evidence to support the cost recovery rates used in CBA.

8. Sustainability impacts

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 changes in urban form may result in sustainability impacts.[7]

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 impacts association with household energy consumption are presented in Table 14. 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 impacts are also expected to apply to non-residential development although the evidence is limited.

Table 14 Household energy consumption sustainability impacts 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	0.73	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)	$60 ($57-$63)	$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

[7] Note that land-use change also has the potential to generate sustainability disbenefits, in particular, through impacts on the natural environment such as carbon sequestration, visual amenity and biodiversity.

8.1 Estimating sustainability impacts

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

The level of evidence for sustainability impacts needs to be carefully evaluated before it can be used in a CBA. In particular, sustainability impacts should be specific to the energy consumption patterns of the areas being evaluated. Where material and relevant to the transport project in question, other sustainability benefits (e.g. reduced air pollution) should also be based on location-specific population and exposure characteristics.

The following approach is recommended for the estimation of sustainability impacts 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 14 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:

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

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 sustainability impacts in subsequent years of the analysis period.

8.2 Household energy consumption sustainability impact example

In the area being examined, there is an increase of 60 high density dwellings, and a reduction of 60 low density dwellings, with a household energy consumption environmental externality per annum of $198 for high density and $364 for low density (as per Table 14). 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 –60 x –$384 = $23,040 per annum. The net sustainability impact is therefore $23,040 – $11,880 = $11,160 per annum.

9. Public health cost changes

Transport projects that result in a denser pattern of urban development may have grounds to claim public health cost savings associated with net increased incidence of trips using active transport. There is evidence that residents in dense urban environments tend to walk and cycle more than residents at the fringe.

ATAP Part M4 provides guidance on active travel. In reporting the health benefits of active travel, it distinguishes between private and external costs. Private costs are the illness (morbidity and mortality) costs associated with physical inactivity, while the external costs are the health system costs involved in catering for people with those illnesses and are paid for by governments. In M4, it is assumed that when making travel decisions, private costs are perceived, but not external costs. It is assumed here that this also applies in household location decisions. The private cost is therefore already accounted in the user benefit estimation, but an additional benefit needs to be included to reflect the reduced external cost.

The private health benefits accruing to individuals are therefore expected to 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 constitute an additional active travel benefit that would not be captured in a standard CBA.

Multiple studies have found that 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.

If a CBA includes public health benefits from land-use change, the onus is on the project proponent to demonstrate that the forecast increases in active travel are reasonable.

Recommended parameter values for estimation of public health benefits are shown in Table 15.

Table 15 Health system benefits of active travel per km according to physical; activity ($2020)

Walking

	Inactive	Insufficiently active	Sufficiently active	Weighted per km benefit
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

	Inactive	Insufficiently active	Sufficiently active	Weighted per km benefit
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

It is recommended that public health benefits should be estimated only for projects that are expected to result in increases in activity greater than 10 minutes for an individual at a time 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.

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:

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

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 public health benefit per kilometre is $1.08, then the 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 Figure 4. 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

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 — dependent 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 Department for Transport (DfT, 2020). This approach involves estimating land value uplift arising from land use development, assuming that the transport initiative already exists. It is 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).[8] 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 (DfT, 2020):

- 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[9]) and subtracting from this an estimate of the development costs[10] 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 as per 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.

The need to undertake the analysis on an ad hoc, site by site basis makes it challenging for large areas of analysis and unsuitable for projects that are likely to have a geographically dispersed impact on land use.

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[8] Where land-use impacts refer to land-use change over a spatial area that is commensurate with the area that is assessed by the transport model.

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

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

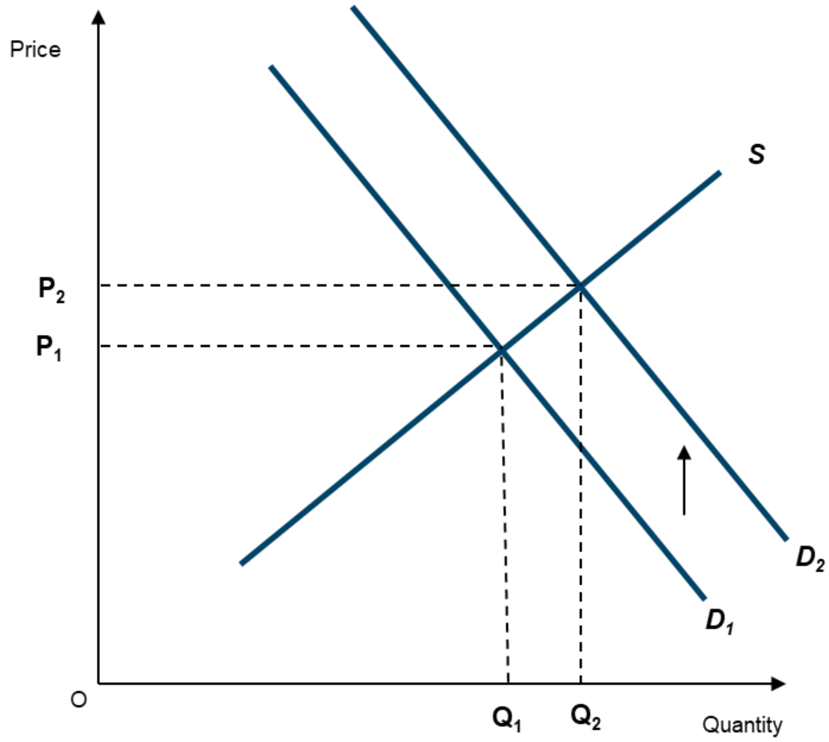
Appendix A Infrastructure-land use transmission mechanisms

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 Figure 5, 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

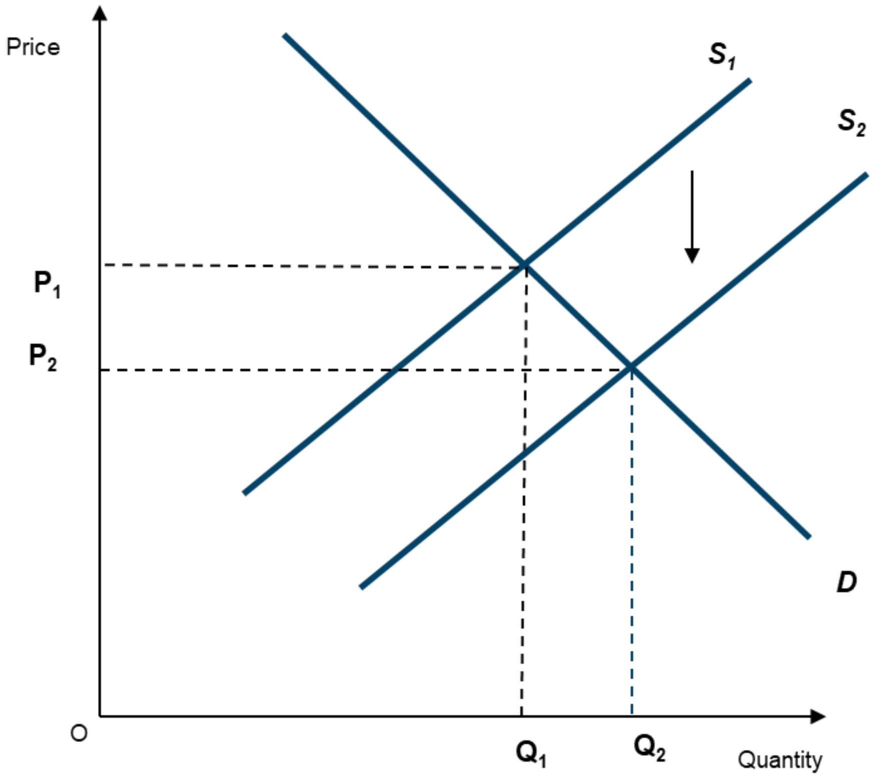
A.2 Supply-side mechanism

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.

Figure 6 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

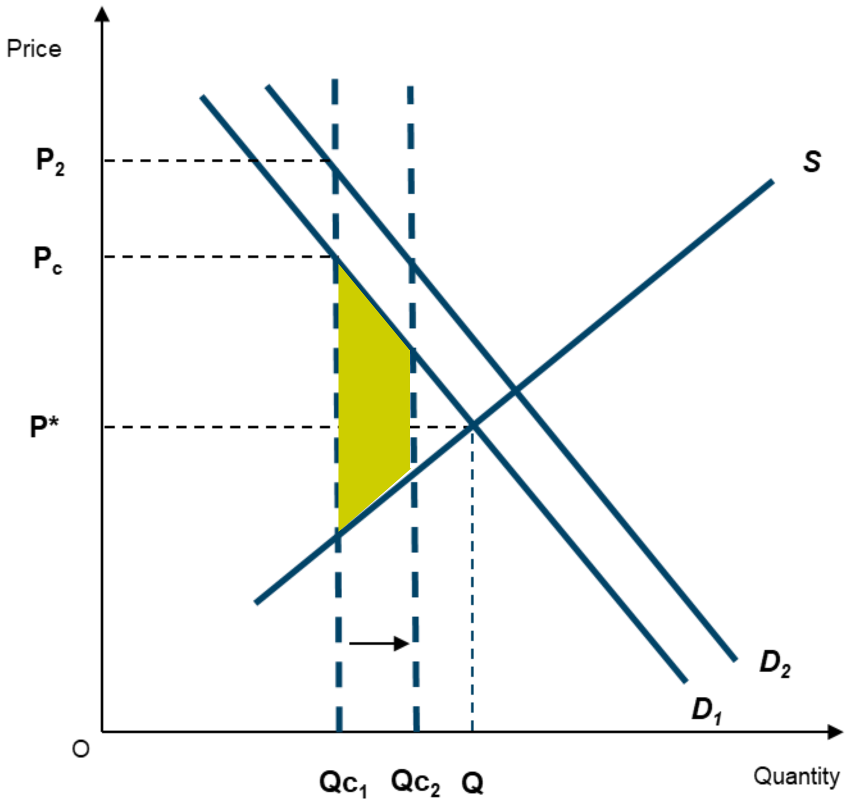


Source: EY

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 Figure 7. 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 floor space 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 Theoretical explanation of higher value land-use benefits

This appendix follows on from Appendix A providing a theoretical explanation of higher value land-use benefits.

Figure 8 is shows the same demand and supply curves as Figure 7 representing the effect of a transport improvement shifting the demand curve for floor space rightward and upward (from D_1 and D_2) accompanied by relaxation of a regulatory constraint, from Q_1 to Q_2. As a result of the upward sloping supply curve, the marginal cost of land rises from c_1 to c_2. The price of per square metre of floor space rises slightly from p_1 to p_2, but it could fall depending on how the diagram is drawn. The size of the vertical shift in the demand curve between the Base Case and Project Case is labelled Δt.

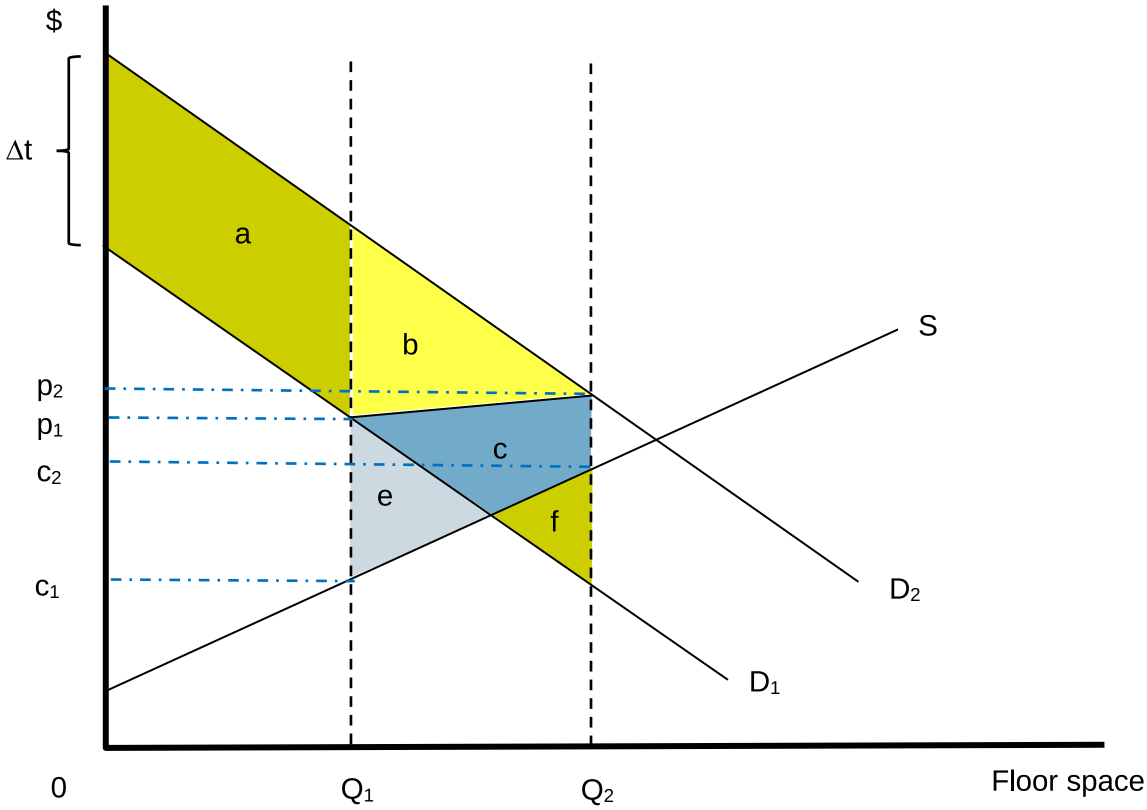
Following Venables (2016, p. 27), the increase in economic welfare comprises of two components — transport user benefits and higher value land-use benefits.

Benefit = transport user benefit + higher value land-use benefits =

areas (a + b) + areas (c + e) =

$$\Delta t\left[Q_1 + \frac{1}{2}(Q_2 - Q_1)\right] + \frac{1}{2}(Q_2 - Q_1)[(p_2 - c_2) + (p_1 - c_1)]$$

Figure 8 Transport and land-use benefits



Source: Based on Douglas and O'Keeffe 2016, p. 8

The transport benefits estimated in the CBA from savings in generalised costs of usage of transport infrastructure are converted into increased willingness-to-pay for land use equal to area *a* for existing users and half of areas *b* + *c* + *f* for induced users. Since area *b* = areas *c* + *f*, the benefit from induced demand, applying the rule-of-a-half is $\frac{1}{2}\Delta t(Q_1 + Q_2) = \frac{1}{2}\ areas\ b + c + f = area\ b$.

Areas *e* + *c* is the higher value land-use benefit arising from the fact that for each additional square metre of floor space, users willingness-to-pay, given by the extent to which its market price exceeds the resource cost of supplying it (construction cost plus the value of the land in its Base Case use). The marginal welfare gain for each additional square metre of floor space, *p* – *c*, is integrated over the increase in the amount supplied from Q_1 to Q_2. This is an application of the principle discussed in ATAP Part T2 Cost–benefit analysis, Sections 7.2 and 7.4 on impacts of transport initiatives on related markets where prices differ from marginal social costs.

Figure 8 shows that higher value land-use benefits do not double count second round transport benefits. Area *b* in Figure 8 is the triangular consumers' surplus benefit associated with induced travel stemming from the land-use change. It is distinct from the higher value land-use benefit, areas *e* + *c*.

For estimation of the higher value land-use benefit in practice, Chapter 5 recommends use of the residual land value (RLV) defined as the present value of the total revenue from a potential development, minus the present value of all development costs, including the developers' profit margin. The total revenue from the development is $p_2(Q_2 - Q_1)$ in terms of Figure 8. Thus there is an assumption that p_2 is not much different from p_1. The amount subtracted from the total revenue is the resource cost of the additional development, $\frac{1}{2}(Q_2 - Q_1)(c_1 + c_2)$. Thus there is a further assumption that the development costs including the developers' profit margin equals the resource costs of the additional development.

The development costs will include developer contributions to the cost of additional public infrastructure. If there is over- or under-recovery of public infrastructure costs for the additional development, the necessary resource correction can made in the CBA separate from the higher value land-use benefit calculation in the manner recommended in Chapter 7.

Figure 8 illustrates the importance of the dependency and conditionality requirement for land-use change benefits. If the regulatory constraint were relaxed in the Base Case to a level past the point where the D_1 demand curve and the supply curve intersect, and there was adequate transport capacity to handle the increased traffic, there would be a benefit of area *e*. This should not be attributed to the transport initiative, because society can obtain the benefit without investing in the transport initiative.

Venables (2016, p. 27) goes on to note that the total land value uplift only equals the welfare increase where there is no change in the quantity of land supplied. The land value uplift is the change in price times the initial quality, plus the additional quantity minus its average resource cost.

$$Land\ value\ uplift = (p_2 - p_1)Q_1 + (Q_2 - Q_1)\left[p_2 - \frac{1}{2}(c_2 + c_1)\right]$$

Rearranging the benefit equation above to

$$Benefit = \Delta t Q_1 + \frac{1}{2}(Q_2 - Q_1)[(p_2 - c_2) + (p_1 - c_1) + \Delta t]$$

It can be seen that the land value uplift only equals the benefit where $p_2 - p_1 = \Delta t$. The price of land must not be influenced by any change in supply for transport benefits to be fully capitalised into land values.

Appendix C Treatment of existing capital in estimating higher value land-use benefits

This appendix provides a justification for the recommendation in Section 5.1 that higher value land-use benefits can be measured as the economic value of the incremental floor space made available as a result of the project minus the resource costs of providing the incremental floor space and minus the depreciated value of existing capital.

It was argued in Appendix B that the economic value of additional floor space is given by the extent to which the market price exceeds the resource cost of supplying it. The latter is the construction cost plus the value of the land in its Base Case use.

Say a three-story building in the Base Case is demolished in the Project Case to make way for an eight-story building. Building maintenance costs are ignored for simplicity. As the Base Case and Project Case buildings sit on the same land, the opportunity cost of the unimproved land is not a consideration.

The following notation is used.

RP_2 is the annual rent from the upper five stories of the Project Case Building

RP_1 is the annual of rent from the lower three stories of the Project Case building

RB_1 is the present value of rent from the three story Base Case building

In economic problems that involve comparisons of capital with different ages, it is simplest to use continuous compounding and an infinite time period.

The present value of annual rent, the same amount, *R*, each year, continuously compounded over an infinite time period is the annual rent divided by the discount rate, *r*, known as a 'perpetuity', that is,

$$\int_0^\infty Re^{-rt}dt = \frac{R}{r}$$

KP_2 is the capital cost of constructing the upper five stories of the Project Case building.

KP_1 is the capital cost of constructing the lower three stories of the Project Case building

KB_1 is the present value of capital costs for the three-story Base Case building.

The present value of capital costs for the Project Case building, $KP_2 + KP_1$, is the construction cost incurred in year zero plus the construction cost of replacing the building at the end of each life cycle. If the building has a life of *T* years, the construction cost is incurred in years zero, *T, 2T, 3T, 4T* and so on.

The construction cost could be considered to include demolition costs of the previous building and lost rent during the construction period.

With continuous compounding, the present value of a monetary amount, *a*, paid at time zero and then forever afterwards at intervals of *T* years is $\frac{a}{1-e^{-rT}}$.

So the present value of the capital cost of the Project Case building is $\frac{KP_2+KP_1}{1-e^{-rT}}$.

The present value of the capital cost of the Base Case building, KB_1, needs to account for the age of the existing building, δ. The building will be replaced in year $T - \delta$, and again in another T years and so on. So KB_1 is the present value of reconstructing the three story building year in years $T - \delta$, $2T - \delta$, $3T - \delta$, $4T - \delta$ and so on.

If the building was replaced in year zero, that is, $\delta = 0$, the present value would be $\frac{KB_1}{1-e^{-rT}}$. Delaying the reconstructions by $T - \delta$ years, the present value becomes $\frac{e^{-r(T-\delta)}KB_1}{1-e^{-rT}}$.

The higher value land-use benefit arises from the surplus by which the market price, which indicates marginal willingness-to-pay, exceeds opportunity costs. This is a positive amount due to the scarcity value of the land.

In the Project Case, the surplus, SP, is the present value of rents minus capital costs.

$$SP = \frac{RP_2 + RP_1}{r} - \frac{KP_2 + KP_1}{1 - e^{-rT}}$$

The Base Case surplus, SB, is

$$SB = \frac{RB_1}{r} - \frac{e^{-r(T-\delta)}KB_1}{1 - e^{-rT}}$$

The gain in surplus between the Project Case compared with the Base Case, that is, the benefit, is

$$Benefit = SP - SB = \frac{RP_2 + RP_1}{r} - \frac{KP_2 + KP_1}{1 - e^{-rT}} - \frac{RB_1}{r} + \frac{e^{-r(T-\delta)}KB_1}{1 - e^{-rT}}$$

This can be rearranged as follows:

$$Benefit = \frac{RP_2}{r} - \frac{KP_2}{1 - e^{-rT}} + \frac{RP_1}{r} - \frac{RB_1}{r} - \frac{KP_1}{1 - e^{-rT}} + \frac{KB_1}{1 - e^{-rT}} - \frac{KB_1}{1 - e^{-rT}} + \frac{e^{-r(T-\delta)}KB_1}{1 - e^{-rT}}$$

$$Benefit = \left(\frac{RP_2}{r} - \frac{KP_2}{1 - e^{-rT}}\right) + \left(\frac{RP_1 - RB_1}{r} - \frac{KP_1 - KB_1}{1 - e^{-rT}}\right) - \frac{\left[1 - e^{-r(T-\delta)}\right]KB_1}{1 - e^{-rT}}$$

The first bracketed term, $\frac{RP_2}{r} - \frac{KP_2}{1-e^{-rT}}$, is the residual land value (RLV) of the incremental floor space, the market value (present value of rents) minus the construction cost for the additional five stories.

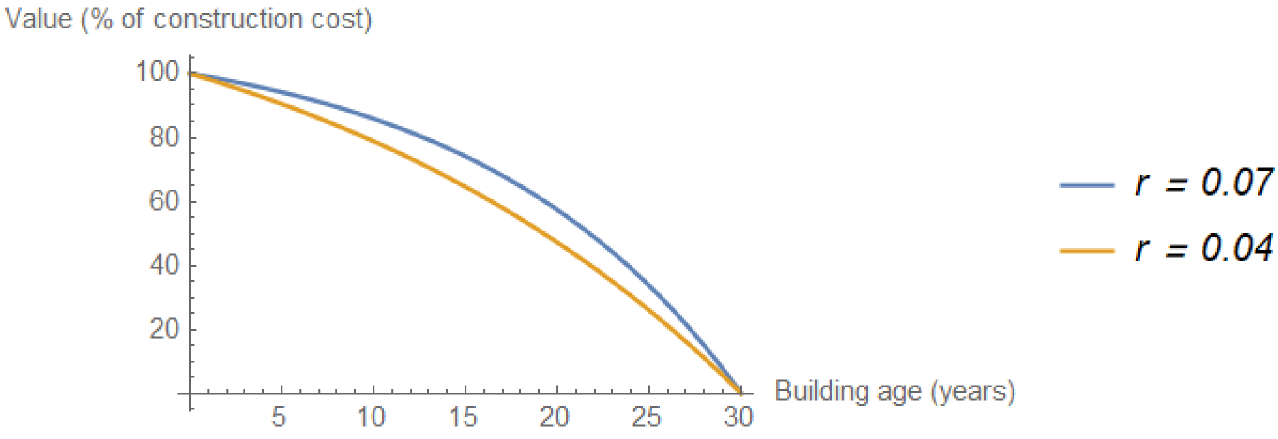
The second bracketed term, $\frac{RP1-RB_1}{r} - \frac{KP_1-KB_1}{1-e^{-rT}}$, will be zero if both rental revenues and capital costs are identical for the Base Case three story building and Project Case lower three floors, $RP_1 = RB_1$ and $KP_1 = KB_1$. If the replacement (Project Case) capital for the existing floor space is of higher quality than the Base Case capital, then rental revenues will also be higher than for the Base Case, $RP_1 > RB_1$ and $KP_1 > KB_1$. In a competitive market, it would be reasonable to assume that the present value of the additional rental revenue equals the present value of the additional capital cost for the higher quality infrastructure, $RP_1 - RB_1 = KP_1 - KB_1$, so the second bracketed term can be taken to equal zero.[11]

[11] Building costs are more than proportionate to the number of floors due to needs for lifts, more car parking and stronger foundations and structural supports for taller buildings. It is assumed that the additional costs of the eight-story building are included in KP_2 and recovered in RP_2.

The last term, $\frac{[1-e^{-r(T-\delta)}]KB_1}{1-e^{-rT}}$, is the depreciated value of the existing (Base Case) capital and is deducted from the RLV. If the existing capital is at the end of its life, $T = \delta$, the last term disappears. If the existing capital is new, $\delta = 0$, the full cost of the existing capital should be deducted.

Figure 9 shows plots of $\frac{[1-e^{-r(T-\delta)}]KB_1}{1-e^{-rT}}$ for KB_1 = 100, T = 30 years and r = 4% and 7% as the age of the existing capital, δ, increases from zero to 30 years.

Figure 9 Value of existing capital as a function of age



The curve becomes less concave the lower the discount rate and approaches a straight line as the discount rate approaches zero. In practice, the straight-line depreciation can serve as an acceptable approximation.

In summary, the higher value land-use benefit is can be taken as the RLV for incremental floor space minus the depreciated value of existing capital.

$$\frac{RP_2}{r} - \frac{KP_2}{(1-e^{-rT})} - \frac{[1-e^{-r(T-\delta)}]KB_1}{1-e^{-rT}} \approx$$

$$RLV_{increment} - \frac{T-\delta}{T}KB_1$$

Another arrangement of the benefit formula, which suggests a more detailed way to calculate the incremental RLV than simply gross floor area multiplied by unit values per square metre, is as follows:

$$Benefit = \left(\frac{RP_2 + RP_1}{r} - \frac{KP_2 + KP_1}{1-e^{-rT}}\right) - \left(\frac{RB_1}{r} - \frac{KB_1}{1-e^{-rT}}\right) - \frac{[1-e^{-r(T-\delta)}]KB_1}{1-e^{-rT}} \approx$$

$$RLV_{Project\ case} - RLV_{Base\ case} - \frac{T-\delta}{T}KB_1$$

The first term in brackets is the RLV for the entire Project Case building — all eight floors.

The second term in brackets is the RLV for a new Base Case building — three stories.

The last term is the depreciated value of the existing Base Case building.

It is acknowledged that the value of existing capital can be very difficult to estimate. Some suggested approaches are given in Section 5.1.

Appendix D User benefit differences with first and second round impacts

Chapter 6 addresses second-round user benefits associated with land use-changes. This appendix looks in more detail at the distinction between first- and second-round impacts in user benefit estimation and explains how they can be negative.

Section 7.3 of ATAP Part T2 CBA discusses the measurement of benefits of transport projects in urban networks. Section 7.3.2 of T2 focuses on how induced demand is accounted for in that estimation. It refers to literature pointing out that inclusion of induced demand in the analysis can make a significant difference to user benefit estimates. Failure to account for induced demand can lead to material overstatement of benefits. T2 concludes that induced demand should be fully accounted for in benefit estimation. With that in mind, we now consider benefit estimation with and without first and second round impacts.

Figure 10 below applies to road travel along a particular route between an origin-destination pair during peak hour. It shows demand curves D, and average user cost curves AC for the Base Case (subscript 1) and Project Case (improvement project, subscript 2). Three possible cases are considered for how induced demand is treated in a CBA, represented by three demand curves:

- Case M: vertical demand curve D_M — no induced demand at all. Travel in the Base Case and the Project Case are identical.
- Case N: demand curve D_N — first round induced demand only, i.e. assuming land use patterns are fixed. Demand responsiveness can be caused by one or more of mode change, change of time of day of travel (peak shifting) and base case residents and workers making additional trips (generated demand).
- Case P: demand curve D_P — first- plus second-round induced demand. D_P shows combined first and second-round demand responsiveness. While D_N assumed fixed land use patterns, D_P allows for land use to adjust in response to the transport improvement. Demand responsiveness is greater. Case P fully accounts for all induced demand.

The Base Case equilibrium is at point W. The equilibrium in the Project Case will be at X, Y and Z respectively for the three induced demand cases.

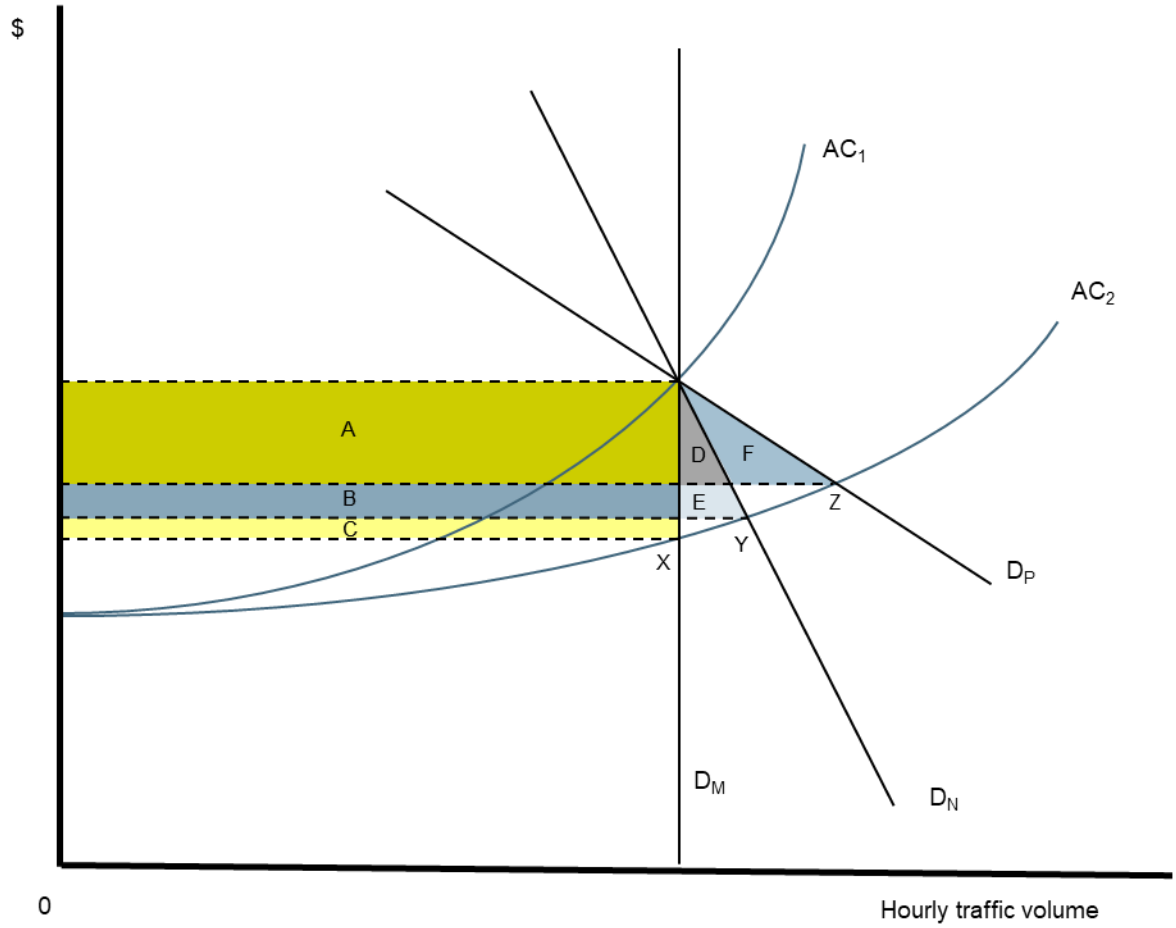
Referring to the labelled areas in the Figure 10, Table 16 below shows for the three cases:

- user benefit, and
- the change in user benefit, by component, going from cases M to N to P.

Table 16 User benefit measurement without and with first and second-round impacts

Case	User benefit	Change in user benefit: M to N to P			
		Existing users	Induced demand		Total change
			First-round	Second-round	
M	A + B + C	na	na	na	na
N	A + B + D + E	– C	+ D + E	na	D + E – C
P	A +D + F	– B	– E	+ F	F – E – B

Figure 10 User benefit measurement without and with first and second-round impacts



The second round impact on user benefit (that is, going from case N to case P) will be:

- Positive when F > B + E
- Negative when F < B + E.

In practice, whether failure to properly account for induced demand results in an under- or over- estimation of user benefits depends on the relative size of areas B, C, D, E and F. As T2 points out, these in turn depend on:

- The level of congestion
- The elasticity of demand and
- The scale of the improvement.

A proper quantitative analysis is required to properly assess these cases. The net result will depend on the specifics of each application.

However, Figure 10 suggests that the second round benefit, F – E – B, is likely to be:

- Positive in uncongested conditions, i.e. F > B + E
- Negative in congested conditions, i.e. F < B + E. This would typically be the case for large project improvements in congested networks, which are the conditions where significant land use changes might be expected.

Appendix E 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.

Table 17 provides an overview of the travel behavioural responses of typical strategic transport models in use in Australia.

Table 17 Overview of travel behaviour

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.

Appendix F Treatment of public infrastructure costs

Chapter 7 addresses estimation of benefits due to public infrastructure cost impacts of land-use changes resulting from transport initiatives. The methodology treats as benefits only differences between the resource cost of the infrastructure and the amount beneficiaries pay, not the whole resource cost. There are different views about this.

3. The difference in public infrastructure costs between the Base Case and Project Case should be counted as a benefit of a transport initiative. This view is rejected because it ignores the benefits associated with the location decisions reflected in the land-use patterns that give rise to the changed public infrastructure needs.
4. Changes in public infrastructure costs between the Base Case and Project Case can be ignored because the land-use market takes into account both benefits and costs of public infrastructure.
5. The second view is correct provided the beneficiaries of public infrastructure pay the full costs. It is not the correct where public infrastructure costs are under- or over-recovered. Such distortions prevent the benefits and costs of location decisions being properly reflected in market prices. If costs of additional public infrastructure, are not recovered in full from the beneficiaries, the cost will exceed the benefit as measured by beneficiaries' willingness-to-pay and there will be a net disbenefit. If public infrastructure costs are over-recovered, there will be a benefit from additional provision. If there is a reduction in needs for public infrastructure, under-recovery (a subsidy) will lead to a benefit, and over-recovery to a disbenefit. In all cases, the benefit or disbenefit is the gap between the private and social cost, not the full social cost. If CBA results were presented to show the impacts on different groups in society, a public infrastructure benefit (disbenefit) would appear as a gain (loss) to the government responsible for providing and charging for public infrastructure. This is an application of the principle discussed in ATAP Part T2 Cost–benefit analysis, Sections 7.2 and 7.4 on impacts of transport initiatives on related markets where prices differ from marginal social costs.

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